

# Chemistry Department Program Review 2009-2010



Central Washington University

Central Washington University

College of the Sciences

**Department of CHEMISTRY**

January 25, 2010

Prepared by the faculty and staff of  
The Chemistry Department

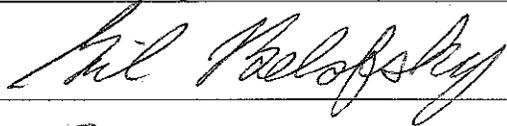
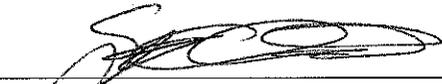
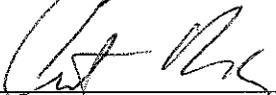
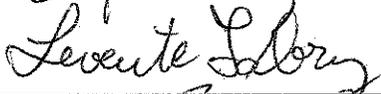
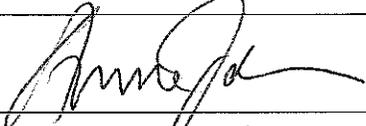
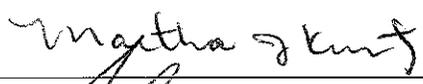
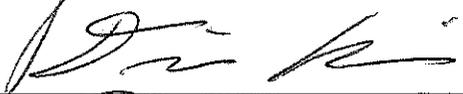
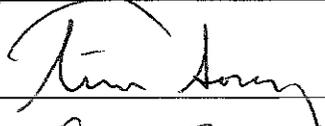
  
\_\_\_\_\_  
*Department Chair*

\_\_\_\_\_  
*College Dean*

## Verification of Faculty Review

Each full-time faculty member on duty in the Department of Chemistry has been asked to sign the statement presented:

By my signature below, I am verifying that I have had the opportunity to see and read the department's self-study report, which is being submitted.

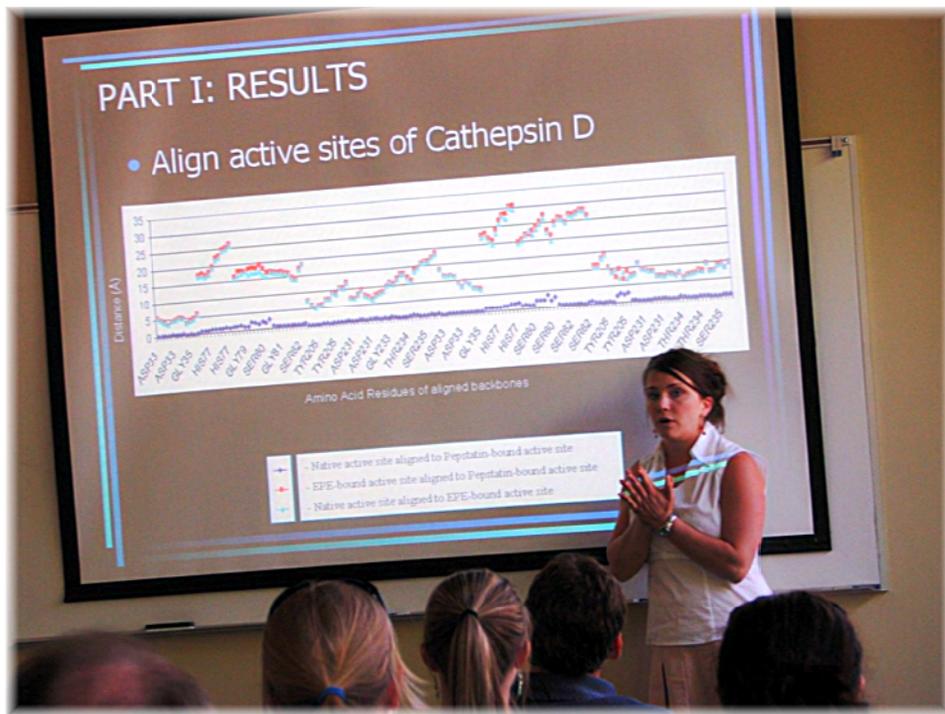
Name	Signature	Date
Gil Belofsky		1/25/10
Steve Chamberland		1/25/10
Anthony Diaz		1/25/10
Levente Fabry		1/25/10
Yingbin Ge		1/25/10
Anne Johansen		1/25/10
Todd Kroll		1/25/10
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Dion Rivera		1/25/10
Tim Sorey		1/25/10
Carin Thomas		1/25/10

**SELF STUDY – DEPARTMENT OF CHEMISTRY**  
**Academic Years 2004-2005 through 2008-2009**

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# Introduction to Department/Programs



# Program Review Self Study

## Department of Chemistry, 2009-2010

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### I. Introduction to Department/Programs

#### A. Department mission statement

The mission of the Department of Chemistry at Central Washington University (CWU) is to send into society thoughtful, creative, and informed people grounded in the principles and applications of chemistry.

#### B. Brief description of department and program contexts including date of last review

The Department of Chemistry includes twelve tenured/tenure track faculty, two with split appointments with the Science Education Department (a total of 11 FTE). Areas of faculty expertise include analytical chemistry (1), biochemistry (2), chemical education (2), environmental chemistry (1), inorganic chemistry (1), organic chemistry (4), and physical chemistry (1). During 2009/10 the department employed two full-time non-tenure track faculty. The faculty are supported by a full-time department secretary, a 10-month laboratory manager, a full-time stockroom manager, a 9-month stockroom assistant, a half-time computer technician, and two instrument technicians (full-time and 0.75 time). The instrument technicians serve the Departments of Biological and Geological Sciences in addition to Chemistry.

The Department of Chemistry offers the B.S., B.S. with Biochemistry emphasis, B.A. in Chemistry Teaching, and M.S. in Chemistry, as well as minors in Chemistry and Chemistry Teaching. The B.S. degree is approved by the American Chemical Society. In addition, the Chemistry Department has a very large service course commitment, providing chemistry prerequisites and science general education courses for students across the university. The department values teaching at all levels and is proud of its teaching accomplishments. A strong culture of faculty/student collaboration in scholarship has been established. All tenured/tenure track faculty have active research programs involving students. Seven of the faculty have garnered external funding for their activities during the period under review.

During the past five years the Chemistry Department has experienced modest growth in the number of majors and dramatic growth in service course enrollment. This growth has been accommodated by three new faculty lines, the addition of a half-time computer technician, a new nine-month stockroom assistant, and an increase in the number of graduate teaching assistantships available.

The Chemistry Department is housed in the twelve year old Science Building which also houses the Departments of Biological Sciences and Science Education. The Chemistry Department occupies over 20,000 square feet of useable space and shares over 11,000 square feet of space, including classrooms, with other departments. The department is well-equipped with instrument

holdings worth over \$1,000,000, although many of the instruments are beginning to show signs of age.

The last internal (CWU) program review was carried out in 2004/05. Nearly concurrent with the internal review was an extensive review process by the American Chemical Society (ACS) as a part of our successful application for certification of our Chemistry B.S. degree.

**C. Describe departmental governance system and provide organizational chart for department.**

Organizational chart is provided as Chart 1.

Department chairs are elected by the faculty to four-year terms. The department chair oversees all department operations and serves as supervisor for all but one of the department's staff members. The stockroom manager serves as supervisor for the stockroom assistant. The chair also serves as supervisor for the two engineering technicians shared by the Departments of Biological Sciences, Chemistry, and Geological Sciences. Oversight of the graduate program is shared with a faculty member who is assigned as Graduate Coordinator.

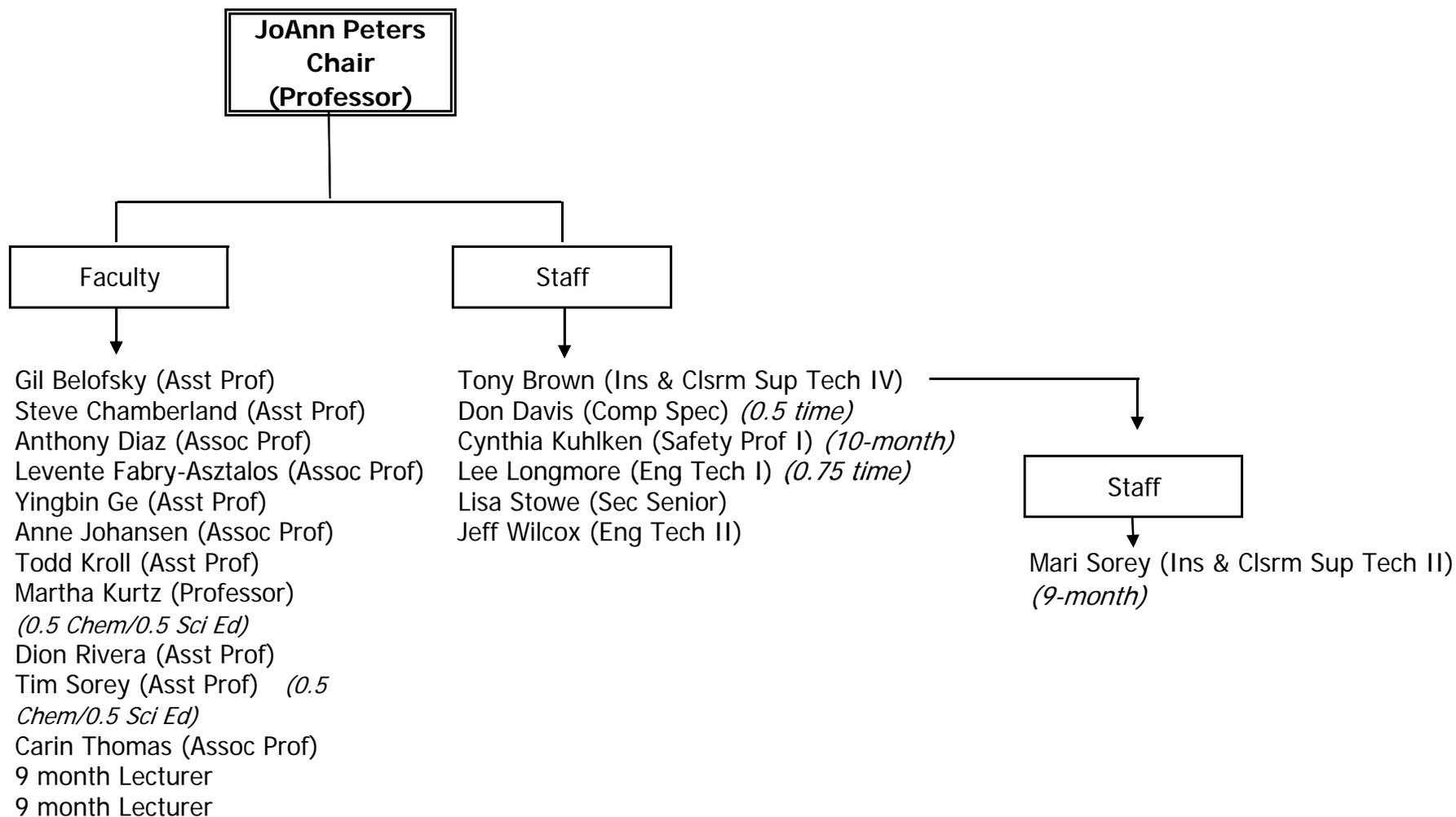
Most decisions are made through discussion and consultation with department members, either during department meetings attended by faculty and staff, through committee meetings, or through informal discussion. The department strives for transparency and inclusiveness in decision making. Department meetings are held twice a month, on average, and are scheduled as necessary. Committee structure varies with the tasks facing the department. List of current committees:

- Graduate Committee
- First Year Chemistry Committee
- Biochemistry Curriculum Committee
- Assessment Committee
- Safety Committee
- Personnel Committee
- Organizing Committee for ACS Puget Sound Section Undergraduate Research Symposium

**D. Department/Programs**

1. List department/program goals. (See below.)
2. Describe the relationship of each department/program goal to relevant college and university strategic goals. Explain how each relevant strategic goal for the university and college are being met within the department. (See below.)
3. Identify what data was used to measure (assess) goal attainment. (See Tables 1A, 1B, 1C.)
4. Describe the criterion of achievement (standard of mastery) for each goal. (See Tables 1A, 1B, 1C.)
5. Describe the major activities that enabled goal attainment. (See below.)

**Chart 1: Chemistry Department Organizational Chart  
2010**



***Goal 1. Offer excellent instruction in chemistry to meet the needs of the variety of undergraduate and graduate students the department serves.***

Related College of the Sciences (COTS) and University (CWU) goals:

- COTS Goal I: Provide for an outstanding academic and student experience in the College of the Sciences.
- COTS Goal II: Provide for an outstanding academic and student life in college programs and courses at the university centers.
- COTS Goal III: Provide for outstanding graduate programs that meet focused regional needs and achieve academic excellence.
- COTS Goal VII: Create and sustain productive, civil, and pleasant learning environments.
- CWU Goal I: Maintain and strengthen an outstanding academic and student life on the Ellensburg campus.
- CWU Goal II: Provide for an outstanding academic and student life at the university centers.
- CWU Goal V: Achieve regional and national prominence for the university.

Goal was achieved through:

- obtaining and maintaining approval of our flagship B.S. in Chemistry by the American Chemical Society.
- providing coursework directed towards the needs of students who will apply chemistry in the understanding of disciplines such as Biology, Engineering, Environmental Sciences, Geology, and professional programs (Medicine, Veterinary Science, Dentistry, etc.). (See Table 3A.)
- providing opportunities for coursework within the general education program. (See Table 3A.)
- providing upper level coursework suitable for M.S. students and advanced undergraduates.
- maintaining vital, externally funded, research programs that provide opportunities for faculty and students to work collaboratively. (See Table 5 and faculty vitae.)
- maintaining up-to-date instructional laboratory facilities, including computers and instrumentation. (See Section V.)
- working with other academic departments to offer interdisciplinary programs including Environmental Studies, Science Honors, the Douglas Honors College, and Science Education.
- using distance education technology to offer coursework at selected CWU centers. (See Section II.F.)

For additional results, see:

- Section II. E. Effectiveness of instruction
- Section II. G. Assessment of programs and student learning

***Goal 2. Maintain and update instrument, equipment and computing resources for the quality instruction of graduate and undergraduate students.***

Related College of the Sciences (COTS) and University (CWU) goals:

- COTS Goal 1: Provide for an outstanding academic and student experience in the College of the Sciences.
- COTS Goal III: Provide for outstanding graduate programs that meet focused regional needs and achieve academic excellence.
- CWU Goal I: Maintain and strengthen an outstanding academic and student life of the Ellensburg campus.
- CWU Goal III: Strengthen and further diversity our funding base and strengthen infrastructure to support academic and student programs.
- CWU Goal V: Achieve regional and national prominence for the university.

Goal was achieved through:

- efforts of faculty and especially staff, including:
  - two instrument technicians (1.75 positions) shared by the Departments of Biological Sciences, Chemistry, and Geological Sciences.
  - laboratory manager and stockroom personnel.
- hiring a new half-time computer technician with assistance from a High Demand grant from the Higher Education Coordinating Board (HECB).
- use of department resources in tandem with University's WIN-WIN program, and a High Demand grant from the HECB to keep hardware and common software up-to-date. (See Section V.)
- use of external funds, combined with faculty start-up funds provided by the University, to create and maintain computational facilities for student/faculty research. (See Section V.)

***Goal 3. Increase the quality and diversity of undergraduate majors in the various chemistry programs.***

Related College of the Sciences (COTS) and University (CWU) goals:

- COTS Goal I: Provide for an outstanding academic and student experience in the College of the Sciences.
- COTS Goal VII: Create and sustain productive, civil, and pleasant learning environments.
- CWU Goal I: Maintain and strengthen an outstanding academic and student life of the Ellensburg campus.
- CWU Goal VI: Build inclusive and diverse campus communities that promote intellectual inquiry and encourage civility, mutual respect, and cooperation.

Goal was achieved through:

- maintaining connections with area high schools and regional two year colleges.
- maintaining connections with local universities, industry, Pacific Northwest National Laboratory, and alumni.
- emphasizing opportunities for student involvement in chemistry and the Chemistry Department, including employment as teaching and research assistants.
- advising and providing support for the Chemistry Club (Student Affiliates American Chemical Society Chapter).
- maintaining e-mail communication with all chemistry majors and minors.
- maintaining an up-to-date department webpage.
- attending CWU recruiting and advising events.

***Goal 4. Maintain a high quality graduate program in chemistry.***

Related College of the Sciences (COTS) and University (CWU) goals:

- COTS Goal I: Provide for an outstanding academic and student experience in the College of the Sciences.
- COTS Goal III: Provide for outstanding graduate programs that meet focused regional needs and achieve academic excellence.
- CWU Goal I: Maintain and strengthen an outstanding academic and student life of the Ellensburg campus.
- CWU Goal V: Achieve regional and national prominence for the university.

Goal was achieved through:

- offering appropriate coursework with frequency that allows students to graduate in a timely way.

- providing opportunities for scholarly work; increasing the number of faculty has increased options for faculty-mentored thesis research.
- increasing the number of graduate teaching assistantships available, and providing opportunities for teaching assistants to work with expert faculty guidance.
- increasing external funding for scholarly work. (See Table 5.)
- increasing enrollment in graduate program, providing more camaraderie and opportunities for students to interact with peers.
- clarifying expectations for research proposals, department seminars, and thesis work.

***Goal 5. Maintain an enthusiastic, active faculty.***

Related College of the Sciences (COTS) and University (CWU) goals:

- COTS Goal I: Provide for an outstanding academic and student experience in the College of the Sciences.
- COTS Goal VII: Create and sustain productive, civil, and pleasant learning environments.
- CWU Goal I: Maintain and strengthen an outstanding academic and student life of the Ellensburg campus.
- CWU Goal V: Achieve regional and national prominence for the university.

Goal was achieved through:

- promoting a department culture that values faculty contributions in the areas of teaching, scholarship, and service.
- recruiting, then hiring, well-qualified faculty using institutional and departmental goals as a guide.
- revising the Chemistry Department's Guidelines for Reappointment, Tenure and Promotion in order to clarify expectations for faculty performance. (See Appendix II.)
- documenting and applauding faculty efforts and accomplishments as part of reappointment and post-tenure review processes.
- providing new faculty with adequate start-up funds and release time for the initiation of externally fundable, competitive research programs.
- providing adequate research facilities for all faculty.

- maintaining shared instrumentation and computer facilities.
- using the department's share of summer school profits to provide funds for professional development of faculty and staff.
- encouraging and facilitating applications for professional leave.
- making department decisions through consensus whenever possible; making sure that all voices are heard during department meetings.
- encouraging non-tenure track faculty to be involved in all aspects of the department, to the extent that their demanding workloads permit.
- striving to distribute teaching and service loads fairly, while matching faculty interest and expertise with work assignments.

For additional results, see:

- Table 5. Faculty profile
- Section III. B. Faculty vitae

***Goal 6. Maintain an enthusiastic, active staff.***

Related College of the Sciences (COTS) and University (CWU) goals:

- COTS Goal 1: Provide for an outstanding academic and student experience in the College of the Sciences.
- COTS Goal VII: Create and sustain productive, civil, and pleasant learning environments.
- CWU Goal I: Maintain and strengthen an outstanding academic and student life of the Ellensburg campus.
- CWU Goal V: Achieve regional and national prominence for the university.

Goal was achieved through:

- recruiting, then hiring, well-qualified staff.
- promoting a department culture that values staff contributions; regularly and publicly acknowledging staff contributions.
- working within the framework of the CWU plan for regular review of staff performance with emphasis on professional growth and mutual feedback.

- using the department's share of summer school profits to provide funds for professional development of staff and faculty; encouraging staff to participate in professional organizations, workshops, appropriate professional meetings, and trainings.
- allowing release time for job-related training and continuing their education whenever feasible.
- making department decisions through consensus whenever possible; making sure that all voices, including staff, are heard during department meetings.
- allowing for flexible working hours when feasible.

***Goal 7. Serve the academic community and the general public through scholarly research and service activities.***

Related College of the Sciences (COTS) and University (CWU) goals:

- COTS Goal I: Provide for an outstanding academic and student experience in the College of the Sciences.
- COTS Goal IV: Develop a diversified funding base to support curriculum and academic facilities, student and faculty research and scholarships, as well as faculty development, service and applied research in college disciplines.
- COTS Goal V: Build partnerships that support academic program quality and student experiences in the college of the sciences, including those with private, professional, academic, government, and community-based organizations.
- COTS Goal VI: Strengthen the college's contributions to the field of education.
- CWU Goal I: Maintain and strengthen an outstanding academic and student life of the Ellensburg campus.
- CWU Goal III: Strengthen and further diversity our funding base and strengthen infrastructure to support academic and student programs.
- CWU Goal IV: Build mutually beneficial partnerships with the public sector, industry, professional groups, institutions, and the communities surrounding our campuses.
- CWU Goal V: Achieve regional and national prominence for the university.

Goal was achieved through:

- Initiating and maintaining faculty-mentored research efforts; at this time all tenured/tenure-track faculty are actively involved in research.
- Seeking external funding for scholarly work. During the period under review, research efforts were funded by sources including the National Science Foundation (NSF), National Institutes of Health (NIH), American Chemical Society-Petroleum Research Fund (ACS-PRF), Research Corporation, the M. J. Murdock Trust, the U.S. Department of Interior (National Park Service), The U.S. Department of Education (Fund for the Improvement of Postsecondary Education (FIPSE)), and private industry. (See faculty vitae.)

- Serving on national, regional or local boards concerned with professional and/or research activities. (See faculty vitae.)
- Disseminating research results through publishing in professional journals, presentations at professional meetings, and invited presentations at other universities. (See Table 5 and faculty vitae.)
- Serving the professional community through the review of manuscripts for professional journals.
- Serving the professional community through the review of grant proposals, and serving on review panels for funding agencies including the ACS-Petroleum Research Fund, National Science Foundation, and the National Institutes of Health.
- Participating in outreach to the region's K-12 schools.
- Providing educational programs for the community.
- Maintaining and expanding state certification of the Chemistry Department's Environmental Testing Laboratory.

### **Program Goals for the B.A., Chemistry Teaching**

In addition to the Chemistry Department Goals, the Science Education Department faculty have worked in collaboration to develop three goals specific to the teaching programs offered or supported through their department. Since the number of students acquiring these degrees is small, this strategy allows for aggregate analysis of data across programs. This provides us with more meaningful data and serves to improve all science education programs.

All teaching major courses and programs are aligned to meet the CWU Center for Teaching and Learning, Washington State, National Science Teachers Association (NSTA), National Science Education, and National Council for Accreditation of Teacher Education (NCATE) standards. The coursework and experiences offered as part of each degree program are specifically designed to help students meet the following program goals:

***SCED Program Goal 1:*** *Teacher candidates will have a comprehensive, modern knowledge base of concepts, principles, and methods in science.*

***SCED Program Goal 2:*** *Teacher candidates will be effective teachers of secondary science students.*

***SCED Program Goal 3:*** *Teacher candidates will actively engage in science education reform and reflect and grow throughout their careers.*

See Table 1B for how these goals align with department, college and university goals and the methods of assessing these goals. Table 4B gives the student learning outcome assessments associated with these program goals.

Table 1A. CWU Department/Program Assessment Plan  
 Department: Chemistry Department  
 Program: Bachelor of Science, Bachelor of Science with Biochemistry Emphasis, and Bachelor of Arts

Department/Program Goals	Related College Goals	Related University Goals	Method(s) of Assessment (What is the assessment?)	Who/What Assessed (population, item)	When Assessed (term, dates)	Criterion of Achievement (Expectation of how good things should be?)
1. Offer excellent instruction in chemistry to meet the needs of the variety of undergraduate and graduate students the department serves.	Goal 1 Goal 3 Goal 5 Goal 6	Goal 1 Goal 3 Goal 5 Goal 6	- SEOI - Peer teaching evaluations - Student exit portfolios - Student exit surveys - Alumni surveys - ACS exam scores	- Major programs and curricula - Chemistry faculty	- Quarterly SEOI. - Annual department retreat. - ACS review every 5 years. - Annual review of student exit portfolios.	- Maintain ACS accreditation - The teaching performance of all faculty rated satisfactory or better during annual performance reviews. - SEOI ratings for teaching effectiveness at or above university average. - ACS exam scores of chemistry majors at or above national averages. - All exit and alumni surveys reflect student satisfaction and confidence in the chemistry training received at CWU. - Routine dissemination of courses through distance education.
2. Maintain and update instrument, equipment and	Goal 1 Goal 4	Goal 1	- Monitor age and performance of	- Student and research	- Routinely by instrument	- All instrumentation and software are

computing resources for the quality instruction of graduate and undergraduate students.	Goal 6		chemistry instrumentation and software	laboratory facilities - Student computing facilities	technicians. - Annual department retreat.	modern by the current standards of the discipline. - All instrumentation and software are routinely replaced or upgraded as needed.
3. Increase the quality and diversity of undergraduate majors in the various chemistry programs.	Goal 1 Goal 7	Goal 1 Goal 6	- Number of faculty searches conforming to OEO guidelines for recruiting woman and minority faculty - Diversity of student population in chemistry relative to regional demographics and university averages - Number of faculty involved in outreach programs designed to increase diversity within our majors population - Number of students successfully completing major programs in chemistry	- Chemistry majors, minors, and graduate students - Chemistry faculty - Faculty activities	- Annual department retreat.	- All faculty searches conform to OEO guidelines. - Diversity of student population is reflective of regional and university demographics. - At least one-third of faculty involved in outreach activities or STEP program. - At least 80% of students entering major programs in chemistry successfully obtain their degree.
4. Maintain a high quality graduate program in chemistry.	Goal 1 Goal 3 Goal 4 Goal 5 Goal 6	Goal 1 Goal 3 Goal 5	- Number of students enrolled in MS program - Number and variety of graduate courses offered per year	- M.S. program and curriculum - Faculty research programs	- Annual department retreat.	- Research and teaching assistantships for graduate students are competitive with those at comparable institutions.

			<ul style="list-style-type: none"> <li>- Dollar amount and number of graduate student stipends</li> <li>- Dollar amount and number of research grants within the department</li> <li>- Number of publications produced by research groups in the chemistry department</li> </ul>			<ul style="list-style-type: none"> <li>- RA or TA funding is available to every graduate student.</li> <li>- Offer at least four graduate courses per year.</li> <li>- Every research group is supported by internal or external grant funds.</li> <li>- At least two peer reviewed articles are published in international scientific journals by the chemistry department each year.</li> </ul>
5. Maintain an enthusiastic and active faculty.	<ul style="list-style-type: none"> <li>Goal 1</li> <li>Goal 3</li> <li>Goal 4</li> <li>Goal 6</li> <li>Goal 7</li> </ul>	<ul style="list-style-type: none"> <li>Goal 1</li> <li>Goal 3</li> <li>Goal 5</li> <li>Goal 6</li> </ul>	<ul style="list-style-type: none"> <li>- Faculty teaching loads.</li> <li>- Dollar amount and number of research grants within the department</li> <li>- Number of publications produced by research groups in the chemistry department</li> <li>- Faculty performance review</li> </ul>	<ul style="list-style-type: none"> <li>- Faculty</li> <li>- Faculty research programs</li> </ul>	<ul style="list-style-type: none"> <li>- Teaching loads reviewed quarterly.</li> <li>- Annual department retreat.</li> </ul>	<ul style="list-style-type: none"> <li>- Teaching loads are reflective of individual professor's needs and are in alignment with ACS accreditation.</li> <li>- Every research group is supported by internal or external grant funds.</li> <li>- At least two peer reviewed articles are published in international scientific journals by the chemistry department each year.</li> <li>- Faculty performance review files reflect a record</li> </ul>

						of continued growth and achievement
6. Maintain an enthusiastic, active staff.	Goal 1 Goal 3 Goal 4	Goal 1 Goal 3 Goal 6	- Amount of funding available for professional development of staff - Number of training sessions, workshops, or other professional development functions attended by staff - Staff performance review - Number of staff attending department meetings	- Chemistry department staff - Staff support opportunities	- Annual department retreat.	- Sufficient funding is available for all staff to explore professional development opportunities. - At least one staff member participates in a professional development opportunity each year. - Annual review of staff performance reflect a record of continued growth and achievement - 100% of staff attend all department meetings
7. Serve the academic community and the general public through scholarly research and service activities.	Goal 1 Goal 3 Goal 4 Goal 5	Goal 1 Goal 4 Goal 5	- Dollar amount and number of research grants within the department - Number of publications produced by research groups in the chemistry department - Number of faculty memberships in professional organizations / societies - Number of	- Faculty - Faculty research programs		- Every research group is supported by internal or external grant funds. - At least two peer reviewed articles are published in international scientific journals by the chemistry department each year. - All faculty are members of at least one professional organization / society. - At least half of

			faculty attending professional conferences - Number of outreach programs involving chemistry faculty - Number of faculty involved in outreach programs			chemistry faculty attend at least one professional conference each year. - Department actively involved in at least three outreach activities each year. - At least one-third of faculty involved in outreach activities or STEP program.
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Table 1B. CWU Department/Program Assessment Plan

Department: Chemistry/Science Education

Program: Bachelor of Arts in Chemistry Teaching

Program Goals	Related Department Goal	Related College Goals	Related University Goals	Method(s) of Assessment (What is the assessment?)	Who/What Assessed (population, item)	When Assessed (term, dates)	Criterion of Achievement (Expectation of how good things should be?)
1. Teacher candidates will have a comprehensive, modern knowledge base of concepts, principles, and methods in chemistry.	SCED Department Goal (DG) 1, 3, 4, 5	COTS Goal 1, 2, 6	CWU Goal 1, 2, 6	<ul style="list-style-type: none"> <li>Science Program major/minor teaching portfolio, WEST-E content assessment, entry to and exit from program survey</li> <li>SCED 324 course portfolio</li> <li>Practicum field observation</li> <li>WA pedagogy assessment</li> <li>American Chemical Society Content Exam</li> </ul>	<ul style="list-style-type: none"> <li>All Chemistry Teaching major, minor, and endorsement students</li> </ul>	<ul style="list-style-type: none"> <li>End of major/minor program, prior to student teaching</li> <li>SCED 324</li> <li>Student teaching</li> </ul>	<ul style="list-style-type: none"> <li>Minimum requirement is proficiency for this outcome. Student must provide suitable evidence and reflect on performance relative to associated NSES, NSTA, and WA Comp standards.</li> <li>SCED 324 portfolio performance benchmark proficiency</li> <li>All standards met for WA Pedagogy Assessment</li> </ul>
2. Teacher candidates will be effective teachers of secondary chemistry students.	SCED DG 1, 2, 3, 4, 7, 8	COTS Goal 1, 2,5, 6, 7	CWU Goal 1, 2, 6	<ul style="list-style-type: none"> <li>Science Program major/minor teaching portfolio, WEST-E content assessment, entry to and exit from program survey</li> <li>SCED 324 course portfolio</li> </ul>	<ul style="list-style-type: none"> <li>All Chemistry Teaching major, minor, and endorsement students</li> </ul>	<ul style="list-style-type: none"> <li>End of major/minor program, prior to student teaching</li> <li>SCED 324</li> <li>Student</li> </ul>	<ul style="list-style-type: none"> <li>Minimum requirement is proficiency for this outcome. Student must provide suitable evidence and reflect on performance relative to associated NSES, NSTA, and WA Comp standards.</li> <li>SCED 324 portfolio</li> </ul>

				<ul style="list-style-type: none"> <li>• Practicum field observation</li> <li>• WA pedagogy assessment</li> </ul>		teaching	<p>performance benchmark proficiency</p> <ul style="list-style-type: none"> <li>• All standards met for WA Pedagogy Assessment</li> </ul>
3. Teacher candidates will actively engage in science education reform and reflect and grow throughout their careers.	SCED DG 2, 3, 4, 7, 8	COTS Goal 1, 2, 6	CWU Goal 1, 2, 6	<ul style="list-style-type: none"> <li>• Science Program major/minor teaching portfolio, entry to and exit from program survey</li> <li>• SCED 324 course portfolio</li> <li>• Practicum field observation</li> </ul>	<ul style="list-style-type: none"> <li>• All Chemistry Teaching major, minor, and endorsement students</li> </ul>	<ul style="list-style-type: none"> <li>• End of major/minor program, prior to student teaching</li> <li>• SCED 324</li> </ul>	<ul style="list-style-type: none"> <li>• Minimum requirement is proficiency for this outcome. Student must provide suitable evidence and reflect on performance relative to associated NSES, NSTA, and WA Comp standards.</li> <li>• SCED 324 portfolio performance benchmark proficiency</li> </ul>

Table 1C. CWU Department/Program Assessment Plan Preparation Form  
 Department: Chemistry Department  
 Program: Master of Science

Department/Program Goals	Related College Goals	Related University Goals	Method(s) of Assessment (What is the assessment?)	Who/What Assessed (population, item)	When Assessed (term, dates)	Criterion of Achievement (Expectation of how good things should be?)
1. Offer excellent graduate instruction in chemistry to meet the needs of the variety of graduate students the department serves.	Goal 1 Goal 3 Goal 5 Goal 6	Goal 1 Goal 3 Goal 5 Goal 6	- SEOI - Peer teaching evaluations - Alumni surveys	- Major programs and curricula - Chemistry faculty	- Quarterly SEOI. - Annual department retreat.	- The teaching performance of all faculty rated satisfactory or better during annual performance reviews. - SEOI ratings for teaching effectiveness at or above university average. - All alumni surveys reflect student satisfaction and confidence in the chemistry training received at CWU.
2. Maintain and update instrument, equipment and computing resources for the quality instruction of graduate students.	Goal 1 Goal 4 Goal 6	Goal 1	- Monitor age and performance of chemistry instrumentation and software	- Student and research laboratory facilities - Student computing facilities	- Routinely by instrument technicians. - Annual department retreat.	- All instrumentation and software are modern by the current standards of the discipline. - All instrumentation and software are routinely replaced or upgraded as needed.
3. Increase the number, quality and diversity of graduate students.	Goal 1 Goal 7	Goal 1 Goal 6	- Number of faculty searches conforming to OEO guidelines for recruiting woman and minority faculty - Diversity of student population in chemistry relative to regional demographics and university averages - Number of faculty involved in outreach programs designed to increase diversity within our majors population	- Chemistry graduate students - Chemistry faculty - Faculty activities	- Annual meeting of Graduate Committee	- All faculty searches conform to OEO guidelines. - Diversity of student population is reflective of regional and university demographics. - At least one-third of faculty involved in outreach activities or STEP program. - All students entering the program obtain their degree.

4. Maintain a high quality graduate program in chemistry.	Goal 1 Goal 3 Goal 4 Goal 5 Goal 6	Goal 1 Goal 3 Goal 5	<ul style="list-style-type: none"> <li>- Number of students enrolled in MS program</li> <li>- Number and variety of graduate courses offered per year</li> <li>- Dollar amount and number of graduate student stipends</li> <li>- Dollar amount and number of research grants within the department</li> <li>- Number of publications produced by research groups in the chemistry department</li> </ul>	<ul style="list-style-type: none"> <li>- M.S. program and curriculum</li> <li>- Faculty research programs</li> </ul>	<ul style="list-style-type: none"> <li>- Annual department retreat.</li> </ul>	<ul style="list-style-type: none"> <li>- Research and teaching assistantships for graduate students are competitive with those at comparable institutions.</li> <li>- RA or TA funding is available to every graduate student.</li> <li>- Offer at least four graduate courses per year.</li> <li>- Every research group is supported by internal or external grant funds.</li> <li>- At least two peer reviewed articles are published in international scientific journals by the chemistry department each year.</li> </ul>
5. Maintain an enthusiastic and active faculty.	Goal 1 Goal 3 Goal 4 Goal 6 Goal 7	Goal 1 Goal 3 Goal 5 Goal 6	<ul style="list-style-type: none"> <li>- Faculty teaching loads.</li> <li>- Dollar amount and number of research grants within the department</li> <li>- Number of publications produced by research groups in the chemistry department</li> <li>- Faculty performance review</li> </ul>	<ul style="list-style-type: none"> <li>- Faculty</li> <li>- Faculty research programs</li> </ul>	<ul style="list-style-type: none"> <li>- Teaching loads reviewed quarterly.</li> <li>- Annual department retreat.</li> </ul>	<ul style="list-style-type: none"> <li>- Teaching Loads are reflective of individual professor's needs and are in Alignment with ACS accreditation.</li> <li>- Every research group is supported by internal or external grant funds.</li> <li>- At least two peer reviewed articles are published in international scientific journals by the chemistry department each year.</li> <li>- Faculty performance review files reflect a record of continued growth and achievement</li> </ul>
6. Maintain an enthusiastic, active staff.	Goal 1 Goal 3 Goal 4	Goal 1 Goal 3 Goal 6	<ul style="list-style-type: none"> <li>- Amount of funding available for professional development of staff</li> <li>- Number of training sessions, workshops, or other professional development functions attended by staff</li> <li>- Staff performance review</li> </ul>	<ul style="list-style-type: none"> <li>- Chemistry department staff</li> <li>- Staff support opportunities</li> </ul>	<ul style="list-style-type: none"> <li>- Annual department retreat.</li> </ul>	<ul style="list-style-type: none"> <li>- Sufficient funding is available for all staff to explore professional development opportunities.</li> <li>- At least one staff member participates in a professional development opportunity each year.</li> <li>- Annual review of staff</li> </ul>

			- Number of staff attending department meetings			performance reflect a record of continued growth and achievement - 100% of staff attend all department meetings
7. Serve the academic community and the general public through scholarly research and service activities.	Goal 1 Goal 3 Goal 4 Goal 5	Goal 1 Goal 4 Goal 5	- Dollar amount and number of research grants within the department - Number of publications produced by research groups in the chemistry department - Number of faculty memberships in professional organizations / societies - Number of faculty attending professional conferences - Number of outreach programs involving chemistry faculty - Number of faculty involved in outreach programs	- Faculty - Faculty research programs		- Every research group is supported by internal or external grant funds. - At least two peer reviewed articles are published in international scientific journals by the chemistry department each year. - All faculty are members of at least one professional organization / society. - At least half of chemistry faculty attend at least one professional conference each year. - Department actively involved in at least three outreach activities each year. - At least one-third of faculty involved in outreach activities or STEP program.

# Degree Programs & Curricula



## II. Description of degree programs and curricula

- A. List each degree program (undergraduate and graduate) offered in department by location, regardless of state or self support. Include minor and undergraduate certificate program(s).

**Table 2 (Section II, A.)  
Programs Offered in Department 2004-2009**

Degree Program	Delivery Location(s)	# Students in Major					# Degrees Awarded				
		2004-2005	2005-2006	2006-2007	2007-2008	2008-2009	2004-2005	2005-2006	2006-2007	2007-2008	2008-2009
BS – ACS Certified	Ellensburg	N/O	N/O	3	17	18	N/O	N/O	3	9	3
BS	Ellensburg	25	21	27	17	19	4	6	1	2	0
BS - Biochemistry	Ellensburg	50	50	44	44	45	5	9	13	8	11
BA	Ellensburg	4	5	3	2	5	0	1	1	0	2
BA – Teaching	Ellensburg	6	8	9	15	8	1	0	0	3	1
<b>Total, all undergraduate programs</b>	Ellensburg	<b>87</b>	<b>84</b>	<b>86</b>	<b>95</b>	<b>95</b>	<b>10</b>	<b>16</b>	<b>18</b>	<b>22</b>	<b>17</b>
MS	Ellensburg	6	7	8	10	10	2	1	2	3	2
Minor Programs	Delivery Location(s)	# Students in Minor					#Minors Completed				
		2004-2005	2005-2006	2006-2007	2007-2008	2008-2009	2004-2005	2005-2006	2006-2007	2007-2008	2008-2009
Chemistry	Ellensburg	77	78	76	75	86	30	38	39	23	36
Chemistry - Teaching	Ellensburg	6	7	6	6	10	3	3	1	1	1
<b>Total, all minor programs</b>	Ellensburg	<b>83</b>	<b>85</b>	<b>82</b>	<b>81</b>	<b>96</b>	<b>33</b>	<b>41</b>	<b>40</b>	<b>24</b>	<b>37</b>

*N/O = course not offered that year*

**B.** Provide a table that lists courses, location, and student number for the following:

1. General Education contributions
  - a. courses delivered
  - b. location
  - c. number of students
2. Professional Educators contributions
  - a. courses delivered
  - b. location
  - c. number of students
3. Service Course delivery
  - a. courses delivered
  - b. location
  - c. number of students

The following chemistry courses are required by other university programs.

**CHEM 101, Contemporary Chemistry:** required by the Mid Level Math Science Teaching minor and option for the B.S. in Environmental Studies and Aviation Science.

**CHEM 111, 112, 113, Introduction to General/Organic/Biochemistry:** all or part of this series is required in certain Biological Sciences, Nutrition, Industrial and Engineering Technology programs, and in preparation for allied health science programs such as dental hygiene and nursing. Listed as an option for Aviation Science, Earth Science Teaching major, B.S. in Environmental Studies, B.S. in Global Wine Studies, B.S. in Technology Education.

**CHEM 181, 182, 183, General Chemistry:** all or part of this series is required in certain Biological Sciences, Geology, Physics, Industrial and Engineering Technology programs and in preparation for professional health science programs such as medicine, dentistry, optometry, pharmacy, physical therapy, and veterinary medicine. Listed as an option for Aviation Science, B.S. in General Science Teaching and B.S. in Construction Management.

**CHEM 332, Quantitative Analysis, CHEM 345 Environmental Chemistry:** required by B.S. in Environmental Studies with Environmental Chemistry specialization.

**CHEM 361, 362, 363, Organic Chemistry:** all or part of this series is required in certain programs of Biological Sciences and in preparation for professional health science programs such as medicine, dentistry, optometry, pharmacy, and veterinary medicine.

**CHEM 431, 432, Biochemistry:** all or part of the series is a requirement or an elective for certain programs of Biological Sciences and preparation for professional health science programs such as medicine, dentistry, optometry, pharmacy, and veterinary

medicine. These courses were offered at CWU-Lynnwood for the first time spring-summer of 2008 for the General Science Teaching program offered at the center by the CWU Science Education Department.

**Table 3A (Section II, B.)  
Courses, Contributions, Locations  
(Does not include summer enrollments)**

Contributing area	Delivery Location	# Students				
		2004-2005	2005-2006	2006-2007	2007-2008	2008-2009
General Education Courses	Location(s)					
Chem 101, Contemporary Chemistry	Ellensburg	95	1	132	139	112
Chem 111, Introduction to Chemistry	Ellensburg	262	183	291	323	313
Chem 111Lab, Introduction to Chemistry Lab	Ellensburg	259	180	278	307	295
Chem 181, General Chemistry	Ellensburg	268	291	293	316	362
Chem 181Lab, General Chemistry Laboratory 1	Ellensburg	253	257	263	290	333
Professional Education Courses	Location(s)					
None						
Service Courses	Location(s)					
Chem 101, Contemporary Chemistry	Ellensburg	95	1	132	139	112
Chem 111, Introduction to Chemistry	Ellensburg	262	183	291	323	313
Chem 111Lab, Introduction to Chemistry Lab	Ellensburg	259	180	278	307	295
Chem 112, Introduction to Organic Chemistry	Ellensburg	56	60	57	68	103
Chem 112Lab, Introduction to Organic Chemistry Lab	Ellensburg	52	53	57	65	96
Chem 113, Introduction to Biochemistry	Ellensburg	61	54	60	68	60
Chem 113Lab, Introduction to Biochemistry Lab	Ellensburg	57	49	58	66	58
Chem 181, General Chemistry 1	Ellensburg	268	291	293	316	362

Chem 181Lab, General Chemistry Laboratory 1	Ellensburg	253	257	263	290	333
Chem 182, General Chemistry 2	Ellensburg	168	174	213	173	243
Chem 182Lab, General Chemistry Laboratory 2	Ellensburg	161	151	192	162	221
Chem 183, General Chemistry 3	Ellensburg	153	139	185	161	169
Chem 183Lab, General Chemistry Laboratory 3	Ellensburg	146	122	149	143	148
Chem 332, Quantitative Analysis	Ellensburg	28	27	29	26	33
Chem 345, Environmental Chemistry	Ellensburg	9	N/O	12	N/O	N/O
Chem 361, Organic Chemistry 1	Ellensburg, Yakima, Wenatchee	140	138	123	158	149
Chem 361Lab, Organic Chemistry Laboratory 1	Ellensburg	127	111	118	139	118
Chem 362, Organic Chemistry 2	Ellensburg, Yakima, Wenatchee	147	126	121	147	142
Chem 363, Organic Chemistry 3	Ellensburg, Yakima, Wenatchee	77	71	55	79	74
Chem 363Lab, Organic Chemistry Laboratory 2	Ellensburg	60	40	54	65	61
Chem 431, Biochemistry 1	Lynnwood	0	0	0	10	7

*N/O = course not offered that year*

**C. Required measures of efficiency for each department for the last five years**

1. Number of instructional staff in department

**Table 3 B (Section II, C.)  
Number of Instructional Staff in Department**

Degree Program Instructional Staff	# Staff each year				
	2004- 2005	2005- 2006	2006- 2007	2007- 2008	2008- 2009
Faculty FTE Tenured/Tenure Track	7.5	8	9	7.5	8.5
Faculty FTE Non-Tenure Track	1.67	1.13	2	3.56	3.38
Grad Assist. FTE	2	2.5	2.5	1.5	1.5

**D.** Describe currency of curricula in discipline. How does the curriculum compare to recognized standards promulgated by professionals in the discipline (e.g., state, national, and professional association standards)?

Currency is ensured in all programs by using the most recent editions of standard textbooks that are used in universities across the nation, by requiring faculty to engage in scholarly or other activities that routinely bring them into contact with colleagues at other institutions, and by encouraging faculty to regularly attend professional meetings where major developments in their field are presented and discussed.

The **B.S. in Chemistry** is approved by the American Chemical Society. Maintaining approval requires annual reporting to the ACS Committee on Professional Training. Currency of the curriculum is examined during the review.

The **B.A. in Chemistry Teaching major** is housed in the Chemistry Department and supported through the Science Education Department. It qualifies students to teach chemistry at the high school or middle level and satisfies the criteria for a Washington State Endorsement in Chemistry. Students must pass the WEST-E in Chemistry and should consider working toward endorsement in a second area such as biology, earth science, physics, broad area science, middle level science or mathematics. The **Chemistry Teaching minor** is restricted to students working on a teaching major in Biology, Earth Science, Physics or General Science. It, along with a passing score on the Chemistry WEST-E exam, meets the Washington State Endorsement Competencies for Chemistry.

Curricula in science education courses and programs conform to the state and national education standards as well as to the standards set by CWU's Center for Teaching and Learning. Within the science departments all secondary teaching majors (biology, chemistry, earth science, and physics) reflect national trends and standards prepared by the NSTA, NCATE, and the State of Washington.

**E. Effectiveness of instruction** – Describe how the department addresses the scholarship of teaching with specific supporting documentation including each of the following:

1. Departmental teaching effectiveness – report a five-year history of the “teaching effectiveness” department means as reported on SEOIs, indexed to the university mean on a quarter-by-quarter basis.

While SEOI values are typically a bit lower than College of the Sciences and University averages, Chemistry Department courses usually score higher on the questions related to challenge and difficulty.

**Table 4.** SEOI Data for Effectiveness of Instructor: Comparison of Chemistry, COTS and University values. Average values, on a 1 to 5 scale for the answer to question, "Instructor's teaching effectiveness was":

		FALL		WINTER		SPRING	
		Lecture	Lab	Lecture	Lab	Lecture	Lab
<b>2004-05</b>	Chemistry	4.23	3.81	4.04	4.21	3.85	4.48
	The Sciences	4.28	4.28	4.27	4.27	4.28	4.28
	CWU	4.30	4.26	4.33	4.42	4.35	4.44
<b>2005-06</b>	Chemistry	4.34	3.97	4.24	4.26	4.61	4.16
	The Sciences	4.28	4.28	4.29	4.29	4.35	4.35
	CWU	4.31	4.38	4.31	4.44	4.35	4.48
<b>2006-07</b>	Chemistry	4.13	4.35	4.29	4.17	4.03	4.35
	The Sciences	4.25	4.25	4.30	4.30	4.30	4.30
	CWU	4.29	4.47	4.33	4.43	4.33	4.52
<b>2007-08</b>	Chemistry	4.01	4.18	4.13	4.30	4.21	4.23
	The Sciences	4.24	4.24	4.30	4.30	4.34	4.34
	CWU	4.30	4.38	4.33	4.29	4.35	4.39
<b>2008-09</b>	Chemistry	4.13	4.07	4.10	4.24	4.31	4.45
	The Sciences	4.30	4.30	4.24	4.24	4.33	4.33
	CWU	4.31	4.20	4.31	4.36	4.36	4.51

2. What evidence other than Student Evaluation of Instruction (SEOI) is gathered and used in the department to evaluate the effectiveness of instruction?

The Chemistry Department employs peer review in the form of classroom visits and examination of teaching materials by peers, teaching self-reflection statements, and examinations of student learner outcomes in our evaluation of teaching effectiveness. These materials are examined as a part of the reappointment process for tenure track faculty, tenure and promotion decisions, and at the time of post tenure review.

3. Effectiveness of instructional methods to produce student learning based upon programmatic goals including innovative and traditional methods – examples include:
  - a. Collaborative research between student and faculty
  - b. Inquiry-based, open ended learning

Of the items in the list, a and b (listed above) are the most relevant to the Chemistry Department. A majority of our laboratory courses and all of our independent research courses (CHEM 295, 395, 495, 595) involve inquiry-based components. Teaching effectiveness in formal laboratory courses is evaluated using SEOI questionnaires and the methods described in question 2 above. Teaching effectiveness in research laboratories has not been formally evaluated in the past. Indirect measures of success include the number of research presentations and publications produced by students and faculty, and the willingness of many students to repeat the research courses over the course of several quarters.

**F. Degree to which distance education technology is used for instruction.**

1. Interactive television

The year-long organic chemistry lecture sequence has been delivered to students at the Yakima and Wenatchee centers by interactive television. Students travel to Ellensburg to take the lab.

2. Online

The Chemistry Department has not offered on-line courses, largely because of the huge challenge of teaching laboratories on-line. Many of the faculty do make extensive use of web-sites and web-based materials in teaching.

**G. Assessment of programs and student learning**

1. List student learner outcomes for each graduate and or undergraduate degree program and note how the outcomes are linked to department, college and university mission and goals.
  - a. Describe the specific method used in assessing each student learning outcome. Also specify the population assessed, when the assessment took place, and the standard of mastery (criterion) against which you will compare your assessment results. If appropriate, list survey or questionnaire response rate from total population (e.g., alumni, employers served).

See Tables 4A, 4B, and 4C.

2. List the results for each student learning outcome.
  - a. Provide results in specific quantitative or qualitative terms for each learning outcome.
  - b. Compare results to standards of mastery listed above.
  - c. Provide a concise interpretation of results.

Beginning in 2007/08, each department is required to prepare annual reports for each program, based on the departments' plans for assessing student learner outcomes. The Chemistry Department's assessment reports from June 2008 and June 2009 are included in Appendix I.

3. Based upon the results for each outcome listed above describe:
  - a. Specific changes to your program as they affect student learning (e.g., curriculum, teaching methods).
  - b. List specific changes related to assessment process if any.

Exit and alumni surveys have been revised, and an entrance survey has been instituted, in order to better assess student attitudes. A new learner outcome concerning ethics in science has been added. For details see Assessment Reports and Surveys contained in Appendix I.

**Table 4A.** CWU Student Learning Outcome Assessment Plan Preparation Form  
Department of Chemistry  
 Program: Bachelor of Science in Chemistry

<b>Student Learning Outcomes (performance, knowledge, attitudes)</b>	<b>Related Program/ Departmental Goals</b>	<b>Related College Goals</b>	<b>Related University Goals</b>	<b>Method(s) of Assessment (What is the assessment?)*</b>	<b>Who Assessed (Students from what courses – population)**</b>	<b>When Assessed (term, dates) ***</b>	<b>Standard of Mastery/ Criterion of Achievement (How good does performance have to be?)</b>
1. Apply the standard technical information and perform experimental techniques of analytical, biochemistry, inorganic, organic, and physical chemistry.	Goal 1 Goal 2	Goal 1	Goal 1	- Grades in relevant courses - Student exit portfolio - Student exit survey -Alumni survey -ACS content exams	- Chemistry majors in all required courses for BS degree in chemistry	- Quarterly - Annual review of student exit portfolios.	- Graduates maintain 2.0 for course average and an average of 2.25 in courses within the major. - ACS exams consistent with national averages - All students' portfolio components will be rated at satisfactory or higher.
2. Write and speak clearly in the language and style of the discipline.	Goal 1	Goal 1	Goal 1	- Grades in relevant courses - Student written lab reports - Student research reports for those students who performed research - Student exit portfolio	- Chemistry majors in all required courses for BS degree in chemistry. Course exams require some short answer as well as drawing of chemical structures and diagrams - CHEM 183Lab (written abstracts) - CHEM 361Lab, 363Lab, 382Lab, 383Lab, 431Lab, 452Lab (full or partial lab reports; brief oral presentations) - CHEM 295,395 or 495, student research reports - CHEM 388 poster presentation - CHEM 488 oral presentation	- Quarterly - Annual review of student exit portfolios.	- Graduates maintain 2.0 for course average and an average of 2.25 in courses within the major. - All students receive a grade of C+ or better on their poster presentation in CHEM 388 - All students receive a grade of C+ or better on their oral presentation in CHEM 488 - All artifacts of writing in exit portfolio are rated at satisfactory or better.

3. Demonstrate critical thinking skills that utilize qualitative and quantitative problem solving.	Goal 1	Goal 1	Goal 1	<ul style="list-style-type: none"> <li>- Grades in relevant courses</li> <li>- ACS content exams</li> </ul>	<ul style="list-style-type: none"> <li>- Chemistry majors in all required courses for BS degree in chemistry</li> </ul>	<ul style="list-style-type: none"> <li>- Quarterly</li> <li>- Annual review of student exit portfolios.</li> </ul>	<ul style="list-style-type: none"> <li>- Graduates maintain 2.0 for course average and an average of 2.25 in courses within the major.</li> <li>- ACS exams consistent with national averages</li> </ul>
4. Use computers and the modern software of the discipline.	Goal 1 Goal 2	Goal 1	Goal 1	<ul style="list-style-type: none"> <li>- Grades in laboratory courses</li> <li>- Grades in CHEM 388 and CHEM 48</li> <li>- Student exit portfolio</li> </ul>	<ul style="list-style-type: none"> <li>- Chemistry majors in laboratory courses. These courses require the use of software for instrumentation control, data analysis, and reporting</li> <li>- CHEM 388 and 488</li> <li>- Chemistry majors submitting exit portfolios (all majors)</li> </ul>	<ul style="list-style-type: none"> <li>- Quarterly</li> <li>- Annual review of student exit portfolios.</li> </ul>	<ul style="list-style-type: none"> <li>- Graduates maintain 2.0 for course average and an average of 2.25 in laboratory courses within the major.</li> <li>- All students receive a grade of C+ or better on their poster presentation in CHEM 388</li> <li>- All students receive a grade of C+ or better on their oral presentation in CHEM 488</li> <li>- The research or lab report component in the students' portfolio will be rated at satisfactory or higher.</li> </ul>
5. Retrieve and critically analyze chemical literature.	Goal 1	Goal 1	Goal 1	<ul style="list-style-type: none"> <li>Course grades in:</li> <li>-CHEM 388</li> <li>-CHEM 488</li> <li>-Student Research CHEM 295, CHEM 395, and/or CHEM 495</li> <li>- Student exit portfolio</li> </ul>	<ul style="list-style-type: none"> <li>- CHEM 388</li> <li>- CHEM 488</li> <li>- CHEM 295, 395 or 495 (research)</li> <li>- Chemistry majors submitting exit portfolios (all majors)</li> </ul>	<ul style="list-style-type: none"> <li>- Quarterly</li> <li>- Annual review of student exit portfolios.</li> </ul>	<ul style="list-style-type: none"> <li>- All students receive a grade of C+ or better on their poster presentation in CHEM 388</li> <li>- All students receive a grade of C+ or better on their oral presentation in CHEM 488</li> <li>- The research report component in the students' portfolio will be rated at satisfactory or higher.</li> </ul>
6. Practice health and safety protocols that are integral to the discipline.	Goal 1	Goal 1	Goal 1	<ul style="list-style-type: none"> <li>- Grades in laboratory courses</li> </ul>	<ul style="list-style-type: none"> <li>- Chemistry majors in laboratory courses.</li> <li>- Chemistry majors working in research labs.</li> </ul>	<ul style="list-style-type: none"> <li>- Quarterly</li> </ul>	<ul style="list-style-type: none"> <li>- All students receive a grade of C+ or better in laboratory courses.</li> <li>- All research students receive a grade of B or better.</li> </ul>

7. Work effectively in group situations.	Goal 1 Goal 3	Goal 1 Goal7	Goal 1 Goal 6	- Grades in laboratory courses - Grades in student research courses: CHEM 295, CHEM 395, and/or CHEM 495 - Exit Survey		- Quarterly - Annual review of student exit portfolios.	- All students receive a grade of C+ or better in laboratory courses. - All research students receive a grade of B or better. - All students respond with 4/5 or 5/5 to question on exit survey regarding how well the curriculum prepared them to work as part of a team.
8. Act ethically and responsibly in the handling and reporting of data.	Goal 1	Goal 1 Goal7	Goal 1 Goal 6	- Grades in student research courses: CHEM 295, CHEM 395, and/or CHEM 495 - Exit Survey		- Quarterly - Annual review of student exit portfolios.	- All research students receive a grade of B or better. - Reflective assessment in student exit portfolio. - All students respond with 4/5 or 5/5 to question on exit survey regarding how they value the ethical handling and reporting of data.

\*Method(s) of assessment should include those that are both direct (tests, essays, presentations, projects) and indirect (surveys, interviews) in nature

\*\*Data needs to be collected and differentiated by location (Ellensburg campus vs University Centers – see NWCCU standard 2.B.2)

\*\*\*Timing of assessment should be identified at different transition points of program (i.e., admission, mid-point, end-of-program, post-program)

**Table 4A, continued.** CWU Student Learning Outcome Assessment Plan Preparation Form  
Department of Chemistry  
 Program: Bachelor of Arts in Chemistry

<b>Student Learning Outcomes (performance, knowledge, attitudes)</b>	<b>Related Program/ Departmental Goals</b>	<b>Related College Goals</b>	<b>Related University Goals</b>	<b>Method(s) of Assessment (What is the assessment?)*</b>	<b>Who Assessed (Students from what courses – population)**</b>	<b>When Assessed (term, dates) ***</b>	<b>Standard of Mastery/ Criterion of Achievement (How good does performance have to be?)</b>
1. Apply the standard technical information and perform experimental techniques of analytical, biochemistry, inorganic, organic, and physical chemistry.	Goal 1 Goal 2	Goal 1	Goal 1	- Grades in relevant courses - Student exit portfolio - Student exit survey -Alumni survey -ACS content exams	- Chemistry majors in all required courses for BA degree in chemistry	- Quarterly - Annual review of student exit portfolios.	- Graduates maintain 2.0 for course average and an average of 2.25 in courses within the major. - ACS exams consistent with national averages - All students' portfolio components will be rated at satisfactory or higher.
2. Write and speak clearly in the language and style of the discipline.	Goal 1	Goal 1	Goal 1	- Grades in relevant courses - Student written lab reports - Student research reports for those students who performed research - Student exit portfolio	- Chemistry majors in all required courses for BA degree in chemistry. Course exams require some short answer as well as drawing of chemical structures and diagrams - CHEM 183Lab (written abstracts) - full or partial lab reports; brief oral presentations: CHEM 361Lab, 363Lab (if taken), 382Lab, 383Lab, 431Lab (if taken), 452Lab (if taken) - CHEM 295,395 or 495, student research reports - CHEM 388 poster presentation - CHEM 488 oral presentation	- Quarterly - Annual review of student exit portfolios.	- Graduates maintain 2.0 for course average and an average of 2.25 in courses within the major. - All students receive a grade of C+ or better on their poster presentation in CHEM 388 - All students receive a grade of C+ or better on their oral presentation in CHEM 488 - All artifacts of writing in exit portfolio are rated at satisfactory or better.

3. Demonstrate critical thinking skills that utilize qualitative and quantitative problem solving.	Goal 1	Goal 1	Goal 1	<ul style="list-style-type: none"> <li>- Grades in relevant courses</li> <li>- ACS content exams</li> </ul>	<ul style="list-style-type: none"> <li>- Chemistry majors in all required courses for BA degree in chemistry</li> </ul>	<ul style="list-style-type: none"> <li>- Quarterly</li> <li>- Annual review of student exit portfolios.</li> </ul>	<ul style="list-style-type: none"> <li>- Graduates maintain 2.0 for course average and an average of 2.25 in courses within the major.</li> <li>- ACS exams consistent with national averages</li> </ul>
4. Use computers and the modern software of the discipline.	Goal 1 Goal 2	Goal 1	Goal 1	<ul style="list-style-type: none"> <li>- Grades in laboratory courses</li> <li>- Grades in CHEM 388 and CHEM 48</li> <li>- Student exit portfolio</li> </ul>	<ul style="list-style-type: none"> <li>- Chemistry majors in laboratory courses. These courses require the use of software for instrumentation control, data analysis, and reporting</li> <li>- CHEM 388 and 488</li> <li>- Chemistry majors submitting exit portfolios (all majors)</li> </ul>	<ul style="list-style-type: none"> <li>- Quarterly</li> <li>- Annual review of student exit portfolios.</li> </ul>	<ul style="list-style-type: none"> <li>- Graduates maintain 2.0 for course average and an average of 2.25 in laboratory courses within the major.</li> <li>- All students receive a grade of C+ or better on their poster presentation in CHEM 388</li> <li>- All students receive a grade of C+ or better on their oral presentation in CHEM 488</li> <li>- The research or lab report component in the students' portfolio will be rated at satisfactory or higher.</li> </ul>
5. Retrieve and critically analyze chemical literature.	Goal 1	Goal 1	Goal 1	<ul style="list-style-type: none"> <li>Course grades in:</li> <li>-CHEM 388</li> <li>-CHEM 488</li> <li>-Student Research CHEM 295, CHEM 395, and/or CHEM 495</li> <li>- Student exit portfolio</li> </ul>	<ul style="list-style-type: none"> <li>- CHEM 388</li> <li>- CHEM 488</li> <li>- CHEM 295, 395 or 495 (research)</li> <li>- Chemistry majors submitting exit portfolios (all majors)</li> </ul>	<ul style="list-style-type: none"> <li>- Quarterly</li> <li>- Annual review of student exit portfolios.</li> </ul>	<ul style="list-style-type: none"> <li>- All students receive a grade of C+ or better on their poster presentation in CHEM 388</li> <li>- All students receive a grade of C+ or better on their oral presentation in CHEM 488</li> <li>- The research report component in the students' portfolio will be rated at satisfactory or higher.</li> </ul>
6. Practice health and safety protocols that are integral to the discipline.	Goal 1	Goal 1	Goal 1	<ul style="list-style-type: none"> <li>- Grades in laboratory courses</li> </ul>	<ul style="list-style-type: none"> <li>- Chemistry majors in laboratory courses.</li> <li>- Chemistry majors working in research labs.</li> </ul>	<ul style="list-style-type: none"> <li>- Quarterly</li> </ul>	<ul style="list-style-type: none"> <li>- All students receive a grade of C+ or better in laboratory courses.</li> <li>- All research students receive a grade of B or better.</li> </ul>

7. Work effectively in group situations.	Goal 1 Goal 3	Goal 1 Goal7	Goal 1 Goal 6	- Grades in laboratory courses - Grades in student research courses: CHEM 295, CHEM 395, and/or CHEM 495 - Exit Survey		- Quarterly - Annual review of student exit portfolios.	- All students receive a grade of C+ or better in laboratory courses. - All research students receive a grade of B or better. - Reflective assessment in student exit portfolio.
8. Act ethically and responsibly in the handling and reporting of data.	Goal 1	Goal 1 Goal7	Goal 1 Goal 6	- Grades in student research courses: CHEM 295, CHEM 395, and/or CHEM 495 - Exit Survey		- Quarterly - Annual review of student exit portfolios.	- All research students receive a grade of B or better. - Reflective assessment in student exit portfolio. - All students respond with 4/5 or 5/5 to question on exit survey regarding how they value the ethical handling and reporting of data.

\*Method(s) of assessment should include those that are both direct (tests, essays, presentations, projects) and indirect (surveys, interviews) in nature

\*\*Data needs to be collected and differentiated by location (Ellensburg campus vs University Centers – see NWCCU standard 2.B.2)

\*\*\*Timing of assessment should be identified at different transition points of program (i.e., admission, mid-point, end-of-program, post-program)

**Table 4A, continued.** CWU Student Learning Outcome Assessment Plan Preparation Form  
Department of Chemistry  
 Program: Bachelor of Science, with Biochemistry Emphasis

<b>Student Learning Outcomes (performance, knowledge, attitudes)</b>	<b>Related Program/ Departmental Goals</b>	<b>Related College Goals</b>	<b>Related University Goals</b>	<b>Method(s) of Assessment (What is the assessment?)*</b>	<b>Who Assessed (Students from what courses – population)**</b>	<b>When Assessed (term, dates) ***</b>	<b>Standard of Mastery/ Criterion of Achievement (How good does performance have to be?)</b>
1. Apply the standard technical information and perform experimental techniques of analytical, biochemistry, inorganic, organic, and physical chemistry.	Goal 1 Goal 2	Goal 1	Goal 1	- Grades in relevant courses - Student exit portfolio - Student exit survey -Alumni survey -ACS content exams	- Chemistry majors in all required courses for BS degree in Biochemistry	- Quarterly - Annual review of student exit portfolios.	- Graduates maintain 2.0 for course average and an average of 2.25 in courses within the major. - ACS exams consistent with national averages - All students' portfolio components will be rated at satisfactory or higher.
2. Write and speak clearly in the language and style of the discipline.	Goal 1	Goal 1	Goal 1	- Grades in relevant courses - Student written lab reports - Student research reports for those students who performed research - Student exit portfolio	- Chemistry majors in all required courses for BS degree in Biochemistry. Course exams require some short answer as well as drawing of chemical structures and diagrams - CHEM 183Lab (written abstracts) - Full or partial lab reports; brief oral presentations: CHEM 361Lab, 363Lab, 382Lab, 383Lab (if taken), 431Lab, 452Lab (if taken) - CHEM 295,395 or 495, student research reports - CHEM 388 poster presentation - CHEM 488 oral presentation	- Quarterly - Annual review of student exit portfolios.	- Graduates maintain 2.0 for course average and an average of 2.25 in courses within the major. - All students receive a grade of C+ or better on their poster presentation in CHEM 388 - All students receive a grade of C+ or better on their oral presentation in CHEM 488 - All artifacts of writing in exit portfolio are rated at satisfactory or better.

3. Demonstrate critical thinking skills that utilize qualitative and quantitative problem solving.	Goal 1	Goal 1	Goal 1	<ul style="list-style-type: none"> <li>- Grades in relevant courses</li> <li>- ACS content exams</li> </ul>	<ul style="list-style-type: none"> <li>- Chemistry majors in all required courses for BS degree in Biochemistry</li> </ul>	<ul style="list-style-type: none"> <li>- Quarterly</li> <li>- Annual review of student exit portfolios.</li> </ul>	<ul style="list-style-type: none"> <li>- Graduates maintain 2.0 for course average and an average of 2.25 in courses within the major.</li> <li>- ACS exams consistent with national averages</li> </ul>
4. Use computers and the modern software of the discipline.	Goal 1 Goal 2	Goal 1	Goal 1	<ul style="list-style-type: none"> <li>- Grades in laboratory courses</li> <li>- Grades in CHEM 388 and CHEM 48</li> <li>- Student exit portfolio</li> </ul>	<ul style="list-style-type: none"> <li>- Chemistry majors in laboratory courses. These courses require the use of software for instrumentation control, data analysis, and reporting</li> <li>- CHEM 388 and 488</li> <li>- Chemistry majors submitting exit portfolios (all majors)</li> </ul>	<ul style="list-style-type: none"> <li>- Quarterly</li> <li>- Annual review of student exit portfolios.</li> </ul>	<ul style="list-style-type: none"> <li>- Graduates maintain 2.0 for course average and an average of 2.25 in laboratory courses within the major.</li> <li>- All students receive a grade of C+ or better on their poster presentation in CHEM 388</li> <li>- All students receive a grade of C+ or better on their oral presentation in CHEM 488</li> <li>- The research or lab report component in the students' portfolio will be rated at satisfactory or higher.</li> </ul>
5. Retrieve and critically analyze chemical literature.	Goal 1	Goal 1	Goal 1	<ul style="list-style-type: none"> <li>Course grades in:</li> <li>-CHEM 388</li> <li>-CHEM 488</li> <li>-Student Research CHEM 295, CHEM 395, and/or CHEM 495</li> <li>- Student exit portfolio</li> </ul>	<ul style="list-style-type: none"> <li>- CHEM 388</li> <li>- CHEM 488</li> <li>- CHEM 295, 395 or 495 (research)</li> <li>- Chemistry majors submitting exit portfolios (all majors)</li> </ul>	<ul style="list-style-type: none"> <li>- Quarterly</li> <li>- Annual review of student exit portfolios.</li> </ul>	<ul style="list-style-type: none"> <li>- All students receive a grade of C+ or better on their poster presentation in CHEM 388</li> <li>- All students receive a grade of C+ or better on their oral presentation in CHEM 488</li> <li>- The research report component in the students' portfolio will be rated at satisfactory or higher.</li> </ul>
6. Practice health and safety protocols that are integral to the discipline.	Goal 1	Goal 1	Goal 1	<ul style="list-style-type: none"> <li>- Grades in laboratory courses</li> </ul>	<ul style="list-style-type: none"> <li>- Chemistry majors in laboratory courses.</li> <li>- Chemistry majors working in research labs.</li> </ul>	<ul style="list-style-type: none"> <li>- Quarterly</li> </ul>	<ul style="list-style-type: none"> <li>- All students receive a grade of C+ or better in laboratory courses.</li> <li>- All research students receive a grade of B or better.</li> </ul>

7. Work effectively in group situations.	Goal 1 Goal 3	Goal 1 Goal7	Goal 1 Goal 6	- Grades in laboratory courses - Grades in student research courses: CHEM 295, CHEM 395, and/or CHEM 495 - Exit Survey		- Quarterly - Annual review of student exit portfolios.	- All students receive a grade of C+ or better in laboratory courses. - All research students receive a grade of B or better. - Reflective assessment in student exit portfolio.
8. Act ethically and responsibly in the handling and reporting of data.	Goal 1	Goal 1 Goal7	Goal 1 Goal 6	- Grades in student research courses: CHEM 295, CHEM 395, and/or CHEM 495 - Exit Survey		- Quarterly - Annual review of student exit portfolios.	- All research students receive a grade of B or better. - Reflective assessment in student exit portfolio. - All students respond with 4/5 or 5/5 to question on exit survey regarding how they value the ethical handling and reporting of data.

\*Method(s) of assessment should include those that are both direct (tests, essays, presentations, projects) and indirect (surveys, interviews) in nature

\*\*Data needs to be collected and differentiated by location (Ellensburg campus vs University Centers – see NWCCU standard 2.B.2)

\*\*\*Timing of assessment should be identified at different transition points of program (i.e., admission, mid-point, end-of-program, post-program)

**Table 4B.** CWU Student Learning Outcome Assessment Plan Preparation Form  
Department of Chemistry/Science Education  
 Program: Bachelor of Arts, Chemistry Teaching

<b>Student Learning Outcomes (performance, knowledge, attitudes)</b>	<b>Related Program/ Departmental Goals</b>	<b>Related College Goals</b>	<b>Related University Goals</b>	<b>Method(s) of Assessment (What is the assessment?)*</b>	<b>Who Assessed (Students from what courses – population)**</b>	<b>When Assessed (term, dates) ***</b>	<b>Standard of Mastery/ Criterion of Achievement (How good does performance have to be?)</b>
Demonstrate an ability to individually and collaboratively engage in inquiry and integrate the nature of science.	SCED Goal 1, 3, 4 CHEM Goal 1	COTS Goal 1, 4, 6	CWU Goal 1, 6	<ul style="list-style-type: none"> <li>Science Program major/minor teaching portfolio, WEST-E content assessment, entry to and exit from program survey</li> <li>Practicum field observation</li> <li>WA pedagogy assessment</li> </ul>	<ul style="list-style-type: none"> <li>All Biology, Chemistry, Earth Science, and Physics Teaching major and minor students</li> </ul>	<ul style="list-style-type: none"> <li>End of major/minor program, prior to student teaching</li> <li>SCED 324</li> <li>Student teaching</li> </ul>	<ul style="list-style-type: none"> <li>Minimum requirement is proficiency for this outcome. Student must provide suitable evidence and reflect on performance relative to associated NSES, NSTA, and WA Comp standards.</li> <li>SCED 324 portfolio performance benchmark proficiency</li> <li>All standards met for WA Pedagogy Assessment</li> </ul>
Explain and apply fundamental science content concepts, principles, and methods.	SCED Goal 1, 3, 5 CHEM Goal 1	COTS Goal 1, 4, 6	CWU Goal 1, 6	<ul style="list-style-type: none"> <li>Science Program major/minor teaching portfolio, WEST-E content assessment, entry to and exit from program survey</li> <li>Practicum field</li> </ul>	<ul style="list-style-type: none"> <li>All Biology, Chemistry, Earth Science, and Physics Teaching major and minor students</li> </ul>	<ul style="list-style-type: none"> <li>End of major/minor program, prior to student teaching</li> <li>SCED</li> </ul>	<ul style="list-style-type: none"> <li>Minimum requirement is proficiency for this outcome. Student must provide suitable evidence and reflect on performance relative to associated NSES, NSTA, and WA Comp</li> </ul>

				<p>observation</p> <ul style="list-style-type: none"> <li>• WA pedagogy assessment</li> <li>• Major Field Test - Biology</li> </ul>		<p>324</p> <ul style="list-style-type: none"> <li>• Student teaching</li> </ul>	<p>standards.</p> <ul style="list-style-type: none"> <li>• SCED 324 portfolio performance benchmark proficiency</li> <li>• All standards met for WA Pedagogy Assessment</li> </ul>
<p>Demonstrate an ability to effectively facilitate learning for all students.</p>	<p>SCED Goal 2, 3, 4 CHEM Goal 1</p>	<p>COTS Goal 1, 6</p>	<p>CWU Goal 1, 6</p>	<ul style="list-style-type: none"> <li>• Science Program major/minor teaching portfolio, entry to and exit from program survey</li> <li>• Practicum field observation</li> <li>• WA pedagogy assessment</li> </ul>	<ul style="list-style-type: none"> <li>• All Biology, Chemistry, Earth Science, and Physics Teaching major and minor students</li> </ul>	<ul style="list-style-type: none"> <li>• End of major/minor program, prior to student teaching</li> <li>• SCED 324</li> <li>• Student teaching</li> </ul>	<ul style="list-style-type: none"> <li>• Minimum requirement is proficiency for this outcome. Student must provide suitable evidence and reflect on performance relative to associated NSES, NSTA, and WA Comp standards.</li> <li>• SCED 324 portfolio performance benchmark proficiency</li> <li>• All standards met for WA Pedagogy Assessment</li> </ul>
<p>Create safe, effective learning environments that support inquiry, collaboration, intellectual risk-taking, ethical decision-making, and student</p>	<p>SCED Goal 1, 2, 3, 4 CHEM Goal 1</p>	<p>COTS Goal 1, 6, 7</p>	<p>CWU Goal 1, 6</p>	<ul style="list-style-type: none"> <li>• Science Program major/minor teaching portfolio, WEST-E content assessment, entry to and exit from program survey</li> <li>• Practicum field</li> </ul>	<ul style="list-style-type: none"> <li>• All Biology, Chemistry, Earth Science, and Physics Teaching major and minor students</li> </ul>	<ul style="list-style-type: none"> <li>• End of major/minor program, prior to student teaching</li> </ul>	<ul style="list-style-type: none"> <li>• Minimum requirement is proficiency for this outcome. Student must provide suitable evidence and reflect on performance relative to associated NSES, NSTA, and WA Comp</li> </ul>

construction of knowledge.				<p>observation</p> <ul style="list-style-type: none"> <li>• WA pedagogy assessment</li> </ul>		<ul style="list-style-type: none"> <li>• SCED 324</li> <li>• Student teaching</li> </ul>	<p>standards.</p> <ul style="list-style-type: none"> <li>• SCED 324 portfolio performance benchmark proficiency</li> <li>• All standards met for WA Pedagogy Assessment</li> </ul>
Demonstrate an ability to assess teaching and learning outcomes using multiple methods, effectively evaluate teaching and learning effectiveness, and improve practice based on reflection and data.	<p>SCED Goal 2, 3, 4, 7, 8 CHEM Goal 1</p>	<p>COTS Goal 1, 6</p>	<p>CWU Goal 1, 6</p>	<ul style="list-style-type: none"> <li>• Science Program major/minor teaching portfolio, entry to and exit from program survey</li> <li>• Practicum field observation</li> <li>• WA pedagogy assessment</li> </ul>	<ul style="list-style-type: none"> <li>• All Biology, Chemistry, Earth Science, and Physics Teaching major and minor students</li> </ul>	<ul style="list-style-type: none"> <li>• End of major/minor program, prior to student teaching</li> <li>• SCED 324</li> <li>• Student teaching</li> </ul>	<ul style="list-style-type: none"> <li>• Minimum requirement is proficiency for this outcome. Student must provide suitable evidence and reflect on performance relative to associated NSES, NSTA, and WA Comp standards.</li> <li>• SCED 324 portfolio performance benchmark proficiency</li> <li>• All standards met for WA Pedagogy Assessment</li> </ul>
Demonstrate an ability to make science personally and socially relevant to individual and community by incorporating current events	<p>SCED Goal 1, 2, 4 CHEM Goal 1</p>	<p>COTS Goal 1, 5, 6</p>	<p>CWU Goal 4, 6</p>	<ul style="list-style-type: none"> <li>• Science Program major/minor teaching portfolio, entry to and exit from program survey</li> <li>• Practicum field</li> </ul>	<ul style="list-style-type: none"> <li>• All Biology, Chemistry, Earth Science, and Physics Teaching major and minor students</li> </ul>	<ul style="list-style-type: none"> <li>• End of major/minor program, prior to student teaching</li> </ul>	<ul style="list-style-type: none"> <li>• Minimum requirement is proficiency for this outcome. Student must provide suitable evidence and reflect on performance relative to associated NSES, NSTA, and WA Comp</li> </ul>

within collaborative and social networks.				<p>observation</p> <ul style="list-style-type: none"> <li>• WA pedagogy assessment</li> </ul>		<ul style="list-style-type: none"> <li>• SCED 324</li> <li>• Student teaching</li> </ul>	<p>standards.</p> <ul style="list-style-type: none"> <li>• SCED 324 portfolio performance benchmark proficiency</li> <li>• All standards met for WA Pedagogy Assessment</li> </ul>
Participate in a variety of activities that enhance professional development and improve teaching effectiveness.	<p>SCED Goal 2, 7, 8 CHEM Goal 1</p>	<p>COTS Goal 1, 6</p>	<p>CWU Goal 1, 6</p>	<ul style="list-style-type: none"> <li>• Science Program major/minor teaching portfolio, entry to and exit from program survey</li> <li>• Practicum field observation</li> <li>• WA pedagogy assessment</li> </ul>	<ul style="list-style-type: none"> <li>• All Biology, Chemistry, Earth Science, and Physics Teaching major and minor students</li> </ul>	<ul style="list-style-type: none"> <li>• End of major/minor program, prior to student teaching</li> <li>• SCED 324</li> <li>• Student teaching</li> </ul>	<ul style="list-style-type: none"> <li>• Minimum requirement is proficiency for this outcome. Student must provide suitable evidence and reflect on performance relative to associated NSES, NSTA, and WA Comp standards.</li> <li>• SCED 324 portfolio performance benchmark proficiency</li> <li>• All standards met for WA Pedagogy Assessment</li> </ul>

\*Method(s) of assessment should include those that are both direct (tests, essays, presentations, projects) and indirect (surveys, interviews) in nature

\*\*Data needs to be collected and differentiated by location (Ellensburg campus vs University Centers – see NWCCU standard 2.B.2)

\*\*\*Timing of assessment should be identified at different transition points of program (i.e., admission, mid-point, end-of-program, post-program)

**Table 4C.** CWU Student Learning Outcome Assessment Plan Preparation Form  
Department of Chemistry  
 Program: Master of Science in Chemistry

<b>Student Learning Outcomes (performance, knowledge, attitudes)</b>	<b>Related Program/ Departmental Goals</b>	<b>Related College Goals</b>	<b>Related University Goals</b>	<b>Method(s) of Assessment (What is the assessment?)*</b>	<b>Who Assessed (Students from what courses – population)**</b>	<b>When Assessed (term, dates) ***</b>	<b>Standard of Mastery/ Criterion of Achievement (How good does performance have to be?)</b>
1. Apply technical information and independently perform advanced experimental techniques and data analysis.	Goal 1 Goal 2	Goal 1	Goal 1	- Grades in relevant courses - Student written proposal and thesis - Alumni survey	- All Chemistry graduate students	- Quarterly for classes - Yearly for proposal and thesis	- Graduates maintain 3.0 for course average.
2. Write and speak clearly in the language and style of the discipline.	Goal 1	Goal 1	Goal 1	- Grades in relevant courses (CHEM 505 and other grad classes) - Student written proposal and thesis (CHEM 700) - Student proposal defense and thesis defense (CHEM 589)	- All Chemistry graduate students	- Quarterly for classes - Yearly for proposal and thesis	- Graduates maintain 3.0 for course average
3. Demonstrate critical thinking skills that utilize qualitative and quantitative problem solving.	Goal 1	Goal 1	Goal 1	- Grades in relevant courses	- All Chemistry graduate students	- Quarterly for classes - Yearly for proposal and thesis	- Graduates maintain 3.0 for course average
4. Retrieve and critically analyze chemical literature.	Goal 1	Goal 1	Goal 1	Course grades in: - CHEM 505 - CHEM 589 - CHEM 700 - Student proposal and thesis.	- All Chemistry graduate students	- Quarterly - Annual review of student proposals and theses.	- Graduates maintain 3.0 for course average
5. Practice health and safety protocols that are integral to the discipline.	Goal 1	Goal 1	Goal 1	- Methods section in student's thesis	- All Chemistry graduate students	- Quarterly	- Graduates maintain 3.0 for course average

\*Method(s) of assessment should include those that are both direct (tests, essays, presentations, projects) and indirect (surveys, interviews) in nature

\*\*Data needs to be collected and differentiated by location (Ellensburg campus vs University Centers – see NWCCU standard 2.B.2)

\*\*\*Timing of assessment should be identified at different transition points of program (i.e., admission, mid-point, end-of-program, post-program)

# Faculty



### III. Faculty

- A. Faculty profile - Using attached chart show faculty participation for mentoring student research, professional service activities, scholarly activities including grant writing and teaching.

See Table 5.

- B. Copies of all faculty vitae – see Appendix II.

Gil Belofsky  
Steve Chamberland  
Anthony Diaz  
Levente Fabry-Asztalos  
Yingbin Ge  
Anne Johansen  
Todd Kroll  
Martha Kurtz  
JoAnn Peters  
Dion Rivera  
Tim Sorey  
Carin Thomas

- C. Faculty awards for distinction: instruction, scholarship, and service.

***Anne Johansen***

- Certificate of Merit, American Chemical Society (ACS), Division of Environmental Chemistry, 2007
- Editor's Citation for Excellence in Refereeing, American Geophysical Union, Journal of Geophysical Research Atmospheres, 2008

***Martha Kurtz***

- CWU Distinguished Professor: Service (2008)
- Washington Higher Education Science Teacher of the Year (2009)

***Carin Thomas***

- Presidential Faculty Award (2007)
- Certificate of Merit, American Chemical Society (ACS), Division of Environmental Chemistry, 2007

- D. Include in appendices performance standards by department, college and university.

See Appendix III.

**Table 5 (Section III)  
Tenured and Tenure-track Faculty Profile**

	2004-2005		2005-2006		2006-2007		2007-2008		2008-2009		5-yr total	Annual avg	Ave % of TT-T faculty
	# items/ #faculty TT - T	% of faculty											
<b>* Scholarship Measures: (Use categories applicable to your departmental &amp; college criteria)</b>													
(e.g. peer reviewed articles)	4/4	44%	6/4	44%	7/6	60%	4/3	33%	11/8	73%	32/25	6.4/5	50.8%
(e.g. abstracts/conference proceedings)	3/3	33%	3/2	22%	1/1	10%	3/3	33%	5/3	27%	15/12	3/2.4	25%
(e.g. conference presentation)	27/6	67%	18/4	44%	22/6	60%	31/7	78%	19/7	64%	117/30	23.4/6	62.6%
Other, etc.	2/1	11%	3/1	11%	1/1	10%	8/3	33%	3/2	18%	17/8	3.4/1.6	16.6%
<b>* Grants: (Use categories applicable to your departmental &amp; college criteria)</b>													
External													
Funded / Unfunded	4F/3U/5	56%	7F/6U/7	78%	8F/4U/5	50%	4F/4U/5	56%	10F/12U/8	73%	33F/29U/30	6.6F/5.8U/6	62.6%
Internal													
Funded / Unfunded	7F/1U/5	56%	5F/3U/6	67%	6F/2U/5	50%	5F/2U/3	33%	6F/7U/6	55%	29F/15U/25	5.8F/3U/5	52.2%
<b>* Service measures: (Use categories applicable to your departmental &amp; college criteria)</b>													
CWU Committees	35/9	100%	45/8	89%	64/9	90%	58/9	100%	42/10	91%	244/45	48.8/9	94%
State Committees			1/1	11%			1/1	11%	1/1	9%	3/3	.60/.60	6.2%
Leadership & Service - Professional Organizations	7/3	33%	10/3	33%	16/6	60%	15/4	44%	11/6	55%	59/22	11.8/4.4	45%
Community Service	20/5	56%	20/4	44%	24/4	40%	14/4	44%	25/4	36%	103/21	20.6/4.2	44%
Other	4/2	22%	8/3	33%	8/3	30%	11/5	56%	10/4	36%	41/17	8.2/3.4	35.4%
<b>* Faculty Mentored Research: (Use categories applicable to your departmental &amp; college criteria)</b>													
Undergrad projects / SOURCE	18/5	56%	21/7	78%	20/8	80%	32/7	78%	34/10	91%	125/37	25/7.4	76.6%
Graduate Committees – Supervising thesis/projects	6/5	56%	11/7	78%	12/8	80%	14/7	78%	12/6	55%	55/33	11/6.6	69.4%
Graduate Committees – Participation thesis/projects	10/7	78%	9/5	56%	13/5	50%	13/7	78%	12/7	64%	57/31	11.4/6.2	65.2%
Other			1/1	11%	3/2	20%	6/2	22%	6/3	27%	16/8	3.2/1.6	16%

A response to all four main categories is mandatory.

The details to support each category should be applicable to your department & college criteria.

# Students



#### IV. Students - for five years

A. Student accomplishments (include SOURCE, career placement information, etc. List students working in field; students placed in masters or doctoral programs.

1. Placement of B.S. and B.A. degree recipients with employers, graduate and professional programs, by year

##### 2004/05

<i><b>Graduate/professional programs:</b></i>	<i><b>Employers:</b></i>
Colorado School of Mines, Chemistry	Glendale High School
Central Washington University, Chemistry	Kittitas County Public Health
Oregon State University, Pharmacy	Lakeside Industries
Temple University, Podiatry	Norwest Applied Hydrology
University of Washington, Chemistry	
Washington State University, Engineering	

##### 2005/06

<i><b>Graduate/professional programs:</b></i>	<i><b>Employers:</b></i>
Bastyr University, Acupuncture Medicine	Amtest Lab
Central Washington University, Chemistry	Atlas Casting
Oregon State University, Pharmacy	Eli Lilly Pharmaceuticals
University of Hawaii, Atmosphere Ocean Systems	Fred Hutchinson Cancer Research Center
University of South Carolina, Biochemistry	REC Silicon
University of Washington, Chemistry	Southwest Research Institute
Washington State University, Chemistry	Sterling Reference Lab

##### 2006/07

<i><b>Graduate/professional programs:</b></i>	<i><b>Employers:</b></i>
Central Washington University, Biology	North Star Casteel
Oregon State University, Materials Science	Pacific Science Center
University of Arizona, Pharmacy	Syntrix
University of California-Santa Barbara, Chemistry	U.S. Oil Refinery
University of Oregon, Chemistry	
University of Washington, Laboratory Medicine	
Washington State University, Physics	

**2007/08**

<b><i>Graduate/professional programs:</i></b>	<b><i>Employers:</i></b>
Central Washington University, Chemistry	Cascade Analytical
Central Washington University, Geology	Eastlake High School
University of Oregon, Chemistry	ICF Consulting
University of Oregon, Materials Science	Moses Lake School District
	SVL Analytical
	TriMed Ambulance
	U.S. Army
	Voxtel, Inc.

**2008/09**

<b><i>Graduate/professional programs:</i></b>	<b><i>Employers:</i></b>
Central Washington University, Chemistry	Analytical Resources, Inc.
Midwestern University, Dentistry	East Valley High School
Oregon Health and Science University, Dentistry	Sterling Reference Labs
Pacific University, Pharmacy	Syntrix
University of Notre Dame, Bioinformatics	
University of Washington, Chemistry	

2. Placement of M.S. graduates with employers, graduate and professional programs, by year

**2005/06**

<b><i>Graduate/professional programs:</i></b>	<b><i>Employers:</i></b>
University of Texas Health Science Center, Chemistry	Pace International
Georgia State University, Medicinal Chemistry	Kittitas County Department of Health

**2007/08**

<b><i>Graduate/professional programs:</i></b>	<b><i>Employers:</i></b>
University of Hawaii, Ocean and Atmosphere Systems	Central Washington University
University of Texas-Dallas, Chemistry	Kittitas County Department of Health
	REC Silicon
	Sterling Reference Labs

3. Student accomplishments, by year

**2004/05**

***Grants Awarded***

- **Symposium on University Research and Creative Endeavor (SOURCE)**
  - Brennan Dawson of the Diaz Research Group, \$500
  - Lindsay Groce of the Diaz Research Group, \$500
- **Thesis**
  - Catharine Collar of the Fabry Research Group, \$695
  - Amy Diaz of the Thomas Research Group, \$700
  - Yinshan Jia of the Fabry Research Group, \$700
  - Tracy Watrous of the Diaz Research Group, \$700
- **Undergraduate Research**
  - Heather Biles of the Fabry Research Group, \$400
  - Nicole Paulk of the Johansen Research Group, \$500
  - Nicholas Salim of the Fabry Research Group, \$300
  - Jugraj Patrick Singh of the Thomas Research Group, \$500

***Honors***

- Lacy Ledbeter was selected as the alternate valedictorian for the 2005 commencement ceremonies. She gave her speech at a luncheon at the President's Reception Center on May 26.
- Two graduating chemistry majors (Lacy Ledbeter and Lindsey Shank) were recognized as Deans Scholars by the university.
- Jennifer Key had her thesis selected for the CWU Distinguished Thesis Award. As a result, her thesis was forwarded to the Western Association of Graduate Schools Thesis competition.
- CWU Student Affiliates Chapter of the American Chemical Society (the chemistry club) was awarded an Honorable Mention by the ACS. There were over 970 chapters at colleges and universities across the US and Puerto Rico. Every chapter is required to submit an annual report of its activities. Based on the review of these reports, chapters are selected for award recognition. Less than 200 of these awards are given each year.

***Invited presentations***

The CWU Chemistry Department was invited to the Regional Conference on Undergraduate Research of the Murdock College Science Research Program held at Lewis & Clark College in November 2004. There were five poster presentations and one oral presentation presented by our undergraduates.

### ***Publications (student authors underlined; undergrads\*, masters#)***

- Andonie, R.; Fabry-Asztalos, L.; Collar, C. J.<sup>#</sup>; Abdul-Wahid, S.<sup>\*</sup>; Salim, N.<sup>\*</sup> Neuro-fuzzy Prediction of Biological Activity and Rule Extraction for HIV-1 Protease Inhibitors. *Proceedings of the IEEE Symposium on Computational Intelligence in Bioinformatics and Computational Biology*, 113-120, 2005.
- Dawson, B.<sup>\*</sup> and Diaz, A.L. Crystal Chemistry, Defect Chemistry, and Degradation Processes in BaMgAl<sub>10</sub>O<sub>17</sub>:Eu<sup>2+</sup>. *Proceedings of the 12th International Display Workshops*, 1 509 – 512, 2005. Invited.
- Lenington, M.J.<sup>#</sup> and DeLuca, J. P. Generation of Triplet Carbenes through Photolysis of Iodonium Ylides. *The Spectrum*, winter 2005.

### ***Scholarship Awards***

Every year departments across campus are invited by the CWU Alumni Association to nominate two majors for the Departmental Scholarship competition. Lindsey Shank and Gayle Smith were each awarded \$1,000 this year.

### ***SOURCE (Symposium on Undergraduate Research and Creative Expression) presentation awards***

- **Oral Presentation Honorable Mention in Chemistry, Physics & IET** Diaz, Amy – Is Salicylate a Selective Chemical Trap for Hydroxyl Radical? Mentor: Dr. Carin Thomas
- **Honorable Mention Poster Session: Life Sciences** Biles, Heather N. and Collar, Catharine J. – Force Field and Charge Comparisons for Cathepsin-D Inhibitors. Mentor: Dr. Levente Fabry-Asztalos

### ***Science Honors***

Three chemistry majors were asked to join the inaugural Science Honors cohort; each student received a monetary grant along with the distinction of being selected for this program:

- Heather Biles, junior biochemistry major working with Levente Fabry
- Lindsay Groce, senior chemistry major working with Anthony Diaz
- Nicholas Salim, junior biochemistry major working with Levente Fabry

## **2005/06**

### ***Grants Awarded***

- **College of the Sciences Undergraduate Research**
  - Krista Bjorge of the Sorey Research Group
  - Lindsay Groce of the Diaz Research Group
  - David Nguyen of the Sorey Research Group
  - David Nguyen of the Fabry Research Group
  - Nicole Paulk of the Johansen Research Group
  - Nicholas Salim of the Fabry Research Group
  - Elizabeth Scott of the Sorey Research Group

- **Thesis**
  - Ryan Jorgensen of the DeLuca Research Group
  - Lindsey Shank of the Johansen Research Group
- **Undergraduate Research**
  - Grant Barker of the Thomas Research Group, \$500
  - Kaori Noridomi of the Fabry Research Group
  - Nicole Paulk of the Johansen Research Group, \$500
  - Nicholas Salim of the Fabry Research Group
  - Elizabeth Scott of the Sorey Research Group
- **Undergraduate Travel**
  - Nicole Paulk of the Johansen Research Group, \$500

### *Honors*

- One graduating chemistry major (Amy Armintrout) was recognized as a Deans Scholar by the university.
- CWU Student Affiliates Chapter of the American Chemical Society (the chemistry club) was awarded an Honorable Mention by the ACS.

### *Invited presentations*

The CWU Chemistry Department was invited to the Regional Conference on Undergraduate Research of the Murdock College Science Research Program held at Northwest Nazarene University in November 2005. There was one poster and one oral presentation presented by chemistry undergraduates involved in the Science Honors Program.

### *Publications (student authors underlined; undergrads\*, masters#)*

- Andonie, R.; Fabry-Asztalos, L.; Abdul-Wahid, S.; Collar, C. J.<sup>#</sup>; Salim, N.<sup>\*</sup> An Integrated Soft Computing Approach for Predicting Biological Activity of Potential HIV-1 Protease Inhibitors. *Proceedings of the IEEE International Joint Conference on Neural Networks (IJCNN)*, 7495-7502, 2006.
- Johansen, A.M. and Key, J.M.<sup>#</sup> Photoreductive Dissolution of Ferrihydrite by Methanesulfinic Acid; Evidence of a Direct Link between Dimethylsulfide and Iron-Bioavailability. *GRL*, 33, doi:10.1029/2006GL026010, 2006.
- Watrous-Kelley, T.<sup>#</sup>; Diaz, A.L. and Dang, T.A. Quantitative Determination of Non-Radiative Host-to-Activator Energy Transfer Efficiencies in  $\text{YBO}_3:\text{Eu}^{3+}$  and  $\text{Y}_2\text{O}_3:\text{Eu}^{3+}$  Under VUV Excitation. *Chemistry of Materials*, 18 3130 – 3136, 2006.

### *Scholarship Awards*

Every year departments across campus are invited by the CWU Alumni Association to nominate two majors for the Departmental Scholarship competition. Heather Biles and Nicholas Salim were each awarded \$1,000 this year.

### ***Science Honors***

- Christopher Abdul-Wahid, senior biochemistry major working with Levente Fabry
- Tajinder Heer, senior chemistry major working with Levente Fabry
- William Klein, sophomore chemistry major working with Eric Bullock
- Josie Wells, senior biochemistry major working with Carin Thomas

### ***SOURCE (Symposium on Undergraduate Research and Creative Expression) presentation awards***

- **Oral Presentation First Place Award** Paulk, Nicole – Iron Photochemical Dissolution in Simulated Marine Aerosols Enhanced by Methanesulfinic Acid. Mentor: Dr. Anne Johansen.
- **Poster Presentation First Place Award** Bryner, Stephanie – The Effect of Crystal Violet on Cellular Respiration. Mentor: Dr. Carin Thomas.

2006/07

### ***Grants Awarded***

- **SOURCE/Undergraduate Research**
  - Christopher Abdul-Wahid of the Fabry Research Group, \$1,000
  - Brittany Best of the Johansen Research Group, \$1,000
  - Tajinder Heer of the Fabry Research Group, \$500
  - Jesse Nye of the Fabry Research Group, \$500
  - Tracy O'Connell of the Fabry Research Group, \$500
  - Scott Palmer of the Fabry Research Group, \$500
- **Thesis**
  - Caitlyn Cornell of the Kurtz Research Group
  - James Rivard of the Bullock Research Group
  - Zhen Zhang of the Johansen Research Group
- **Undergraduate Travel**
  - Christopher Abdul-Wahid of the Fabry Research Group
  - Brittany Affholter of the Johansen Research Group
  - Geoff Baran of the Sorey Research Group
  - Tajinder Heer of the Fabry Research Group
  - Bom Kim of the Sorey Research Group
  - David Nguyen of the Fabry Research Group
  - Annika Nieber of the Johansen Research Group
  - Cassandra Warren of the Sorey Research Group

### ***Honors***

- One graduating chemistry major (Megan Jones) was recognized as a Deans Scholar by the university.
- A junior chemistry major, Stephanie Bryner, was one of just 75 students from across the nation selected for the "Posters on the Hill" event held in April in Washington D.C. The Council on Undergraduate Research

(CUR), a national organization that supports and serves as an advocate for undergraduate research, organizes the annual event. Colleges across the nation are invited to submit two abstracts for consideration for the national competition. The “Posters on the Hill” event offers students the opportunity to share their personal stories and the excitement of their discoveries with members of Congress and professional scientists. Stephanie was doing research with Dr. Carin Thomas on the NIH-funded collaboration with the Johansen and Bullock groups.

***Publications (student authors underlined; undergrads\*, masters#)***

- Andonie, R.; Fabry-Asztalos, L.; Magill, L.\*; Abdul-Wahid, S. A New Fuzzy ARTMAP Approach for Predicting Biological Activity of Potential HIV-1 Protease Inhibitors. *Proceedings of the IEEE International Conference on Bioinformatics and Biomedicine (BIBM)*, 56-61, 2007.

***Scholarship Awards***

Every year departments across campus are invited by the CWU Alumni Association to nominate two majors for the Departmental Scholarship competition. Tajinder Heer was awarded \$1,000 this year.

***Science Honors***

- Ryan Atkins, junior major working with Anthony Diaz
- Amanda Blackmore, junior major working with Levente Fabry
- Michael Hase, junior major working with Dion Rivera
- Jesse Nye, senior major working with Levente Fabry
- Katie Warren, junior majors working with Anthony Diaz

***SOURCE (Symposium on Undergraduate Research and Creative Expression) presentation awards***

- **Outstanding Oral Presentation Awards**
  - Klein, William – Designing and Constructing a Research Grade Scanning Tunneling Microscope System for Imaging Individual Molecules in Surface Self-Assembly. Mentor: Dr. Eric Bullock.
  - Telecky, Alan – Novel Synthesis and Optical Characterization of  $\text{Sr}_3\text{Y}_2(\text{BO}_3)_4:\text{Eu}^+$  and  $\text{Sr}_3\text{Y}_2(\text{BO}_3)_3:\text{Eu}^+$ . Mentor: Dr. Anthony Diaz.

**2007/08**

***Grants Awarded***

- **Undergraduate Research**
  - Amanda Blackmore of the Fabry Research Group
  - Craig Gyselinck of the Rivera Research Group
  - Jesse Nye of the Fabry Research Group
- **Undergraduate Travel**
  - Mike Hase of the Rivera Research Group

- Zhenya Balandova, Ed Bain and T.J. Helland of the Sorey Research Group (joint award)

***Publications (student authors underlined; undergrads\*, masters#)***

- Atkins, R.\* and Diaz, A.L. Investigation of Host-to-Activator Energy Transfer and Surface Losses in SrY<sub>2</sub>O<sub>4</sub>:Eu<sup>3+</sup> under VUV Excitation. *Journal of Luminescence*, 128 1463 – 1470, 2008.
- Fabry-Asztalos, L.; Andonie, R.; Collar, C.J.#; Abdul-Wahid, S.; Salim, N.\* A Genetic Algorithm Optimized Fuzzy Neural Network Analysis of the Affinity of Inhibitors for HIV-1 Protease. *Bioorganic & Medicinal Chemistry*, 6, 2903-2911, 2008.
- Key, J.M.#; Paulk, N.\* and Johansen, A.M. Photochemistry of Iron in Simulated Crustal Aerosols with Dimethyl Sulfide Oxidation Products. *Environmental Science & Technology*, 42, 1, 2008.
- Quitadamo, I. J., Faiola, C.\*, Johnson, J., & Kurtz, M. J. Community-based Inquiry Improves Critical Thinking in General Education Biology. *Cell Biology Education-Life Science Education*, 7, 327-337, 2008.

***Scholarship Awards***

Every year departments across campus are invited by the CWU Alumni Association to nominate two majors for the Departmental Scholarship competition. Amanda Blackmore and William Klein were each awarded \$1,000 this year.

***Science Honors***

- Heather Durkee, senior major working with Dion Rivera
- Rusty Mann, senior biochemistry major working with Anthony Diaz
- Annika Nieber, senior chemistry major working with Anne Johansen and Jim Johnson of Biological Sciences
- Sara Rosario, senior biochemistry major working with Carin Thomas

***SOURCE (Symposium on Undergraduate Research and Creative Expression) presentation awards***

- **Oral Presentation Awards**
  - Cornell, Caitlyn (grad student) – Measured Effects of Community-Based Inquiry on Critical Thinking in Non-Majors Chemistry. Mentor: Dr. Martha Kurtz.
  - Warren, Katie (undergrad) – Determination of Host to Activator Energy Transfer Efficiency in YBO<sub>3</sub>:Eu<sup>3+</sup> and (Y, Gd)BO<sub>3</sub>:Eu<sup>3+</sup>. Mentor: Dr. Anthony Diaz.
  - Blackmore, Amanda (undergrad) – Synthesis Towards Novel 1,3-Azaborine Heterocycles as Potential Dual-Mode HIV-1 Protease Inhibitors. Mentor: Dr. Levente Fabry.

- Abdul-Wahid, Christopher (undergrad) – Ordered Fuzzy Artmap for Predicting HIV-1 Protease Inhibitor Activity. Mentor: Dr. Levente Fabry.
- **Poster Presentation Award** Brown, Kelley; Kellar, Casey; Charlton, Paul (undergrads) – An Exploratory Study of the Propargylation of Aromatics with  $\text{Pi}(\text{OTf})_3$  in Ionic Liquid Solvent [BMIM][OTf]: New Life for a Classic Transformation. Mentor: Dr. Viorel Sarca.

## 2008/09

### *Grants Awarded*

- **College of the Sciences Undergraduate Research**
  - Mandy Christensen of the Sorey Research Group, \$100
  - Lee Ream of the Fabry Research Group, \$500
  - Cameron Shore of the Ge Research Group, \$100. His proposal was also selected for Honorable Mention.
- **Thesis**
  - Stephanie Bryner of the Thomas Research Group
- **Undergraduate Research**
  - Donald Clayton of the Fabry Research Group, \$500
  - Sarah Clark of the Chamberland Research Group, \$500
  - Sarah Hayden of the Rivera Research Group, \$400
  - Rob Jensen of the Peters Research Group, \$500
  - Casey Kellar of the Sarca Research Group, \$500

### *Honors*

- Heather Durkee has an oral presentation on her Science Honors research accepted to the Western Regional Honors Conference in Spokane, Washington. She conducts research with Dion Rivera.
- A senior chemistry major, Christopher Abdul-Wahid, was one of just 75 students from across the nation selected for the “Posters on the Hill” event held in May in Washington D.C. The Council on Undergraduate Research (CUR), a national organization that supports and serves as an advocate for undergraduate research, organizes the annual event. Colleges across the nation are invited to submit two abstracts for consideration for the national competition. The “Posters on the Hill” event offers students the opportunity to share their personal stories and the excitement of their discoveries with members of Congress and professional scientists. Christopher was conducting computational research under his mentors Dr. Levente Fabry in Chemistry and Dr. Razvan Andonie in Computer Science.

### *Invited presentations*

The CWU Chemistry Department was invited to the Regional Conference on Undergraduate Research of the Murdock College Science Research Program

held at University of Puget Sound in November 2008. There were two poster presentations presented by chemistry undergraduates involved in the Science Honors Program.

***Publications (student authors underlined; undergrads\*, masters#)***

- Aguilar-Islas, A.M.; Wu, J.; Rember, R.; Johansen, A.M. and L. M. Shank.<sup>#</sup> Dissolution of Aerosol-Derived Iron in Seawater: Leach Solution Chemistry, Aerosol Type, and Colloidal Iron Fraction. *Marine Chemistry*, doi:10.1016/j.marchem.2009.01.011, 2009.
- Andonie, R.; Fabry-Asztalos, L.; Crivat, B.; Abdul-Wahid, S.; Abdul-Wahid, C.B.<sup>\*</sup> Fuzzy ARTMAP Rule Extraction in Computational Chemistry. *Proceedings of the IEEE International Joint Conference on Neural Networks*, 157-163, 2009.
- Mahowald, N.M.; Engelstaedter, S.; Luo, C.; Sealy, A.; Artaxo, P.; Benitez-Nelson, C.; Bonnet, S.; Chen, Y.; Chuang, P.Y.; Cohen, D.D.; Dulac, F.; Herut, B.; Johansen, A.M.; Kubilay, N.; Losno, R.; Maenhaut, W.; Paytan, A.; Prospero, J.M.; Shank, L.M.<sup>#</sup>, and Siefert, R.L. Atmospheric Iron Deposition: Global Distribution, Variability, and Human Perturbations. *Annual Review of Marine Science*, 1:245-79, 2009.
- Thomas, C.; Mackey, M.M.<sup>#</sup>; Diaz, A.A.<sup>#</sup> and Cox, D.C.<sup>\*</sup> Hydroxyl Radical is Produced via the Fenton Reaction in Submitochondrial Particles under Oxidative Stress: Implications for Diseases Associated with Iron Accumulation. *Redox Reports* 14(3): 102-108, 2009.
- Warren, K.J.<sup>\*</sup>; Rabinovitz, R.L.<sup>\*</sup> and Diaz, A.L. Investigating the Function of Gd<sup>3+</sup> in (Y,Gd)BO<sub>3</sub>:Eu<sup>3+</sup> Through Measurements of Host-to-Activator Transfer Efficiency," *Proceedings of SID 2009*, 251 – 253, 2009.

***Scholarship Awards***

Every year departments across campus are invited by the CWU Alumni Association to nominate two majors for the Departmental Scholarship competition. Amy Jepsen was awarded \$1,000 this year.

***Science Honors***

- Adam Alman, senior major working with Dion Rivera
- Donald Clayton, senior major working with Levente Fabry
- Rosa Rabinovitz, senior major working with Anthony Diaz
- John Schreiber, senior major working with Gil Belofsky

***SOURCE (Symposium On Undergraduate Research and Creative Expression) presentation awards***

- **Outstanding Oral Presentation Awards**
  - Abdul-Wahid, Christopher – Fuzzy Artmap Rule Extraction in Computational Chemistry. Mentor: Dr. Levente Fabry

- Mann, Rusty – Quantitatively Modeling Surface Trapping in Nano-Scale Yttrium Oxide Doped with Europium. Mentor: Anthony Diaz.
  - **Outstanding Poster Presentation Award** Perez, Edgar – Real-time Comparison Polarimeter for Data Acquisition in Determination of 0<sup>th</sup>, 1<sup>st</sup>, and 2<sup>nd</sup> Order Rate Constants. Mentor: Dr. Tim Sorey.
- B.** Provide one masters project ; two will be randomly selected during site visit.  
Available in either the library or through the departmental office.

"Effect of Dimethyl Sulfide Oxidation Products on Iron Speciation in Photochemical Simulation Experiments", A Thesis Presented to The Graduate Faculty of Central Washington University in Partial Fulfillment of the Requirements for the Degree of Master of Science in Chemistry by Jennifer Michelle Key, March 2005. See Appendix IV.

- C.** Describe departmental policies, services, initiatives, and documented results for successful student advising.

***B.S., Chemistry***

Advising by all Chemistry Department tenured/tenure-track faculty

***B.S., Chemistry with Biochemistry emphasis***

Advising by biochemistry faculty members Carin Thomas, Todd Kroll, David Lygre

***B.A., Chemistry Education***

Advising by chemistry education faculty members Martha Kurtz, Tim Sorey

***M.S., Chemistry***

Advising by Graduate Coordinator and student's research advisor

***Minor, Chemistry***

Advising by all Chemistry Department tenured/tenure-track faculty

***Minor, Chemistry Teaching***

Advising by chemistry education faculty members Martha Kurtz, Tim Sorey

***Pre-Pharmacy***

The Chemistry Department is responsible for advising Pre-Pharmacy students (20 students/year). The advisor is currently Gil Belofsky. Typically 1-3 students per year are accepted to pharmacy programs.

***Pre-Medical***

The Chemistry Department shares the advising of Pre-Medical students (100 students/year) with the Biology Department. Levente Fabry-Asztalos is the Chemistry Department's Pre-Medical Advisor. Efforts include maintaining a

pre-medical information website, maintaining contact with region medical schools and attending workshops, conducting pre-medical student interviews, and writing letters of recommendation. Typically 6-9 graduates per year are accepted to medical programs.

- D. Describe other student services offered through the department including any professional societies or faculty-led clubs or organizations and their activities.

***Chemistry Club (Student Affiliate Chapter of the American Chemical Society)***

This is a very active club involved in public outreach, service, educational, and social activities. Their activities during the review period include volunteering for Expanding Your Horizons workshops for middle school students, organizing chemistry magic shows for Boo Central, organizing "Concert for the Cure" to raise funds for the American Cancer Society (several of the chemistry faculty/staff play in a rock and roll band), visits to local chemical industries and Pacific Northwest National Laboratories, and a trip to a national meeting of the American Chemical Society. The current faculty advisors for the club are Tim Sorey and Dion Rivera.

***Pre-Medical Club***

The club holds informational meetings with the pre-medical advisor and hosts presentations by local medical professionals.

***Pre-Pharmacy Club***

The club holds informational meetings with the pre-pharmacy advisor.

# Facilities and Equipment by Location



## V. Facilities and equipment by location

- A. Describe facilities available to department and their adequacy (program delivery location, size, functionality, adjacencies, lighting, ventilation, finishes, plumbing, electrical outlets, etc.). Describe anticipated needs in the next three to five years.

### *Existing facilities*

- See Table 6 for a listing of Chemistry laboratory, office, and classroom space.
- Blueprints are available in Facilities Management if more detail is needed.

### *Anticipated needs*

- **Office space.** Further growth in faculty and/or staff to accommodate increasing enrollment will require additional office space. All offices are currently occupied.
- **Research space.** Hiring of additional tenure track faculty members will require additional research space. Ideally this would be new space within the building, possibly space vacated by Science Education if space is made available for that department in Science Phase II. The minimum requirement would be for the restructuring of existing space to accommodate additional faculty member(s) and student collaborators.

- B. Describe equipment available to department. Include program delivery location and its adequacy (office furniture, instructional fixtures, lab equipment, storage cabinets, specialty items, etc.) Describe anticipated needs in the next three to five years.

### *Existing instrumentation*

See Table 7 for a list of existing instrumentation.

### *Anticipated needs*

- **Instrument repair and replacement.** Table 7 indicates instruments that will likely need to be replaced within the next five years, priority for replacement, and cost. Most of the department's instrumentation was purchased at the time that we moved into the new building. As the instrumentation ages the need for repair and replacement has accelerated. Approximately \$16,000 has been spent on instrument maintenance and repair within the last three years.
- **Classroom equipment.** Classroom space within the Science Building is well-equipped and suits our needs admirably. As the number of large classes taught on campus increases, scheduling is becoming more difficult and we have found ourselves teaching in other buildings across campus. Some of these classrooms have not been equipped for teaching science classes. We require adequate whiteboard or blackboard space, computer projection capabilities, overhead projector and/or document camera, space for posting a large periodic table.

- C. Describe technology available to department. Include program delivery location and its adequacy (computers, telecommunications, network systems, multi-media, distance education, security systems, etc.). Describe anticipated need in the next three to five years.

**Table 6.** Description of Science Building space assigned to the Department of Chemistry

<i>Room*</i>	<i>Function</i>	<i>Size (SqFt)</i>	<i>Occupancy</i>	<i>Fume Hood</i>	<i>Sink</i>	<i>Chemical Storage</i>	<i>Safety Features 1</i>
101*	CLAS	1431	80	0	Y	N	N
142*	CLAS	1100	50	0	Y	N	N
147*	CLAS	1845	104	0	Y	N	N
201*	CLAS	787	30	0	Y	N	N
203*	CLAS	784	30	0	Y	N	N
216*	CLAS	1273	72	0	Y	N	N
240*	CLAS	915	48	0	Y	N	N
<b>Classroom Totals</b>		<b>8135</b>	<b>414</b>	<b>0</b>			
328*	COMP	918	24	0	N	N	N
337*	COMP	919	24	0	N	N	N
<b>Computer Lab Totals</b>		<b>1837</b>	<b>48</b>	<b>0</b>			
301*	CONF	492	16	0	N	N	N
302a*	CONF	298	12	0	N	N	N
311b*	CONF	249	8	0	N	N	N
<b>Conference Room Totals</b>		<b>1039</b>	<b>36</b>	<b>0</b>			
102	I/PREP	285	NA	0	N	N	N
104	I/PREP	570	NA	0	N	N	N
117, 117a	I/PREP	296	NA	1	Y	Y	Y
120	I/PREP	221	NA	0	N	N	N
204	I/PREP/RLAB	835	NA	2	Y	Y	Y
212	I/PREP	1732	NA	1	Y	Y	Y
213	I/PREP	291	NA	0	N	N	N

215a	I/PREP	99	NA	1	Y	Y	N
217a	I/PREP	100	NA	0	N	N	N
220*	I/PREP	934	NA	1	Y	Y	Y
<b>Instrument/Prep Room Totals</b>		<b>5363</b>	<b>NA</b>	<b>6</b>			

204a	OFF	100	2	0	N	N	N
207a	OFF	126	1	0	N	N	N
207b	OFF	131	1	0	N	N	N
207c	OFF	133	1	0	N	N	N
207d	OFF	128	1	0	N	N	N
207e	OFF	137	1	0	N	N	N
207f	OFF	137	1	0	N	N	N
302	OFF	475	1	0	Y	N	N
302b	OFF	206	1	0	N	N	N
302c	OFF	145	1	0	N	N	N
302d	OFF	137	1	0	N	N	N
302e	OFF	149	1	0	N	N	N
302f	OFF	172	1	0	N	N	N
302g	OFF	188	1	0	N	N	N
302h	OFF	124	1	0	N	N	N
302j	OFF	140	1	0	N	N	N
303a	OFF	210	2	0	N	N	N
310	OFF	129	1	0	N	N	N
321*	OFF	649	2	0	N	N	N
329*	OFF	527	5	0	N	N	N
<b>Office Space Totals</b>		<b>4143</b>	<b>27</b>	<b>0</b>			

210	RLAB	1377	2	2	Y	Y	Y
210a	RLAB	195	1	1	Y	Y	N

214	RLAB	635	1	0	N	N	N
220a	RLAB	314	1	1	Y	Y	N
304	RLAB	623	1	2	Y	Y	Y
305	RLAB	627	1	4	Y	Y	Y
313/313A	RLAB	608	1	3	Y	Y	Y
314	RLAB	625	1	1	Y	Y	Y
<b>Research Lab Totals</b>		<b>5004</b>	<b>9</b>	<b>14</b>			

103	SLAB	1623	24	6	y	y	y
118	SLAB	1622	24	6	y	y	y
119	SLAB	1587	24	6	Y	Y	Y
202	SLAB	1268	22	12	Y	Y	Y
215	SLAB	722	20	0	N	N	N
217	SLAB	1266	20	4	Y	Y	Y
219	SLAB	1264	24	2	Y	Y	Y
<b>Student Lab Totals</b>		<b>9352</b>	<b>158</b>	<b>36</b>			

303	STOC	1673	NA	2	Y	Y	Y
134a*	STOR	44	NA	0	N	N	N
135*	STOR	125	NA	0	N	Y	Y
135a*	STOR	107	NA	1	Y	Y	Y
136*	STOR	101	NA	0	N	Y	N
136a*	STOR	116	NA	1	N	Y	Y
315*	STOR	210	NA	0	N	N	N
<b>Stockroom and Storage Totals</b>		<b>2376</b>	<b>NA</b>	<b>4</b>			

\* space shared with other departments

<sup>1</sup> safety shower and eyewash

Table 7. Instrument Replacement Projections

Common Support Instrument	Amount	Approx. Age	Suggested Replacement	Estimated Unit Cost	Program Use: Teaching lab (T) research lab (R) Both (B)
Balance Count	63	12+	5	\$2,200	B
Blender Count	2	12	-		R
Centrifuge Count	21	12	-		B
Circulator (Liquid) Count	5	12	-		B
Clean Air Workstation Count	2	6	-		R
Conductivity Meter Count	3	12	1	\$800	B
Deep Freezer Count	2	12	-		B
Evaporator Count	1	12	-		R
Fraction Collector Count	1	20+	-		R
Freezer Count	10	12	1-2	\$2,900	B
Furnace Count	6	12+	-		R
Grinder Count	1	12	-		T
Biological Hood Count	1	12	-		R
Hot-Plate(s) Count	127	12+	10	\$600	B
Hydrogenation Count	1	12	-		B
Incubator Count	5	12	-		B
Magnetic Stirrers Count	7	12	-		B
Melting Point Count	13	12+	-		T
Microscope Count	1	12	-		R
Moisture Analyzer Count	1	12+	-		T
Oscilloscope Count	1	12	-		B
Oven Count	22	12	2	\$1,500	B
Oxygen Meter Count	1	12	-		B
pH Meter Count	9	12	1-2	\$480	B
Pellet Press Count	2	12+	2	\$1,038	B
Refrigerated Centrifuge Count	5	12	-		B
Refrigerator Count	10	12	1-2	\$4,500	B
Rotator Count	2	12	-		B
RotoVap Count	15	12	1-2	\$5,000	B
Shaker(s) Count	3	12	-		B
Sonicator Count	5	12	-		B
Spec 20 Count	24	12	2-3	\$2,000	T
Stir Plate(s) Count	3	12+	-		B
DU520/530 (UV)	15	12	-		B
Vacuum Oven Count	4	12	-		B
Vacuum Pump(s) Count	11	12+	-		B
Vortex Shaker(s) Count	19	12	1-2	\$250	B
Water Bath Count	17	12	1-2	\$2,100	B
Water Circulator Count	2	12	-		B
Water Filtration System Count	5	12	2-3	\$5,000	B

Table 7. Instrument Replacement Projections

Analytical Instruments	Approx. Age	Original Cost	Approx. Replacement Cost	Program Use: Teaching lab (T) research lab (R) Both (B)	Suggested Replacement
<b>Atomic Absorption</b>	20	\$29,507		T	?
<b>BAS Electrochemical Analyzer(s)</b>	11	\$29,202+		T	
<b>Fluorometer – ISA</b>	12	\$69,528+		B	Yes
<b>Fluorometer – Olis</b>	12	\$42,500+		T	?
<b>FTIR – Magna</b>	12	\$52,252+		B	Yes
<b>FTIR – Protégé</b>	12	\$21,748		B	Yes
<b>FTIR – Protégé</b>	12	\$21,748		B	Yes
<b>Gas Chromatograph(s)</b>	11	\$11,322	\$15,000	B	2
<b>Gas Chromatograph – FID</b>	11	\$15507		R	?
<b>Gas Chromatograph – MS</b>	11	\$78,339	\$80,000	B	Yes
<b>Gel Doc System</b>	12	\$8,775		T	
<b>HLPC – Waters</b>	11	\$58,976		B	
<b>HPLC – HP</b>	11	\$64,563		B	
<b>ICP OES</b>	15+	-		T	
<b>IC System – Dionex</b>	12	\$45,277		B	
<b>IC System – Metrohm</b>	.5	\$74,414		R	
<b>Laser Bench</b>	12	-		T	
<b>Microplate Reader(s)</b>	12	\$5,385		R	
<b>NMR – Bruker</b>	11	\$343,347		B	
<b>Oxygen Bomb(s)</b>	12+	-	\$6,145	T	Yes
<b>Polarimeter</b>	11	\$25,177		T	
<b>Scintillation Liquid Counter</b>	12	\$21,902		R	
<b>Supercritical Fluid Extraction</b>	12	\$27,923		R	
<b>Surface Area Analyzer</b>	6	\$9,999		T	
<b>UV-Vis – Cary</b>	11	\$26,093		B	Yes
<b>UV-Vis – HP</b>	11	\$7,346	\$15,000	B	?

### *Existing technology*

- access to distance education classroom in Science Building.
- access to computers, projectors, CD/DVD players, and document cameras in classrooms and selected teaching laboratories.
- access to computers, projectors, CD/DVD players, and document cameras in classrooms and selected teaching laboratories.
- 144 computers, including:
  - 36 computers in the General Chemistry laboratories equipped with hardware interface for data collection
  - 32 computers in research laboratories, including 13 SGI workstations, and a multiprocessor cluster and server for computational research
  - 30 computers used as instrument interfaces
  - 30 computers on faculty/staff desks
  - 8 computers on graduate student desks
  - 8 computers that are being cannibalized for spare parts
- software packages including Sybyl, Spartan, Gaussian, and ChemDraw.

### *Anticipated needs*

- Approximately 20 older computers, mainly in research laboratories will need to be replaced within the next three years.
- The Chemistry Department replaces at least 3 faculty/staff computers annually. As the number of faculty and staff has grown this is no longer a sufficient replacement rate. Unfortunately, our goods and services allocation has not kept pace with department growth.

# Library Resources



## VI. Library resources

Describe general and specific requirements for library resources by program and location that assist in meeting educational and research objectives. Indicate ways in which the present library resources satisfy and do not satisfy these needs. Describe anticipated needs as to the next 5 year period.

The CWU Library is an essential resource for the Chemistry Department. Its holdings allow the Chemistry Department to meet its educational and research objectives. One of the department's program goals is to train students to retrieve and critically analyze the chemical literature.

Currently the library subscribes to the American Chemical Society (ACS) Web Edition which provides electronic access to over 40 journals in the chemical sciences. Faculty and students may access research articles in these journals in one of three formats: Full Text HTML, High Resolution PDF and PDF with links. It is imperative that the library maintain this subscription to ACS journals. In 2005 the department obtained national American Chemical Society approval of the BS in Chemistry which requires access to specific library holdings. To maintain ACS accreditation and approval of our degree programs, faculty and students must have access to refereed journals either in print or electronic format.

The department has also benefited since late 2007 from a library subscription to SciFinder, which is an electronic chemical structure searching service with a basic search tool as well as a substructure search tool (both for ~ \$10,400). During the last calendar year (2009), however, the library renewed only the basic search tool (~\$7,000) and not the substructure tool. It is important for the chemistry department to reinstate the SciFinder substructure search tool and to continue subscribing to both tools in the future.

The following library services provide critical support to chemistry programs:

1. Interlibrary loan office for journals to which CWU does not subscribe
2. Journal holdings in Chemistry
3. Shared non-journal library collections with other libraries (Summit)
4. Online database access (i.e., ACS Publications, ScienceDirect, Web of Science)

# Analysis of the Review Period



## VII. Analysis of the Review Period

### A. What has gone well in the department and each degree program?

1. Explain accomplishments of the past five years.
2. How have accomplishments been supported through external and internal resources?

### Department as a Whole: Staffing

- Hiring of five new tenure track faculty members, including three new faculty lines. Two of the new faculty lines were supported by a High Demand grant from the Higher Education Coordinating Board (HECB) to help meet an increased demand for coursework in the area of organic chemistry. Start-up funds for new faculty were provided through the HECB grant, the COTS Dean, and the Provost. The members of the Chemistry Department worked together to identify suitable research laboratory space for the two new organic chemists, a new biochemist, and physical chemist working in the area of computational chemistry. This necessitated laboratory moves on the part of five of the existing faculty members, assistance from staff members, and financial support from the Academic Facilities Planning Office.
- As the department grows, subgroups or smaller teams within the faculty/staff are beginning to nucleate and organize around areas of shared interest. This has allowed very constructive brainstorming and discussion, and collaboration on scholarly work. For example, Eric Bullock, Anne Johansen, and Carin Thomas wrote a successful NIH proposal for an investigation of toxic effects of atmospheric nanoparticles, and Anthony Diaz, Tim Sorey, and Tony Brown have submitted a manuscript describing curriculum development. Frequent department meetings and informal gatherings (department potlucks, lunches, office birthday celebrations) and a common vision continue to foster department-wide camaraderie and collegiality.
- Revised and expanded Reappointment, Tenure, and Promotion (RTP) guidelines were developed by the Chemistry Department and approved at the College and University levels. Expectations for tenure and promotion to Associate Professor are now more clearly outlined, the departmental process for reappointment and review has been improved, and expectations for post-tenure review and promotion to Full Professor have been added. The revision of this document involved many hours of discussion and was instrumental in forging a shared vision of the Chemistry Department's mission and goals, as well as a unified vision of the future.
- During the last five years, the Chemistry Department has successfully promoted one member to Full Professor status, and has tenured three other members with promotion to Associate Professor. Three tenured faculty have successfully undergone post-tenure review.
- A half-time computer support position was created with support from the HECB grant. A successful search was carried out and Don Davis was hired. Don brings

years of experience with computer and network support in the communications industry.

- Towards the end of the last review period the Chemistry Department's instrument technician position was restructured and converted to 1.75 positions to jointly serve the Chemistry, Biology, and Geology Departments. These positions were filled through a national search process. This arrangement has come to fruition during the period under review. The three departments have worked together to provide training and oversight (supervision is still assigned to the Chemistry Department Chair). The instrument technicians, Jeff Wilcox and Lee Longmore, have done an excellent job. Increased cooperation among the departments on other fronts has been an added benefit of this arrangement.
- The stockroom manager position, filled by Tony Brown, was reclassified from Instructional Support Technician 3 to Instructional and Classroom Support Technician 4. This came about in response to increased enrollment in introductory courses combined with Tony's desire and ability to teach in the first year chemistry sequences. A new stockroom assistant position (full-time, 9 months) was created and filled by Mari Sorey. Mari Sorey has a B.S. in Chemistry and Pharmacy and previous experience as a stockroom assistant at Montana State University. This position was necessitated by combination of increased enrollment and restructuring of Tony Brown's position. Due to increasing enrollments, laboratory instruction can no longer fit a 9-to-5 schedule complete with a lunch break. Lab instruction often begins at 8 am and continues through the lunch hour to (and sometimes beyond) 6 pm.
- Renegotiation of reassigned time for the department chair from 18 to 27 WLU (half-time to three-quarter time). This more accurately reflects the workload and should help make this position both more attractive and more doable for mid-career faculty members.

#### **Department as a Whole: Faculty/Student Scholarship**

- Increase in faculty scholarship activity as measured by publications, presentations, and grant proposals submitted/funded. Number of publications more than doubled (13 to 32). Conference presentations have almost tripled (39 to 117). The majority of publications/presentations include CWU students as co-authors. External grants submitted increased from 45 to 62; external grants funded increased from 21 to 33. Funding has come from the NSF, NIH, American Chemical Society/Petroleum Research Fund, Research Corporation, the M. J. Murdock Trust, the U.S. Department of Interior (National Park Service), the U.S. Department of Education (Fund for the Improvement of Postsecondary Education (FIPSE)), and private industry. Faculty members have also been invited to serve as reviewers of manuscripts for professional journals and reviewers of proposals for funding agencies with increasing frequency. Most notable during the review period is the invitation of faculty to serve on proposal review panels for the NSF, NIH, and ACS-Petroleum Research Fund.

- There has been dramatic growth in the numbers of undergraduate students involved in research mentored by Chemistry Department faculty during the review period. The number of students registered for the research courses (CHEM 295, 395, 495) increased from 53 students over the course of year 1 (31% of Chemistry majors) to 97 students over the course of year 5 (82% of Chemistry majors). At the close of the review period, all tenured/tenure track faculty were involved in mentoring student research. Student research participation has been funded through internal sources, including undergraduate research grants and the Science Honors Program, as well as external funding.
- The Chemistry Department continued to update our safety training and protocols and worked to increase safety awareness by students, staff, and faculty. Standard operating procedures (SOPs) were completed for use of the department's instruments, as well as many of the research laboratories. The Chemistry Club also worked with their faculty advisors to write SOPs for all public demonstrations. Chemistry and Biology staff worked together to bring in an expert to teach a week long safety course. This course was supported by the Dean of COTS and by funds earmarked for staff development raised through the self-support summer school program. The department's focus on safety had a positive impact on both scholarly and instructional activities.
- EPA accreditation for the analytical testing laboratory increased from one to ten components. Throughput of samples and associated funding has also increased. Besides analyzing precipitation samples, the scope has been now expanded to include lake and stream water samples and wine. All are from the region. Funds come from Mt. Rainier and North Cascades National Parks in addition to contracts with industry (in collaboration with Geology and Geography).

#### **Department as a Whole: Infrastructure**

- Updated computers in general chemistry laboratories, faculty and staff offices, largely using the Chemistry Department's goods and service budget with partnership of the University's WIN-WIN program.
- A new computational research laboratory was equipped with start-up funds supplied to Yingbin Ge.
- Through internal grants the department secured funds for a particle surface area analyzer, particle counter (in collaboration with Geology), and a new ion chromatograph. A chemiluminescence flow injection system was purchased with external funds.
- Three new research laboratories (two organic, one biochemistry) were equipped. Start up funds for the organic chemistry laboratories were provided by a HECB High Demand Grant. The biochemistry laboratory set-up was funded through a combination of funds from the HECB Grant and the college/university.

- Repair and maintenance of instruments.
- Through the lobbying efforts of Chemistry faculty led by L. Fabry and the response of the Library and Provost's office, students and faculty now have access to SciFinder, the most powerful and commonly used literature database from research in the molecular sciences.

#### **Programmatic and Curricular Developments: B.S. in Chemistry**

- The B.S. degree was approved by the American Chemical Society. Approval was based on appropriate depth and breadth, currency of curriculum, level of rigor, sufficient staffing, infrastructure and resources. This was a milestone in the development of the department.

#### **Programmatic and Curricular Developments: B.A. in Chemistry Teaching**

- Scores on the WEST-E exam (graduation requirement for students in B.A in Chemical Education) improved dramatically during the review period as a result of analysis and remedial action implemented by the Science Education faculty.
- Elevation of Science Education Program to Department status. While not truly a Chemistry Department accomplishment, two department members have split Chemistry/Science Education appointments. This maturation and expansion of the Science Education endeavor has had a positive impact on the College of the Sciences, including Chemistry.

#### **Programmatic and Curricular Developments: M.S. in Chemistry**

The M.S. program has grown during the past five years: eleven students are currently enrolled compared to six students at the time of the last program review. The M. S. program continues to support the undergraduate programs and faculty scholarship by providing role models and mentoring in the research laboratories and by providing highly qualified teaching assistants. Courses offered in the graduate program are also available to qualified undergraduates, providing them with the opportunity to pursue advanced topics. Graduate students' activities translate into the necessary continuity in the research laboratory to significantly benefit faculty scholarship, which ultimately increases our competitiveness in securing external funding. Such funds have come from NSF (Johansen, Diaz, and through the WATERS grant) and NIH (Johansen, Thomas, Bullock) in addition to internal grants. Besides playing an essential role in the sustainability of research at a primarily undergraduate university, the graduate program is becoming increasingly important in meeting increased teaching demands. Graduate students serve as high quality teaching assistants and occasionally as instructors for 100 level laboratory courses for which the Chemistry Department struggles to meet increasing enrollments. We have been successful in graduating our M.S. students within the expected time frame of two to three years and it is noteworthy that these students were also successful in pursuing their career paths, either by continuing with higher education, going into industry or working in government. Finally, graduate students also facilitate collaborations between departments by forming interdisciplinary graduate committees and/or seeking expertise/instrument support in other departments.

The involvement of chemistry graduate students in the WATERS program is notable. Through this NSF-funded program, students carrying out research in environmental chemistry have been paired with high school teachers, both teaching in the classroom and involving high school students in field research. Students have also been paired with research partners in Tibet.

### **Programmatic and Curricular Developments: Service Courses and Collaborations with Other Departments**

- Accommodating the increased enrollment in our 100 level service courses, a total of over 300 additional students, qualifies as an accomplishment. The enrollment in CHEM 111 at its highest point during the previous review period was 258 students, relative to 313 in year five of the period under review, a 21% increase, not including the students who enrolled during the summer session. Using this measurement, enrollment in CHEM 112 has increased from 60 students to 103 students, a 72% increase. Enrollment in CHEM 113 has increased from 53 students to 60 students, a 13% increase, not including the students who enrolled during summer session. The enrollment in CHEM 181 increased from 260 to 362 students, a 39% increase, while enrollment in CHEM 182 increased from 174 to 243 students, a 40% increase. This increased enrollment has been covered with the help of two full-time non-tenure track instructors, assistance from additional graduate and undergraduate laboratory teaching assistants, and changes to the way that we use equipment in the general chemistry laboratory courses. Starting this year students checked in to laboratory equipment drawers in pairs rather than individually, thus doubling the number of students that we can accommodate in a quarter. This required stocking drawers with additional glassware, a one-time expense paid for with a combination of laboratory fees and assistance from the Dean of COTS.
- Environmental Research and Education Committee (including two Chemistry faculty) developed an interdisciplinary Environmental Studies major with a specialization in Environmental Chemistry. This effort was in part funded by a CWU Spheres of Distinction proposal which also secured funds for a new program director, Greg Brown, hired in 2008 as the result of a national search.
- The Chemistry Department faculty members continue to collaborate with other campus programs, including the Departments of Biological Sciences, Computer Science, Geological Sciences, and Science Education, Science Honors Program, Douglas Honors College, Science Talent Expansion Program (STEP), and the Wine Quality Initiative. Interdisciplinary collaboration is becoming a department hallmark.

### **B. What challenges exist for the department and for each degree program?**

1. Explain major challenges of the past five years.
2. List likely causes of each challenge as supported by documented evidence.

Challenges that were successfully met are described in Part A. New and existing unmet challenges are addressed in this section.

### **Staffing Challenges**

- Sustaining enthusiasm, vigor, satisfaction, and high quality job performance throughout the careers of both faculty and staff. For staff there are few opportunities for salary increases or job advancement. For faculty the workloads are high, making it difficult to sustain high levels of scholarly productivity and creativity, or to undertake time-consuming programmatic or curricular reform.
- Mentoring new faculty and mid-career faculty in a young department.
- Funding for both undergraduate and graduate teaching assistants is insufficient. Our undergraduate teaching assistant budget is not tied to enrollment.

### **Safety Challenges**

- Completing and keeping Chemical Hygiene Plans, including Standard Operating Procedures, up to date for each laboratory.
- Obtaining 100% compliance with laboratory eye protection policies.

### **Program and Curricular Challenges**

- Maintaining reasonable class sizes, especially in the current budget crisis.
- We do not have a sufficient number of faculty and teaching assistants to meet the student demand for 100 level chemistry courses. The need is most acute in the CHEM 111/112/113 series.
- Teaching 100 level laboratory courses to sections of 72 students, with students in three adjoining laboratories, one instructor, and three (mainly) undergraduate teaching assistants is a challenge. This allows laboratory instruction to be efficient from a budget point of view, but makes it difficult to provide a safe, high quality experience for students.
- Increasing the level of mastery of material by students in the first two years of the chemistry curriculum.
- Recruiting science and math education majors.
- Providing quality advising, especially for pre-professional programs.
- Meeting the growing demand for upper level chemistry courses.
- Acquiring assistantships for and recruiting graduate students.
- Providing relevant and sufficient coursework for graduate students.

### **Infrastructure Challenge**

- Maintaining and replacing ageing instrumentation, including the computers and software used as instrument interfaces. Institutional funding for instrument repair and maintenance is insufficient.

### **Other Challenges**

- Obtaining necessary support and cooperation from other groups on campus, including the Graduate Office, Environmental Health and Safety, and Institutional Research.
- We do not have a regular seminar series.

### **C. What past recommendations from the previous program review have been implemented?**

1. How has each recommendation been implemented and how have the department and degree programs been impacted?

- From the Recommendations sections of the executive summary from the last program review:

"Dr. Gutierrez was very clear that the first and most critical issue for the department to address is long-term, proactive planning. Specifically, "a planning exercise where its faculty and staff come to a consensus as to what they want their Department to become in the next five to ten years, how they want it to develop. They need to establish goals and measurable objectives as milestones of progress. It is time for the Department to become proactive."

The current self-study reflects a more cohesive view of our goals and mission, relative to the self-study of five years ago. This has come about, in part, through extensive discussion of department expectations for individual faculty as outlined in the RTP document. Our vision of the department as a whole is where the discussion started, and the expectations for individual faculty reflect this vision. The hiring of five new faculty members provided an unusual opportunity to shape the department according to our common goals. The professional goals of the new faculty are an excellent match for this Chemistry Department. To some extent, the vision of the department has extended to a farther horizon as the individual members have matured and developed a longer, more global view of our role in the university and community.

A long term plan for department growth and student enrollment requires more discussion with the Dean, Provost, and representatives of the other academic disciplines that the Chemistry Department serves. To a large extent, the number of faculty, and the size and number of our classes, are dictated by the programs that we serve. Growing demand for training in health, environment, and engineering-related disciplines has meant a higher demand for our introductory, organic, and biochemistry courses.

- More from Carlos Gutierrez, "The department and the University need to come to consensus as to the type of educational experience it wants for its students, and professional circumstances it wants for its faculty." Indeed. Hopefully, this will be a focus of this winter's budget process.

A minor recommendation addressed the lack of information contained in our catalog course listings. This has been remedied.

- The external reviewer suggested that a more senior faculty member step into the department chair position if possible.

The Chemistry Department remains a relatively young department. Currently, there are two Full Professors; one is chairing the department and the other chairs the Science Education department. The next review period will see continued maturation and additional promotions.

- The external reviewer, the Dean, and the executive summary all recommended that the department and university reach consensus as to reasonable size for the graduate program in Chemistry. The external reviewer recommended that the department and university examine the dollar amount of graduate stipends awarded, keeping in mind both the ability of the department to compete for qualified students and the ability of students to pay their bills.

The Chemistry Department has targeted an enrollment of 15-20 graduate students. This number would allow participation of all of the Graduate Faculty in the mentoring of graduate students, would allow the department to offer a sufficient number and selection of graduate level course offerings, would provide peer-peer interactions for graduate students, and would go a long ways to help the department staff the undergraduate laboratory courses with qualified teaching assistants (and occasionally instructors).

The Chemistry Department's graduate program is not currently supported at a level that would make this enrollment feasible. The lack of assistantships and the size of the assistantships has been a large obstacle to the recruiting of qualified graduate students. Additional funding from the institution and external grants is necessary. At most institutions, even those offering the M.S., the standard is to provide every Chemistry graduate student admitted with an assistantship. The Chemistry Department currently has 5 assistantships from the institution and an additional 2-3 from grants. The number needs to nearly double to meet our target.

## 2. Which recommendations were not implemented and why?

- "The diversity of the students served does not mirror that of Central's service area."

Diversity of students majoring in Chemistry still does not match the diversity of the region served. The Chemistry Department continued to work with the STEP program on recruitment, maintained good relations with the faculty at neighboring

two-year colleges, and worked the Science Education Department to communicate with surrounding high school science teachers. This has not been sufficient. A more focused effort is necessary if we are to significantly increase the number of students from underrepresented groups that we serve.

- Recommendations concerning MS program - see above.
- Seminar series. Both the external reviewer and Dean noted the lack of a seminar series.

During the past five years, our seminar program (visiting lecture series) has been dominated by a series of excellent talks given by applicants for tenure track faculty positions. It is time to renew contacts with the surrounding institutions and develop a sustainable seminar program. The Chemistry Department's share of profits from the self-supported summer program have been used for the professional development of faculty and staff. The recent increase in summer enrollment in the CHEM 111/112/113 series may allow funding of the seminar series. Development of a sustainable seminar series is a goal for the next review period. See Section VIII.

- From Carlos Gutierrez, "Instrumentation ages faster than buildings. Considerable numbers of instruments were purchased when the building was new, and through grants, and those equipment holdings are now at an age that the Department in consultation with the College needs to develop a plan for the maintenance and phased replacement of aging instrumentation."

The Chemistry Department has created an Equipment Committee to spearhead these efforts and to help manage laboratory fees and indirect funds earmarked for instrument maintenance. ***Additional discussion with and support from the College and University is essential.***

**D.** Make a comparison between the last program review and where the department is now.

1. How have the advances been supported?
2. Are there still outstanding, unmet needs/challenges from the last program review? What has the department done to meet these challenges?

These questions have been addressed throughout the report.

# Future Directions



## VIII. Future directions

- A. Describe the department's aspirations for the next three to five years.
- B. In this context, describe ways the department or unit plans to increase quality, quantity, productivity, and efficiency as a whole and for each program. Provide evidence that supports the promise for outstanding performance.

### 100 level chemistry courses

**CHEM 180 series.** The Chemistry Department is dedicated to 100 level courses, both as a service to other departments and general education program, and as an introduction to the field for chemistry majors. Unfortunately, due to insufficient staffing, we have not always been able to give these courses the attention that they deserve. The addition of two new faculty positions during the review period has allowed us to begin to refocus attention on these courses and we plan to build on this momentum during the next three to five years. Our efforts will focus on course content, student preparedness, and the recruitment of a diverse group of talented and motivated students.

During the last few years the Chemistry Department has begun to strengthen the introductory sequence for science majors (the CHEM 180 series). Tim Sorey has led efforts to update and improve the laboratory curriculum, making better use of the MicroLab equipment and software. The department has supported his efforts by committing funds to replace aging equipment in the labs. The faculty who teach in this series have worked to coordinate lab and lecture curricula and to strengthen the lecture curriculum. During the next review period we will continue to further develop and assess the new laboratory curriculum.

We have recently begun to work on strategies for assessing and improving student preparation for the series. At this time these plans include implementation of a test to assess basic skills, and a remedial tutorial offered through the Continuing Education program with our graduate students as instructors. We are also considering strategies for increased tutorial support outside of formal lectures and laboratories, and limited faculty office hours. These strategies include increased coordination with the Supplemental Instruction (SI) program and/or developing a small cadre of "super TAs".

**CHEM 111/112/113.** The department has experienced a dramatic increase in student demand for the CHEM 111/112/113 series. During the upcoming review period we will work to meet the increased demand, update laboratory curriculum, and work with the departments that require these courses to make sure that their needs are being served

**CHEM 101.** The department also has plans to rejuvenate CHEM 101, Contemporary Chemistry. This course represents an excellent opportunity to introduce non-science majors to chemistry. CHEM 101 includes a laboratory component and emphasizes quantitative reasoning. We anticipate that these efforts will proceed in parallel with the implementation of the revised CWU General Education program. Up to three new versions of this course will be developed (CHEM 101A, B, and C). Each version will be interdisciplinary in nature and will

take advantage of existing faculty interests. J. Peters has developed and taught a course in the Chemistry of Materials for Art for students in the Douglas Honors College. This course will be modified as a CHEM 101 version addressing Chemistry and Materials, with a focus on either art or nanotechnology, depending on the instructor. Other likely possibilities include Chemistry and the Environment, and Chemistry and Health. We expect that these courses will appeal to students and will be an affective means to introduce students to chemistry principles and methods.

**Recruiting efforts.** The Chemistry Department plans to work with the newly formed Science Education Department to improve recruitment of talented, motivated, and diverse science and chemistry majors. This is a state-mandated activity for the Science Education Department. Through regular visits, the Science Education Department plans to forge connections to individual science teachers in the central Washington region. These efforts will have dual effect of providing a resource to the teachers and ensuring that they (and therefore hopefully students) will be aware of the excellent opportunities for studying science at CWU. Chemists will accompany the Science Education faculty on a significant number of these visits. We hope that recruiting high quality students into our introductory series will help to improve the experience for all participants.

### **Upper level chemistry courses for majors and minors**

The department plans to consolidate improvements realized during last review period. We will work to maintain American Chemical Society (ACS) approval of our program and will encourage all B.S. students to complete requirements for the ACS-approved degree. A. Diaz and Y. Ge will continue to fine tune the upper level integrated inorganic/physical chemistry laboratory and to reap the benefits of increased expectations for math preparedness in physical chemistry. Two additional tenure track organic faculty members and a new research active tenure track biochemist will have a positive impact on the organic chemistry and biochemistry series. The possibility of implementing an ACS certified B.S. in Biochemistry degree will be explored. We will continue to gradually raise the bar in our undergraduate programs, particularly in Organic Chemistry (the CHEM 360 series) and Quantitative Analysis (CHEM 332). We will continue to provide varied and intensive research experiences for undergraduates.

### **Graduate program**

We would like to increase the number of M.S. students in the program from the current 12 students to a steady enrollment of 15-20 students. A larger cohort will provide for more peer-to-peer interactions, more dynamic upper level courses, and additional TAs and mentors for the undergraduates. We would also like to work with the Biology Department as they implement a new M.S. in Biomedical Sciences.

We plan to refocus a number of our 500 level offerings so that they cross the traditional boundaries between the chemical disciplines, i.e. physical/inorganic,

organic/biochemical, so that they can better serve students from a variety of chemistry disciplines.

### **Replacement/ Upgrade of aging instruments**

The Chemistry Department is committed to maintaining a working complement of modern instrumentation. The engineering technicians will continue to maintain and repair instruments, as well as train students and faculty in use and daily maintenance. The department will work to keep laboratory fees commensurate with costs of running laboratory courses including routine maintenance of instruments and equipment. Some major repairs to large pieces of equipment will likely always be beyond the department's budget and we will continue to seek additional internal funds for these repairs. Avenues for including funds for instrument maintenance in budgets for external funding are being explored.

Replacement or major upgrades of major instruments will likely always be beyond the scope of institutional funding. As instruments purchased over ten years ago with new building equipment funds begin to break irreparably or become obsolete we will need to develop strategies for obtaining external funds for their replacement. These strategies will likely need to link the need for instrument with new innovative curriculum and research. The most pressing needs are replacement of a research-grade infrared spectrometer and replacement of a gas chromatograph/mass spectrometer (GC/MS) with a new GC/MS and/or liquid chromatograph/MS.

### **C. What specific resources would the department need to pursue these future directions?**

- **Two new tenure-track faculty members.** Two additional tenure-track faculty, quite likely in addition to one or two of the existing full-time non-tenure track (NTT) positions. A large percentage of our 100 level courses are currently taught by NTT faculty. Tenure-track positions provide continuity and are extremely important for development of programs and coherent curriculum. We have found that it is very difficult to recruit chemists for NTT positions in the rural setting of central Washington. Tenure-track positions allow us to attract higher caliber candidates with a long-term commitment to the institution and its improvement. The new faculty lines will bolster the both the undergraduate and graduate programs; additional expertise will contribute to existing research efforts.
- **Hiring additional faculty will necessitate additional office space.** We do not have office space available for new faculty in the Science Building. Additional research laboratory space is also desirable.
- **Additional staff to support growing faculty and student enrollment.** Increase three-quarters instrument tech position to full-time. Increase laboratory manager position to full-time. Add an office assistant position, at least half-time.

- **Increased goods and service budget to support growth coupled with continued emphasis on external grant writing to support scholarly work and curriculum development.** Hopefully both can be tied to the acquisition of new equipment and instrumentation. Additional institutional support is required. In particular, the undergraduate teaching assistant budget has been underfunded for at least fifteen years. Keeping up with the demand for service courses continues to place a burden on the department's resources. A teaching assistant budget that is realistically tied to enrollment in laboratory courses would be ideal. Additional faculty and staff require additional phone support, computers and software, copying, pens and pencils, etc.
- **Testing/remedial general chemistry program** will hopefully be largely self-support. However, 3 WLU support will be required for the coordinating faculty member.
- **Additional graduate assistantships.** The lack of adequate assistantships, both the number of assistantships and the dollar value, have severely hindered our ability to attract qualified graduate students. Research assistantships will come through grant writing. We will request teaching assistantships from the institution.
- **Funds for instrument repair.** An increase in laboratory fees at some point in the next five years will provide additional funds for instrument repair. An increase in goods and service budget ear-marked for instrument maintenance and/or a college or university wide budget for instrument maintenance is also requested. There should also be recognition that grant writing is time consuming, as is involvement with selection, installation, and training associated with new instrument purchases. Modest WLU assignments for successful instrument grant writing would be helpful, for example 1-3 WLU reassigned time during the quarter that major instrumentation is installed. Release time would be funded externally if possible, otherwise funded by the institution.

D. What do you want us to know that is not included in this self-study?

See section IX, suggestions for the program review process.

# Suggestions for the Program Review Process



## **IX. Suggestions for the program review process or contents of the self-study?**

Information concerning a department's resources should be included, particularly to provide the external reviewer with framework for the rest of the content of this document. What is the institutional goods and services budget? How many internal and external grants has the department been awarded, and for what purpose? What is the department's share of indirect funds? Are there funds generated by laboratory or other fees? Are there funds generated by summer or other self-support programs?

SELF STUDY – DEPARTMENT OF CHEMISTRY  
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# Assessment Reports and Surveys



## Assessment Report for B.A. in Chemistry, June 2008

**I. Which student learning outcomes were assessed?** We have selected three learning outcomes to assess this year. These outcomes were selected because of the ready availability of data. These learning outcomes are related to the goals articulated by the Department of Chemistry, College of the Sciences, and Central Washington University as described below. The relevant goals are provided at the bottom of this section.

**Student Learning Outcome 1.** *Apply the standard technical information and perform experimental techniques of analytical, biochemistry, inorganic, organic, and physical chemistry.* This year we are assessing this outcome for the analytical chemistry area. In future years we will examine this outcome for other areas of chemistry.

This departmental outcome is related to department goal #1, COTS goal #1, and to university strategic goal #1.

**Student Learning Outcome 5.** *Retrieve and critically analyze chemical literature.*

This departmental outcome is related to department goal #1, COTS goal #1, and to university strategic goal #1.

**Student Learning Outcome 7.** *Work effectively in group situations.*

This departmental outcome is related to department goal #1 and goal #3, COTS goal #1 and goal #7, and university strategic goal #1 and goal #6.

### Relevant Goals

Department of Chemistry:

Goal #1. To provide quality education in chemistry through courses and programs on campus or off campus

Goal #3. To facilitate this learning experience with modern equipment and laboratories, computer technology, cooperative research and service to the local community, the central Washington area and to the state

College of the Sciences:

Goal #1. Provide for an outstanding academic and student experience in the College of the Sciences

Goal #7. Create and sustain productive, civil, and pleasant learning environments

Central Washington University:

Goal #1. Maintain and strengthen an outstanding academic and student life on the Ellensburg campus

Goal #6. Build inclusive and diverse campus communities that promote intellectual inquiry and encourage civility, mutual respect, and cooperation.

**II. Who was assessed?** Students receiving a B.A. in Chemistry during 2006/07. Only one student graduated with a B. A. in Chemistry during this time period.

**III. How were student learning outcomes assessed?**

**Student Learning Outcome 1.** *Apply the standard technical information and perform experimental techniques of analytical, biochemistry, inorganic, organic, and physical chemistry.*

**Standard of mastery/criterion of achievement:**

1. Graduates maintain 2.0 for course average and an average of 2.25 in courses within the major.

One student graduated with a B.A. in Chemistry with an overall gpa of 3.669 and a major gpa of 3.757.

2. ACS exams consistent with national averages

The Chemistry Department administers American Chemical Society (ACS) standardized exams at the end of all appropriate courses. This year we examined the exam scores for Analytical Chemistry and Instrumental Analysis. These exams are administered at the end of CHEM 251 and CHEM 452, respectively. Only those students earning a BS in Chemistry are required to take CHEM 452, Instrumental Analysis. Standardized exam scores for General Chemistry would be included for comparison, but are not available for this student. The individual student scores were compared with the national mean and standard deviation provided by the ACS.

Analytical Chemistry

2001 exam, mean = 28.5, standard deviation = 7.58

Between 1 and 2 standard deviations below the mean	0 students
Within 1 standard deviation below the mean	0 students
Within 1 standard deviation above the mean	0 students
Between 1 and 2 standard deviations above the mean	1 student

Instrumental Analysis

2001 exam, mean = 32.82, standard deviation = 7.82

Between 1 and 2 standard deviations below the mean	0 students
Within 1 standard deviation below the mean	0 students
Within 1 standard deviation above the mean	1 student
Between 1 and 2 standard deviations above the mean	0 students

3. All students' portfolio components will be rated at satisfactory or higher.

Because we focused on the Analytical Chemistry area for this assessment period, we did not rate all portfolio components.

**Student Learning Outcome 5.** Retrieve *and critically analyze chemical literature*

**Standard of mastery/criterion of achievement:**

1. All students receive a grade of C+ or better on their poster presentation in CHEM 388.

The student received a grade of B for CHEM 388.

2. All students receive a grade of C+ or better on their oral presentation in CHEM 488.

The student received a grade of B for CHEM 488.

3. The research report component in the students' portfolio will be rated at satisfactory or higher.

The student did not carry out undergraduate research in the Chemistry Department. Although undergraduate research was carried out in Physics, the report was not included in the portfolio.

**Student learning outcome 7.** *Work effectively in group situations.*

**Standard of mastery/criterion of achievement:**

1. All students receive a grade of C+ or better in laboratory courses.

The five chemistry laboratory grades were: A, A-, B+, B, B-.

2. All research students receive a grade of B or better.

No research credits earned in Chemistry.

3. Reflective assessment in student exit portfolio.

Students were not required to provide a reflective assessment.

#### **IV. What was learned?**

**Student Learning Outcome 1.** *Apply the standard technical information and perform experimental techniques of analytical, biochemistry, inorganic, organic, and physical chemistry.*

As required, the one graduate maintained at least a 2.0 overall gpa and at least a 2.25 gpa for courses within the major; this student maintained an overall gpa of 3.7 and a chemistry major gpa of 3.8.

This year we also examined student scores on the ACS standardized exams in the area of analytical chemistry, as well as the introductory general chemistry. In general chemistry, this student's score is between one and two standard deviations above the mean. The Analytical

Chemistry exam is given at the end of Quantitative Analysis, an intermediate level chemistry course. Again, this student's score is between one and two standard deviations above the mean. Instrumental Analysis is not required for the B.A. in Chemistry, however this student chose to take the course as an elective. The Instrumental Analysis exam is given at the end of Instrumental Analysis, an advanced chemistry course. This student's score is within one standard deviation above the mean. Our analytical chemistry series served this student well. According to this criterion, this student gained a very solid understanding of standard analytical chemistry.

In the future we will examine our graduates' performance on the standardized exams in other areas of chemistry as well.

**Student Learning Outcome 5.** *Retrieve and critically analyze chemical literature.*

CHEM 388 and 488 are the Chemistry Department's undergraduate colloquium courses. In CHEM 388 students prepare a poster on a research topic. Posters are presented during an end of the quarter poster session. In CHEM 488 students prepare oral presentations on a research topic. Their work is presented to the department during a CHEM 488 seminar session at the end of the quarter. This students did well in CHEM 388 and 488, and received grades of B in both courses.

## Assessment Report for B.S. in Chemistry, June 2008

**I. Which student learning outcomes were assessed?** We have selected three learning outcomes to assess this year. These outcomes were selected because of the ready availability of data. These learning outcomes are related to the goals articulated by the Department of Chemistry, College of the Sciences, and Central Washington University as described below. The relevant goals are provided at the bottom of this section.

**Student Learning Outcome 1.** *Apply the standard technical information and perform experimental techniques of analytical, biochemistry, inorganic, organic, and physical chemistry.* This year we are assessing this outcome for the analytical chemistry area. In future years we will examine this outcome for other areas of chemistry.

This departmental outcome is related to department goal #1, COTS goal #1, and to university strategic goal #1.

**Student Learning Outcome 5.** *Retrieve and critically analyze chemical literature.*

This departmental outcome is related to department goal #1, COTS goal #1, and to university strategic goal #1.

**Student Learning Outcome 7.** *Work effectively in group situations.*

This departmental outcome is related to department goal #1 and goal #3, COTS goal #1 and goal #7, and university strategic goal #1 and goal #6.

### Relevant Goals

Department of Chemistry:

Goal #1. To provide quality education in chemistry through courses and programs on campus or off campus

Goal #3. To facilitate this learning experience with modern equipment and laboratories, computer technology, cooperative research and service to the local community, the central Washington area and to the state

College of the Sciences:

Goal #1. Provide for an outstanding academic and student experience in the College of the Sciences

Goal #7. Create and sustain productive, civil, and pleasant learning environments

Central Washington University:

Goal #1. Maintain and strengthen an outstanding academic and student life on the Ellensburg campus

Goal #6. Build inclusive and diverse campus communities that promote intellectual inquiry and encourage civility, mutual respect, and cooperation.

**II. Who was assessed?** Students receiving a B.S. in Chemistry during 2006/07. Four students graduated with a B.S. in Chemistry during this time period. Three of the four earned American Chemical Society certified degrees.

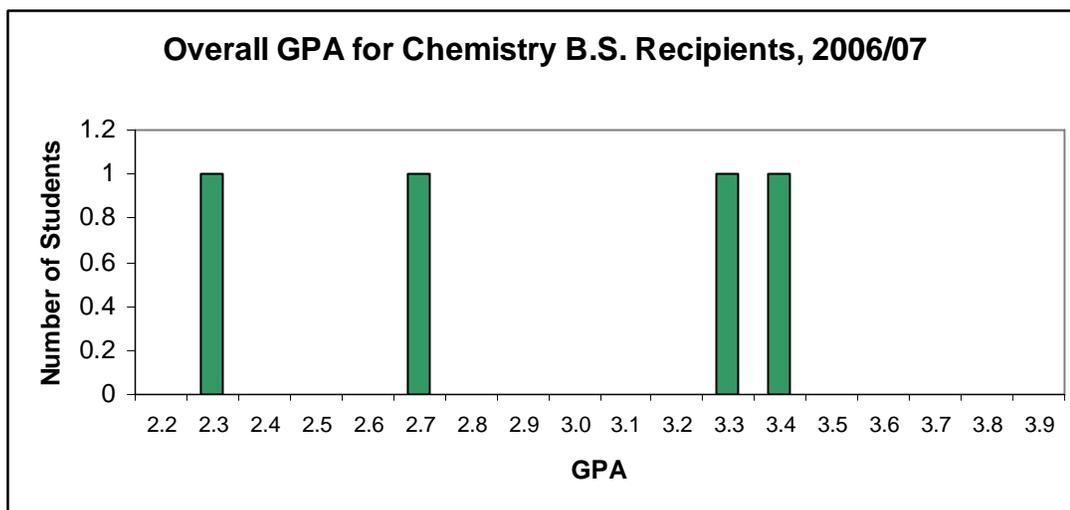
**III. How were student learning outcomes assessed?**

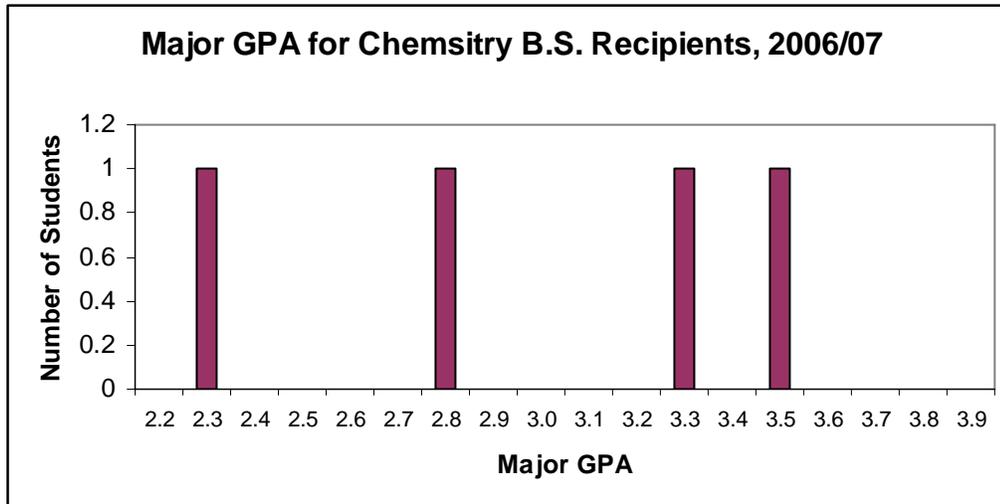
All chemistry majors are required to compile a portfolio before graduating. The portfolio includes an unofficial copy of their transcript, a compilation of all grades received on American Chemical Society (ACS) standardized exams, a copy of the abstract for their CHEM 488 oral presentation to the department, a copy of a laboratory report that showcases their ability to write in the style of the profession and their ability to use modern computer software, and a copy of a research report if undergraduate research was carried out. In the future all chemistry majors will be required to include a reflective assessment in their portfolio. Our assessment of student learning outcomes is based on an examination of the portfolios of students who graduated in the preceding academic year.

**Student Learning Outcome 1.** *Apply the standard technical information and perform experimental techniques of analytical, biochemistry, inorganic, organic, and physical chemistry.*

**Standard of mastery/criterion of achievement:**

1. Graduates maintain 2.0 for course average and an average of 2.25 in courses within the major.





## 2. ACS exams consistent with national averages

The Chemistry Department administers American Chemical Society (ACS) standardized exams at the end of all appropriate courses. This year we examined the exam scores for Analytical Chemistry and Instrumental Analysis. These exams are administered at the end of CHEM 251 and CHEM 452, respectively. Only those students earning a BS in Chemistry are required to take CHEM 452, Instrumental Analysis. The individual student scores were compared with the national mean and standard deviation provided by the ACS. Standardized exam scores for General Chemistry are included for comparison.

### General Chemistry

2001 exam, mean = 36.19, standard deviation = 12.33

2003 exam, mean = 41.03, standard deviation = 10.67

Between 1 and 2 standard deviations below the mean	0 students
Within 1 standard deviation below the mean	2 students
Within 1 standard deviation above the mean	2 students
Between 1 and 2 standard deviations above the mean	0 student

### Analytical Chemistry

2001 exam, mean = 28.5, standard deviation = 7.58

Between 1 and 2 standard deviations below the mean	0 students
Within 1 standard deviation below the mean	1 students
Within 1 standard deviation above the mean	2 students
Between 1 and 2 standard deviations above the mean	1 student

## Instrumental Analysis

2001 exam, mean = 32.82, standard deviation = 7.82

Between 1 and 2 standard deviations below the mean	0 students
Within 1 standard deviation below the mean	1 students
Within 1 standard deviation above the mean	1 student
Between 1 and 2 standard deviations above the mean	2 students

3. All students' portfolio components will be rated at satisfactory or higher.

Because we focused on the Analytical Chemistry area for this assessment period, we did not rate all portfolio components.

### **Student Learning Outcome 5.** Retrieve *and critically analyze chemical literature*

#### **Standard of mastery/criterion of achievement:**

1. All students receive a grade of C+ or better on their poster presentation in CHEM 388.

Student grades for CHEM 388: A-, A, B+, A-

2. All students receive a grade of C+ or better on their oral presentation in CHEM 488.

Student grades for CHEM 488: A, B+, A

3. The research report component in the students' portfolio will be rated at satisfactory or higher.

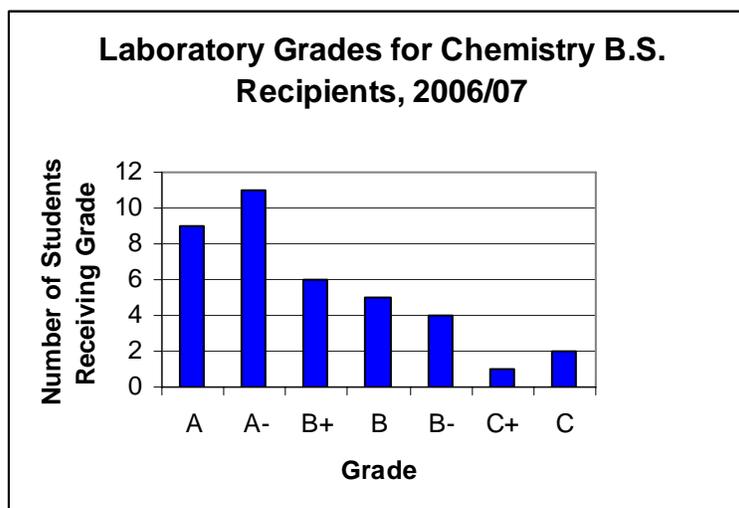
Three out of four students carried out undergraduate research projects; two out of four students provided included a research report in their portfolio. These reports were scored using the attached rubric. Students received a score of 0, 1 or 2 on six items. A score of 2 being excellent, 1 being satisfactory, and 0 being unsatisfactory.

Item	Score, Student 1	Score, Student 2
Statement of Purpose	2	1.7
Overall Grammar/Writing Quality	2	0.7
Use of Professional Language	1.3	1.3
Organization/Presentation of Data or Process	1.7	1.7
Citation/Assessment of Literature	1.3	1.7
Analysis/Discussion	2	1.7
Total	10.3/12	8.8/12

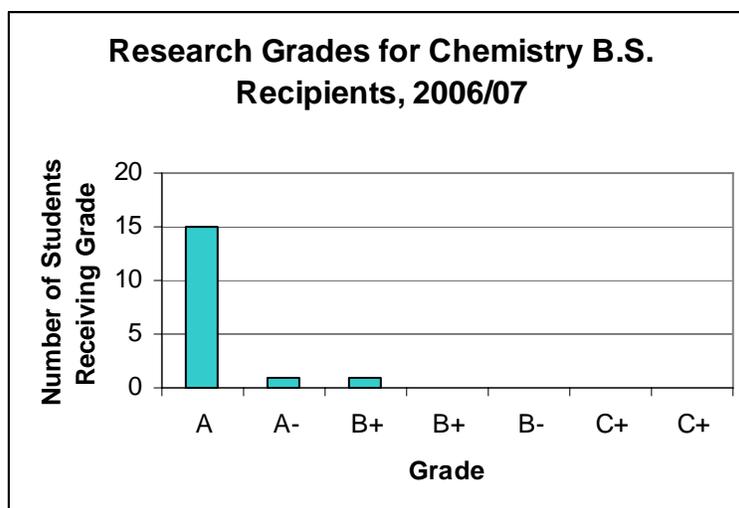
**Student learning outcome 7.** *Work effectively in group situations.*

**Standard of mastery/criterion of achievement:**

1. All students receive a grade of C+ or better in laboratory courses.



2. All research students receive a grade of B or better.



3. Reflective assessment in student exit portfolio.

This is a new assessment. Students were not required to provide a reflective assessment last year.

#### IV. What was learned?

**Student Learning Outcome 1.** *Apply the standard technical information and perform experimental techniques of analytical, biochemistry, inorganic, organic, and physical chemistry.*

As required, all graduates maintained a 2.0 overall gpa and a 2.25 gpa for courses within the major. Half of last year's B.S. recipients maintained a gpa of 3.3 or higher. According to this criterion, the B.S. recipients satisfied Student Learning Outcome 1.

This year we also examined student scores on the ACS standardized exams in the area of analytical chemistry, as well as the introductory general chemistry. In general chemistry, all four graduates had test scores within one standard deviation of the mean, half were above and half were below. The Analytical Chemistry exam is given at the end of Quantitative Analysis, an intermediate level chemistry course. Here, three out of four student scores are above the mean; two scores are within one standard deviation of the mean, and one score is between one and two standard deviations above the mean. The Instrumental Analysis exam is given at the end of Instrumental Analysis, an advanced chemistry course. Again, three out of four student scores are above the mean; one score is within one standard deviation of the mean, and two scores are between one and two standard deviations above the mean. Our analytical chemistry series is serving this group of students well. According to this criterion, they are gaining a very solid understanding of standard analytical chemistry. It is gratifying to see that performance on the standardized exams improved as they moved through our program.

In the future we will examine our graduates' performance on the standardized exams in other areas of chemistry as well.

**Student Learning Outcome 5.** *Retrieve and critically analyze chemical literature.*

CHEM 388 and 488 are the Chemistry Department's undergraduate colloquium courses. In CHEM 388 students prepare a poster on a research topic. Posters are presented during an end of the quarter poster session. In CHEM 488 students prepare oral presentations on a research topic. Their work is presented to the department during a CHEM 488 seminar session at the end of the quarter. This group of students did very well in CHEM 388 and 488; all grades are B+ or higher.

Student ability to use the primary chemical literature is also assessed by evaluating their written reports based on undergraduate research projects. Nearly all undergraduate research projects in chemistry involve hands on research in the laboratory. However, reading the primary literature is usually a component of chemical research, and research reports usually include references to related work carried out by other researchers. Three out of the four students carried our undergraduate research projects; two out of these three students provided a research report in their portfolio. Thus, the first thing that we learned is that we have to be more vigilant in collecting research reports. The two reports submitted by this group of students range from acceptable to very good.

**Student learning outcome 7.** *Work effectively in group situations.*

Students are required to work in teams in nearly all chemistry laboratory courses. The fact that 35 out of 38 laboratory grades for this group of students are B- or higher implies that they can effectively work in group situations. In the research laboratory, 15 out of 17 grades were an A, again implying that these students can work as a member of a team. Next year students will be required to provide a reflective assessment in their portfolio and this will become a criterion for outcome 7.

## Assessment Report for B.S. in Chemistry, Biochemistry Emphasis, June 2008

**I. Which student learning outcomes were assessed?** We have selected three learning outcomes to assess this year. These outcomes were selected because of the ready availability of data. These learning outcomes are related to the goals articulated by the Department of Chemistry, College of the Sciences, and Central Washington University as described below. The relevant goals are provided at the bottom of this section.

**Student Learning Outcome 1.** *Apply the standard technical information and perform experimental techniques of analytical, biochemistry, inorganic, organic, and physical chemistry.* This year we are assessing this outcome for the analytical chemistry area. In future years we will examine this outcome for other areas of chemistry.

This departmental outcome is related to department goal #1, COTS goal #1, and to university strategic goal #1.

**Student Learning Outcome 5.** *Retrieve and critically analyze chemical literature.*

This departmental outcome is related to department goal #1, COTS goal #1, and to university strategic goal #1.

**Student Learning Outcome 7.** *Work effectively in group situations.*

This departmental outcome is related to department goal #1 and goal #3, COTS goal #1 and goal #7, and university strategic goal #1 and goal #6.

### Relevant Goals

Department of Chemistry:

Goal #1. To provide quality education in chemistry through courses and programs on campus or off campus

Goal #3. To facilitate this learning experience with modern equipment and laboratories, computer technology, cooperative research and service to the local community, the central Washington area and to the state

College of the Sciences:

Goal #1. Provide for an outstanding academic and student experience in the College of the Sciences

Goal #7. Create and sustain productive, civil, and pleasant learning environments

Central Washington University:

Goal #1. Maintain and strengthen an outstanding academic and student life on the Ellensburg campus

Goal #6. Build inclusive and diverse campus communities that promote intellectual inquiry and encourage civility, mutual respect, and cooperation.

**II. Who was assessed?** Students receiving a B.S. in Chemistry with Biochemistry Emphasis during 2006/07. Twelve students graduated with a B.S. in Chemistry with Biochemistry Emphasis during this time period.

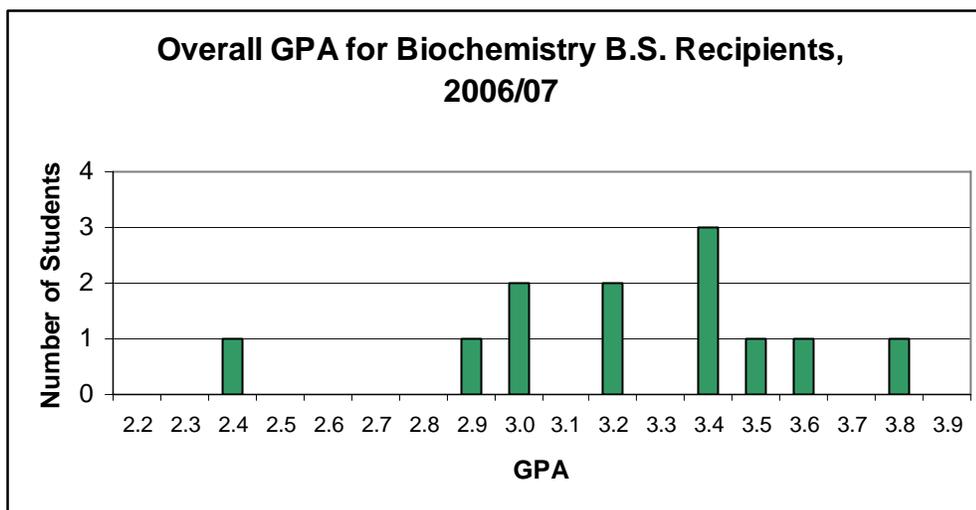
**III. How were student learning outcomes assessed?**

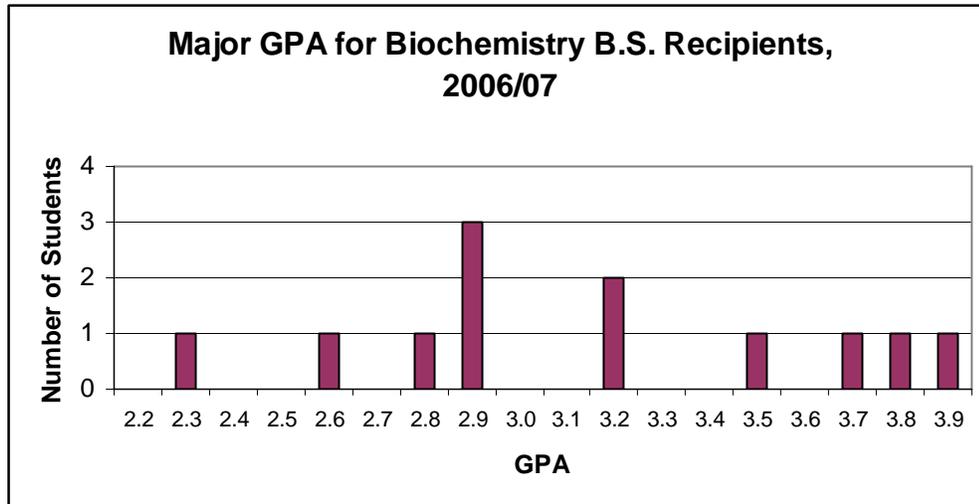
All chemistry majors are required to compile a portfolio before graduating. The portfolio includes an unofficial copy of their transcript, a compilation of all grades received on American Chemical Society (ACS) standardized exams, a copy of the abstract for their CHEM 488 oral presentation to the department, a copy of a laboratory report that showcases their ability to write in the style of the profession and their ability to use modern computer software, and a copy of a research report if undergraduate research was carried out. In the future all chemistry majors will be required to include a reflective assessment in their portfolio. Our assessment of student learning outcomes is based on an examination of the portfolios of students who graduated in the preceding academic year.

**Student Learning Outcome 1.** *Apply the standard technical information and perform experimental techniques of analytical, biochemistry, inorganic, organic, and physical chemistry.*

**Standard of mastery/criterion of achievement:**

1. Graduates maintain 2.0 for course average and an average of 2.25 in courses within the major.





## 2. ACS exams consistent with national averages

The Chemistry Department administers American Chemical Society (ACS) standardized exams at the end of all appropriate courses. This year we examined the exam scores for Analytical Chemistry and Instrumental Analysis. These exams are administered at the end of CHEM 251 and CHEM 452, respectively. Only those students earning a BS in Chemistry are required to take CHEM 452, Instrumental Analysis. The individual student scores were compared with the national mean and standard deviation provided by the ACS. Standardized exam scores for General Chemistry are included for comparison.

### General Chemistry

2001 exam, mean = 36.19, standard deviation = 12.33

2003 exam, mean = 41.03, standard deviation = 10.67

Between 1 and 2 standard deviations below the mean	1 students
Within 1 standard deviation below the mean	4 students
Within 1 standard deviation above the mean	4 students
Between 1 and 2 standard deviations above the mean	1 student

### Analytical Chemistry

2001 exam, mean = 28.5, standard deviation = 7.58

Between 1 and 2 standard deviations below the mean	0 students
Within 1 standard deviation below the mean	8 students
Within 1 standard deviation above the mean	3 students
Between 1 and 2 standard deviations above the mean	1 student

## Instrumental Analysis

2001 exam, mean = 32.82, standard deviation = 7.82

Between 1 and 2 standard deviations below the mean	0 students
Within 1 standard deviation below the mean	1 students
Within 1 standard deviation above the mean	2 student
Between 1 and 2 standard deviations above the mean	0 students

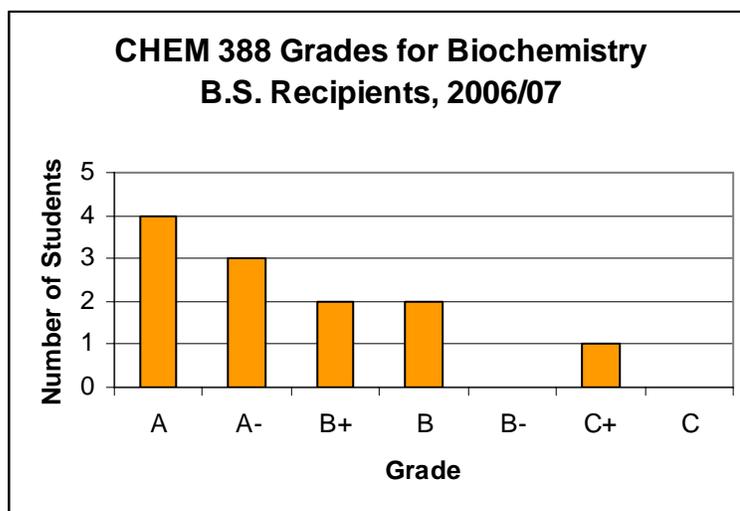
3. All students' portfolio components will be rated at satisfactory or higher.

Because we focused on the Analytical Chemistry area for this assessment period, we did not rate all portfolio components.

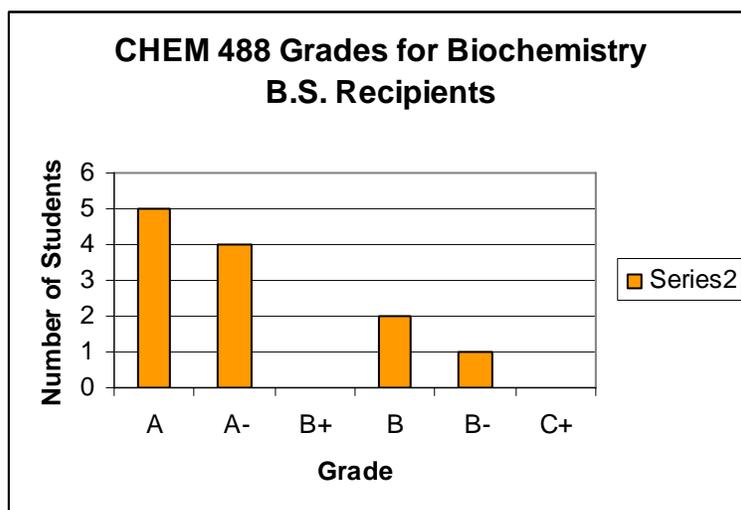
### Student Learning Outcome 5. Retrieve *and critically analyze* chemical literature

#### Standard of mastery/criterion of achievement:

1. All students receive a grade of C+ or better on their poster presentation in CHEM 388.



2. All students receive a grade of C+ or better on their oral presentation in CHEM 488.



3. The research report component in the students' portfolio will be rated at satisfactory or higher.

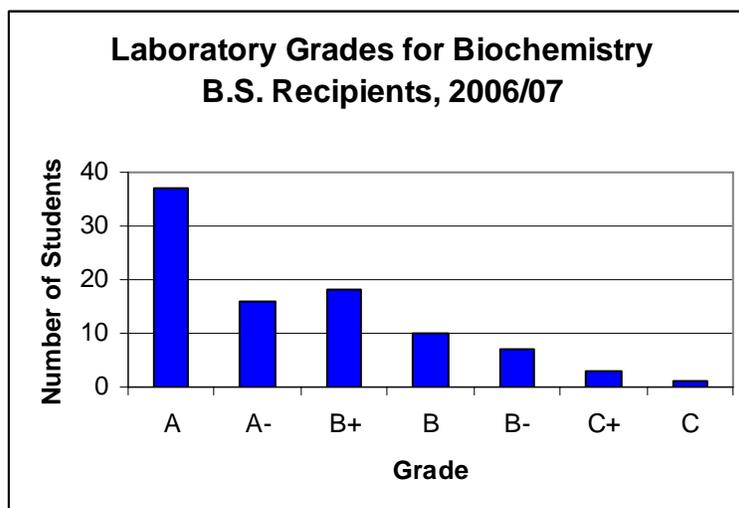
Six out of twelve students carried out undergraduate research projects in Chemistry; four out of six students included a research report in their portfolio. These reports were scored independently by three faculty members using the attached rubric. Students received a score of 0, 1 or 2 on six items, a score of 2 being excellent, 1 being satisfactory, and 0 being unsatisfactory. The scores shown below are the average of scores from the three faculty raters.

Item	Score, Student 1	Score, Student 2	Score, Student 3	Score, Student 4
Statement of Purpose	1.3	2	1.7	1.5
Overall Grammar/Writing Quality	1	0.7	0.7	1
Use of Professional Language	1.3	1	1.7	1.5
Organization/Presentation of Data or Process	1.3	1.3	1.7	1.5
Citation/Assessment of Literature	0.3	1.7	0.3	0.5
Analysis/Discussion	1	1	2	1.5
Total	6.2/12	7.7/12	8.1/12	7.5/12

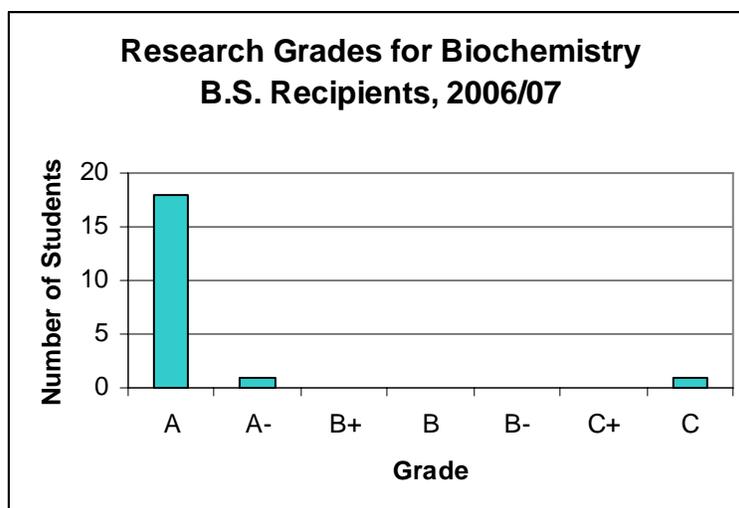
**Student learning outcome 7.** *Work effectively in group situations.*

**Standard of mastery/criterion of achievement:**

1. All students receive a grade of C+ or better in laboratory courses.



2. All research students receive a grade of B or better.



3. Reflective assessment in student exit portfolio.

Students were not required to provide a reflective assessment.

#### IV. What was learned?

**Student Learning Outcome 1.** *Apply the standard technical information and perform experimental techniques of analytical, biochemistry, inorganic, organic, and physical chemistry.*

As required, all graduates maintained a 2.0 overall gpa and a 2.25 gpa for courses within the major. Half of last year's B.S. recipients maintained a gpa of 3.4 or higher. According to this criterion, the B.S. recipients satisfied Student Learning Outcome 1.

This year we also examined student scores on the ACS standardized exams in the area of analytical chemistry, as well as the introductory general chemistry. Scores for the general chemistry exam were available for 10 out of 12 students. In general chemistry, half the scores were above the mean and half were below; 8 out of 10 graduates had test scores within one standard deviation of the mean. The Analytical Chemistry exam is given at the end of Quantitative Analysis, an intermediate level chemistry course. Here, only 4 out of 12 student scores are above the mean. Instrumental Analysis is not a required course for the B.S. with Biochemistry Emphasis. Only three students elected to take this advanced course. The Instrumental Analysis exam is given at the end of Instrumental Analysis. Two out of three student scores are above the mean. The scores for the Analytical Chemistry exam indicate that this goal was not met by this group of students. Examination of SEOI results for Quantitative Analysis by the course instructor(s) has already led to a number of recent changes in this course. In response the course number has been changed from CHEM 251 to CHEM 331, in order to more accurately reflect the course level and as an indication to students of what level of work will be expected. Students find the lab course very demanding, in particular the need to obtain very accurate results. Next year we will include two weeks of quantitative titrations in the CHEM 183 General Chemistry Laboratory course and students will be graded on the accuracy of their results. We expect that this will better prepare students for the upper level laboratory course. We also suspect that more emphasis on topics/experiments related to biochemistry or the environment would make this course more relevant to this group of students.

In the future we will examine our graduates' performance on the standardized exams in other areas of chemistry as well.

**Student Learning Outcome 5.** *Retrieve and critically analyze chemical literature.*

CHEM 388 and 488 are the Chemistry Department's undergraduate colloquium courses. In CHEM 388 students prepare a poster on a research topic. Posters are presented during an end of the quarter poster session. In CHEM 488 students prepare oral presentations on a research topic. Their work is presented to the department during a CHEM 488 seminar session at the end of the quarter. This group of students did very well in CHEM 388 and 488; all grades are C+ or higher and over half are A- or higher.

Student ability to use the primary chemical literature is also assessed by evaluating their written reports based on undergraduate research projects. Nearly all undergraduate research projects in chemistry involve hands on research in the laboratory. In addition, reading the primary

literature is usually a component of chemical research, and research reports usually include references to related work carried out by other researchers. Six out of the twelve students carried out undergraduate research projects; four out of these six students provided a research report in their portfolio. Thus, the first thing that we learned is that we have to be more vigilant in collecting research reports. The four reports submitted by this group of students range from acceptable to very good.

**Student learning outcome 7.** *Work effectively in group situations.*

Students are required to work in teams in nearly all chemistry laboratory courses. The fact that the overwhelming majority of laboratory grades for this group of students are B- or higher implies that they can effectively work in group situations. In the research laboratory, nearly all grades were an A, again implying that these students can work as a member of a team. Next year students will be required to provide a reflective assessment in their portfolio and this will become a criterion for outcome 7.

**Central Washington University  
Assessment of Student Learning  
Department and Program Report**

Please enter the appropriate information concerning your student learning assessment activities for this year.

Academic Year of Report: 2007-08

College: COTS

Department: Chemistry

Programs: B.A. Chemistry Teaching

**1. What student learning outcomes were assessed this year, and why?**

*In answering this question, please identify the specific student learning outcomes you assessed this year, reasons for assessing these outcomes, with the outcomes written in clear, measurable terms, and note how the outcomes are linked to department, college and university mission and goals.*

The Chemistry Department and Department of Science Education feels that it is important to assess chemistry teaching majors in such a way that ensures quality. To do so, seven Student Learning Outcomes (SLO) have been identified that provide a suitably detailed evaluation of student knowledge, skills, and disposition. Please refer to Appendix A for a report of Chemistry Teaching SLO, criterion of mastery, and assessment results.

Student Learning Outcomes:

1. Demonstrate an ability to individually and collaboratively engage in inquiry and integrate the nature of science. (SCED goal 1, 3, 4; COTS Goal 1, 4, 6; CWU Goal 1, 6)
2. Explain and apply fundamental science content concepts, principles, and methods.
3. Demonstrate an ability to effectively facilitate learning for all students. (SCED Goal 1, 3, 5; COTS Goal 1, 4, 6; CWU Goal 1, 6)
4. Create safe, effective learning environments that support inquiry, collaboration, intellectual risk-taking, ethical decision-making, and student construction of knowledge. (SCED Goal 2, 3, 4; COTS Goal 1, 6; CWU Goal 1, 6)
5. Demonstrate an ability to assess teaching and learning outcomes using multiple methods, effectively evaluate teaching and learning effectiveness, and improve practice based on reflection and data. (SCED Goal 1, 2, 3, 4; COTS Goal 1, 6, 7; CWU Goal 1, 6)
6. Demonstrate an ability to make science personally and socially relevant to individual and community by incorporating current events within collaborative and social networks. (SCED Goal 2, 3, 4, 7, 8; COTS Goal 1, 6; CWU Goal 1, 6)
7. Participate in a variety of activities that enhance professional development and improve teaching effectiveness. (SCED Goal 1, 2, 4; COTS Goal 1, 5, 6; CWU Goal 4, 6)

These SLO were chosen because they reflect the criteria necessary to become an effective chemistry teacher. The SLO were originally conceived through a consensus process by examining commonalities in three sets of professional standards; National Science Education Standards for Teaching, National Science Teacher Association Standards, and the Washington Competencies for Chemistry. By using this approach, performance within the program also provides some measure of how well students are able to meet professional standards.

## 2. How were they assessed?

*In answering these questions, please concisely describe the specific methods used in assessing student learning. Please also specify the population assessed, when the assessment took place, and the standard of mastery (criterion) against which you will compare your assessment results. If appropriate, please list survey or questionnaire response rate from total population.*

### A) What methods were used?

The Chemistry Teaching Program used a formative and summative assessment system comprised of several elements:

- 1) Performance-based, standards-aligned electronic portfolio
- 2) WEST-E and American Chemical Society content examinations
- 3) Entry and exit surveys

### Chemistry Teaching Portfolio

The Chemistry Teaching portfolio was used to assess student knowledge, skills, and dispositions relative to professional standards. The Chemistry Teaching Portfolio was built from a common template collaboratively designed and constructed by members of the Department of Science Education, with additional insight provided by content colleagues and K-12 teachers. The portfolio framework was based on the latest scientific research on how people learn (National Research Council, 2005), with assessment focused on: 1) determining student preconceptions, 2) engaging students in authentic scientific inquiry, 3) developing and applying robust content knowledge, and 4) promoting meta-cognitive awareness of teaching and learning process and critical thinking.

Each portfolio element, or dimension, required a reflection and was closely aligned to Chemistry Teaching SLO and professional standards. In an effort to promote critical thinking, students were required to supply evidence they deemed suitable rather than those prescribed by faculty. Students also had to justify their choice of evidence and progress toward meeting professional standards in each reflection. The dimensions of the Chemistry Teaching portfolio (including content strands) are indicated below:

- 1) Inquiry and Nature of Science
- 2) Content
  - a. Analytical/Instrumental Chemistry
  - b. Organic Chemistry
  - c. Biochemistry
  - d. Inorganic Chemistry
  - e. Physical Chemistry

- f. Application of Mathematics and Physics to Chemistry
- 3) Teaching
  - 4) Learning Environments
  - 5) Assessment and Evaluation
  - 6) Relevance
  - 7) Professional Growth. The Content dimension is further subdivided into the major disciplinary themes in biological science, and included:

#### WEST-E and MFT Exams

Student content knowledge was assessed in Science Education (WEST-E) and American Chemical Society disciplines. Minimum scores were required for all exams. Each student had to post total and component scores in the Content dimension of the Chemistry Teaching Portfolio. These scores were also tracked in a separate spreadsheet to identify areas of strength and necessary development.

#### Entry and Exit Surveys

An entry to program survey was used to assess student demographics, disposition toward science education, and program learning expectations. An exit survey was used to evaluate program effectiveness, changes in disposition, and met/unmet learning expectations. A reflection comparing entry and exit survey results was also required in the Chemistry Teaching portfolio.

Prior to being allowed to student teach, portfolios were evaluated by chemistry teaching faculty using a standards-aligned rubric. Students had to demonstrate minimum proficiency for each portfolio dimension. An advising hold that could only be removed by a chemistry teaching or another Science Education faculty member was used to ensure compliance.

#### **B) Who was assessed?**

All eligible chemistry teaching majors, chemistry teaching certification, and endorsement students.

#### **C) When was it assessed?**

Upper division coursework during the academic year, with final portfolio due prior to student teaching. Portfolio was periodically evaluated during advising.

### **3. What was learned?**

*In answering this question, please report results in specific qualitative or quantitative terms, with the results linked to the outcomes you assessed, and compared to the standard of mastery (criterion) you noted above. Please also include a concise interpretation or analysis of the results.*

Please refer to Appendix A for detailed assessment results. Several points of strength and areas for improvement emerged from assessment results, as follows:

- All individuals, N=4, have completed the major program and are in upwards of exemplary/proficient of performing at state benchmarks and have either graduated, gone on to student teach, or are currently employed. This suggests that 100% of graduating and student teaching candidates are currently meeting competency requirements as indicated by Chemistry Teaching portfolio results. These results are not entirely corroborated by the WEST-E pass rate for Chemistry Teaching candidates, since one major has had some difficulty in passing the Chemistry WEST-E several times over the past two years. Therefore the WEST-E pass rate average is artificially low with the reported 43%. Recurring difficulty in the area of Nuclear Chemistry has been identified as an issue with both Chemistry Teaching Majors and Minors.
- American Chemical Society content exam results show that the average of Chemistry Teaching students scores are lower than the national percentile in areas of General Chemistry, Organic Chemistry, and Analytical, with scores of 45.7%, 6.0%, and 30.5%, respectively. It should be noted that Physical Chemistry is observed as a consistently high national percentile mean, 56.3%. There is not enough information from these four majors in the areas of Biochemistry, Inorganic Chemistry, Instrumental Chemistry, and Physical Chemistry. These data are consistent for all chemistry majors. With such a low population, N=4, these data cannot be considered to be statistically significant.
- Generally, the assessment methods employed provided meaningful insight into Chemistry Teaching student knowledge, skills, and dispositions.
- SLO were closely aligned to department, college, and university goals, and covered a range of basic and advanced knowledge and skills. Disposition SLO were lacking.
- Portfolio reflection scores were lower than artifact scores indicating that students need more practice in writing reflections and describing how artifacts show that learning outcomes have been met.
- Survey results and advising discussion indicated that students achieved the majority of their learning goals. Insufficient experience with assessment and evaluation and classroom management were common criticisms. The relative absence of these and field teaching experiences, particularly in College of Education courses, was a common concern.

#### 4. What will the department or program do as a result of that information?

*In answering this question, please note specific changes to your program as they affect student learning, and as they are related to results from the assessment process. If no changes are planned, please describe why no changes are needed. In addition, how will the department report the results and changes to internal and external constituents (e.g., advisory groups, newsletters, forums, etc.).*

Based on collected data, the following revisions to the Chemistry Teaching program are proposed:

##### Improvements for Student Learning

- Add SLO that more explicitly address the development of professional values and dispositions.

- Provide more opportunities for students to experience authentic scientific inquiry in introductory science courses. If inquiry is important in K-12 schools, then more content courses should model investigative science and focus on inquiry.
- Steps have been taken to incorporate nuclear chemistry into the curriculum, after major and minor West-E exam scores slumped in this area (average of 5.75 points out of 10.00 for majors). This information led to the Chemistry Department's Curriculum Committee adjusting our CHEM 180 series scope and sequence of content. Now, nuclear content knowledge is taught, where nuclear fission/fusion and radioisotopes are taught in the first quarter, CHEM 181, and first order radioactive decay in the second quarter, CHEM 182, of general chemistry.
- Encourage submission of higher quality evidence in some content areas like nuclear chemistry from either general or physical chemistry. This is a particular area of deficiency when students report West E exam scores.
- Embed use of current events and community involvement to a greater extent in content and science education courses.
- Help students better connect evidence to developmental progress. Greater emphasis on metacognitive awareness will help students become better learners, which in turn should improve job performance as professional teachers. Improvement in this area will be important considering the increased emphasis on accountability in K-12 schools.
- Help students better learn how to assess and evaluate student learning. Students must have the ability to design, align, and employ effective methods of assessment as an integral part of K-12 accountability. Evidence indicates this is a deficit for many science education students, and they feel it should be emphasized more in College of Education courses. Regardless, greater emphasis on assessment can occur in science education methods courses.
- Help students better connect evidence to developmental progress. Greater emphasis on metacognitive awareness will help students become better learners, which in turn should improve job performance as professional teachers. Improvement in this area will be important considering the increased emphasis on accountability in K-12 schools.
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#### Improvements in Assessment Process

- The artificially low pass rate for Chemistry Endorsement on the WEST-E is 43%. Such a low pass rate sent alarms to the Chemistry Department and Science Education Program. We promptly asked for and quickly received data in the Winter Quarter of 2007 that elucidated the situation for us. The low pass rate was due mainly to a single person who was taking and retaking the WEST-E Chemistry exam multiple times, 5 times in total. This act alone, with such a small number of students taking the Chemistry WEST-E from CWU, decreased the pass rate significantly. Since this time, Chemistry Teaching Advisors have communicated the importance of preparing for this exam with the majors and minors. The advisors have also requested WEST-E information after every offering state-wide so that they can be proactive in advising failing students to either better prepare for the exam or advise them into an alternate career path.
- Some aspects of the Chemistry Teaching portfolio need greater specificity and should be shared with students early in the program so they better understand what is expected.

- Since the Biology, Chemistry, Earth Science, and Physics Teaching portfolios are based on a common template, it would be useful to compare across these programs to identify overall trends in science teacher preparation.
- The LiveText software used to collect student data is disconnected from Blackboard, making it unnecessarily confusing for students and faculty. LiveText is limited in features, and exploration of new options is recommended.

## **5. What did the department or program do in response to last year's assessment information?**

*In answering this question, please describe any changes that have been made to improve student learning based on previous assessment results. Please also discuss any changes you have made to your assessment plan or assessment methods.*

This is the first year that annual assessment reports were required from each program at CWU. Systematic implementation of assessment has been occurring in Chemistry Teaching (and Science Education generally) for several years, partly in response to NCATE accreditation requirements, which has prompted the following:

- Changes to the Chemistry introductory series that will be implemented beginning in the 2008-2009 academic year. A three-quarter introductory lecture and lab sequence was streamlined to a logical chemistry perspective by chemistry faculty. Also, lab manuals have been re-written to integrate skills and tools of inquiry-based approach.
- New Washington competencies for Chemistry teachers were introduced by the state last year, which will require some realignment of the portfolio. Realignment is planned for the 2008-2009 academic year.
- A new SCED senior seminar course was implemented in 2007-2008. The new course, which is required for all new Biology, Chemistry, Earth Science, and Physics Teaching majors, should provide scaffolding needed to better complete the portfolios – particularly in the realm of appropriate writing for reflections and presentations of evidence.

## **6. Questions or suggestions concerning Assessment of Student Learning at Central Washington University:**

The Departments of Chemistry and Science Education recommend the following changes to student learning assessment at CWU:

- Provide more opportunities for chemistry and science education faculty to collaborate upon content and pedagogical courses so that the scope and sequence of coursework and practicum offer all teaching majors what they need to be successful teachers while meeting and exceeding national and state teaching standards.
- Provide more opportunities for training and professional development for how to conduct assessment. Graduate training typically does not include assessment; therefore it is important to not assume faculty know why or how to conduct assessment. Many faculty members may experience a steep learning curve.

- The due dates for the annual Assessment Plans should correspond more closely with annual departmental planning so that necessary changes have the greatest chance of being implemented.
- Provide necessary infrastructure for program assessment. This may include financial and intellectual resources including focused release time, collaboration, and dissemination of best practices across colleges and departments.
- Effective sharing of materials should minimize the reinvention of the wheel, as it were. Examples of rubrics (which will figure prominently in performance evaluations) should be shared as most faculty members are not highly familiar with the use of rubrics.
- Each department should have an assessment coordinator with reasonable workload release. This person should coordinate efforts, not remove assessment responsibility from other faculty.

## Appendix A – Chemistry Teaching Results Matrix

Student Learning Outcome	Criterion of Mastery	Assessment Results
<p><b>1. Demonstrate an ability to individually and collaboratively engage in inquiry and integrate the nature of science.</b></p>	<p>100% average score of Proficient or better for portfolio dimension 1 and associated reflection.</p> <p>100% average score of Proficient or better for relevant aspects of SCED 324 portfolio.</p> <p>Passing of WEST-E Chemistry exam.</p> <p>American Chemical Society content exam scores consistent with national averages.</p> <p>All standards met for WA Pedagogy Assessment.</p>	<p>Students assessed to date: 4</p> <p>Portfolio dimension 1 proficiency:</p> <ul style="list-style-type: none"> <li>• Inquiry Artifact: % 100</li> <li>• Nature of Science Artifact: 100%</li> <li>• Independent Research Artifact: 100%</li> <li>• Dimension 1 Reflection: 100%</li> </ul>
<p><b>2. Explain and apply fundamental science content concepts, principles, and methods.</b></p>	<p>100% average score of Proficient or better for portfolio Dimension 2 and associated reflection.</p> <p>100% average score of Proficient or better for relevant aspects of SCED 324 portfolio.</p> <p>Passing of WEST-E Chemistry exam.</p> <p>American Chemical Society content exam scores consistent</p>	<p>Students assessed to date: 4</p> <p>Portfolio dimension 2 proficiency:</p> <ul style="list-style-type: none"> <li>• Analytical/Instrumental Chemistry Artifact: 100%</li> <li>• Organic Chemistry Artifact: 100%</li> <li>• Biochemistry Artifact: 100%</li> <li>• Inorganic Chemistry Artifact: 100%</li> </ul>

	<p>with acceptable national mean averages.</p> <p>All standards met for WA Pedagogy Assessment.</p>	<ul style="list-style-type: none"> <li>• Physical Chemistry: 100%</li> <li>• Application of Mathematics and Physics to Chemistry Artifact: 100%</li> <li>• Dimension 2 Reflection: 100%</li> </ul> <p>WEST-E passing scores: 42.9%, Passing is 150 and Total Mean is 151 with STD at +/-15.6</p> <p>American Chemical Society content exam scores are within acceptable National percentile averages:</p> <ul style="list-style-type: none"> <li>-General Chemistry: 45.6%</li> <li>-Organic Chemistry: 16.0%</li> <li>-Analytical: 30.5%</li> <li>-Biochemistry: n/a</li> <li>-Inorganic Chemistry: n/a</li> <li>-Instrumental Chemistry: n/a</li> <li>-Physical Chemistry: 56.3%</li> </ul>
<p><b>3. Demonstrate an ability to effectively facilitate learning for all</b></p> <p><b>4. students.</b></p>	<p>100% average score of Proficient or better for portfolio Dimension 3 and associated reflection.</p> <p>100% average score of Proficient or better for relevant aspects of SCED 324 portfolio.</p> <p>Passing of WEST-E Chemistry exam.</p> <p>American Chemical Society content exam scores consistent with national averages.</p> <p>All standards met for WA Pedagogy Assessment.</p>	<p>Students assessed to date: 4</p> <p>Portfolio dimension 3 proficiency:</p> <ul style="list-style-type: none"> <li>• SCED 324 Portfolio Artifact: 100%</li> <li>• Other Teaching Experience Artifact: 100%</li> <li>• Dimension 3 Reflection: 100%</li> </ul>

<p><b>5. Create safe, effective learning environments that support inquiry, collaboration, intellectual risk-taking, ethical decision-making, and student construction of knowledge.</b></p>	<p>100% average score of Proficient or better for portfolio Dimension 4 and associated reflection.</p> <p>100% average score of Proficient or better for relevant aspects of SCED 324 portfolio.</p> <p>Passing of WEST-E Chemistry exam.</p> <p>American Chemical Society content exam scores consistent with national averages.</p> <p>All standards met for WA Pedagogy Assessment.</p>	<p>Students assessed to date: 4</p> <p>Portfolio dimension 4 proficiency:</p> <ul style="list-style-type: none"> <li>• Collaborative Learning Artifact: 100%</li> <li>• Diverse Learning Artifact: 100%</li> <li>• Technology Artifact: 100%</li> <li>• Safety Artifact: 100%</li> <li>• Dimension 4 Reflection: 100%</li> </ul>
<p><b>6. Demonstrate an ability to assess teaching and learning outcomes using multiple methods, effectively evaluate teaching and learning effectiveness, and improve practice based on reflection and data.</b></p>	<p>100% average score of Proficient or better for portfolio Dimension 5 and associated reflection.</p> <p>100% average score of Proficient or better for relevant aspects of SCED 324 portfolio.</p> <p>Passing of WEST-E Chemistry exam.</p> <p>American Chemical Society content exam scores consistent with national averages.</p> <p>All standards met for WA Pedagogy Assessment.</p>	<p>Students assessed to date: 4</p> <p>Portfolio dimension 5 proficiency:</p> <ul style="list-style-type: none"> <li>• Assessment of Student Learning Artifact: 75%</li> <li>• Self Assessment of Teaching Artifact: 100%</li> <li>• Dimension 5 Reflection: 100%</li> </ul>
<p><b>7. Demonstrate an ability to make science personally and socially relevant to individual and community by incorporating current events within collaborative and social networks.</b></p>	<p>100% average score of Proficient or better for portfolio Dimension 6 and associated reflection.</p> <p>100% average score of Proficient or better for relevant aspects of SCED 324 portfolio.</p> <p>Passing of WEST-E Chemistry</p>	<p>Students assessed to date: 4</p> <p>Portfolio dimension 6 proficiency:</p> <ul style="list-style-type: none"> <li>• Incorporation of Current Events Artifact: 100%</li> <li>• Community Involvement Artifact: 100%</li> <li>• Dimension 6 Reflection:</li> </ul>

	<p>exam.</p> <p>American Chemical Society content exam scores consistent with national averages.</p> <p>All standards met for WA Pedagogy Assessment.</p>	100%
<p><b>8. Participate in a variety of activities that enhance professional development and improve teaching effectiveness.</b></p>	<p>100% average score of Proficient or better for portfolio Dimension 7 and associated reflection.</p> <p>100% average score of Proficient or better for relevant aspects of SCED 324 portfolio.</p> <p>Passing of WEST-E Chemistry exam.</p> <p>American Chemical Society content exam scores consistent with national averages.</p> <p>All standards met for WA Pedagogy Assessment.</p>	<p>Students assessed to date: 4</p> <p>Portfolio dimension 7 proficiency:</p> <ul style="list-style-type: none"> <li>• Professional Membership Artifact: 100%</li> <li>• Dimension 7 Reflection: 100%</li> </ul>

**Central Washington University  
Assessment of Student Learning  
Department and Program Report**

**Academic Year of Report:** 2008/09      **College:** COTS  
**Department:** Chemistry      **Program:** B.A. in Chemistry

There were no graduates in this degree program during the 2007/08 academic year.

**Central Washington University  
Assessment of Student Learning  
Department and Program Report**

**Academic Year of Report:** 2008/09      **College:** COTS  
**Department:** Chemistry      **Program:** B.S. in Chemistry

**I. Which student learning outcomes were assessed?** We have selected two learning outcomes to assess this year. These learning outcomes are related to the goals articulated by the Department of Chemistry, College of the Sciences, and Central Washington University as described below. The relevant goals are provided at the bottom of this section.

**Student Learning Outcome 1.** *Apply the standard technical information and perform experimental techniques of analytical, biochemistry, inorganic, organic, and physical chemistry.* This year we are assessing this outcome for the areas of analytical and organic chemistry. This is the second year that we have examined student learning outcomes in the area of analytical chemistry and the first year that we have examined outcomes in the organic chemistry area. In future years we will continue to expand our assessment efforts to the remaining examine areas of chemistry.

This departmental outcome is related to department goal #1, COTS goal #1, and to university strategic goal #1.

**Student Learning Outcome 7.** *Work effectively in group situations.* This is the second year that we have examined this learning outcome. The availability of alumni survey results prompted the examination of this outcome.

This departmental outcome is related to department goal #1 and goal #3, COTS goal #1 and goal #7, and university strategic goal #1 and goal #6.

**Relevant Goals**

Department of Chemistry:

- Goal #1. To provide quality education in chemistry through courses and programs on campus or off campus
- Goal #3. To facilitate this learning experience with modern equipment and laboratories, computer technology, cooperative research and service to the local community, the central Washington area and to the state

College of the Sciences:

- Goal #1. Provide for an outstanding academic and student experience in the College of the Sciences
- Goal #7. Create and sustain productive, civil, and pleasant learning environments

Central Washington University:

- Goal #1. Maintain and strengthen an outstanding academic and student life on the Ellensburg campus
- Goal #6. Build inclusive and diverse campus communities that promote intellectual inquiry and encourage civility, mutual respect, and cooperation.

**II. Who was assessed?** Students receiving a B.S. in Chemistry during 2007/08. Eleven students graduated with this degree during this time period. One of these students entered our program with the A.A. degree, having already completed the general chemistry sequence. Nine of the eleven graduates earned American Chemical Society certified degrees.

### **III. How were student learning outcomes assessed?**

#### **Overview**

Our assessment of student learning outcomes is based on an examination of the portfolios of students who graduated in the preceding academic year, results of an exit survey, and results of an alumni survey. A brief description of each tool follows.

***Student portfolio.*** All chemistry majors are required to compile a portfolio before graduating. Completion of the portfolio is a requirement of CHEM 488, Undergraduate Colloquium. The portfolio includes an unofficial copy of their transcript, a compilation of all grades received on American Chemical Society (ACS) standardized exams, a copy of the abstract for their CHEM 488 oral presentation to the department, a copy of a laboratory report that showcases their ability to write in the style of the profession and their ability to use modern computer software, and a copy of a research report if undergraduate research was carried out.

***Exit survey.*** Students also complete an exit survey as part of CHEM 488. A copy of this survey is included as Appendix A.

***Alumni survey.*** Every five years the Chemistry Department administers a survey by mail to recent graduates. In March 2009 a survey was sent to students graduating with degrees in Chemistry during the period 2004-2008. A copy of the survey is included as Appendix B. The survey is anonymous; responses of those students graduating in 2008 cannot be isolated, neither can student responses be separated by degree type.

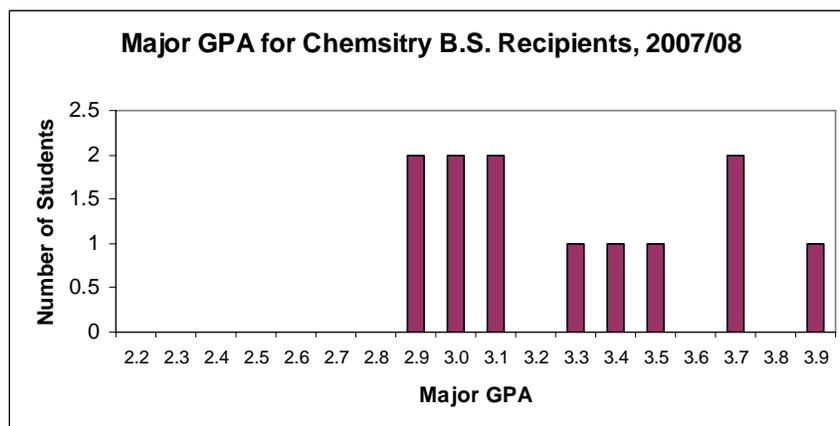
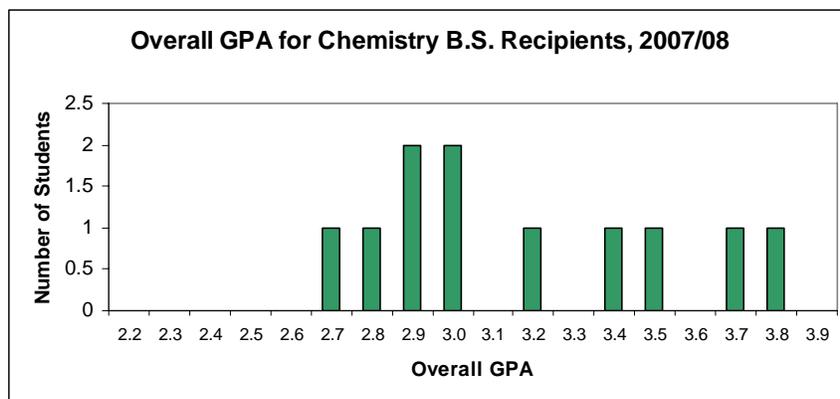
#### **Student Learning Outcome 1**

*Apply the standard technical information and perform experimental techniques of analytical, biochemistry, inorganic, organic, and physical chemistry.*

***Standard of mastery/criterion of achievement:***

1. Graduates maintain 2.0 gpa overall and 2.25 gpa within the major.

Overall GPAs for this group of students ranged from 2.7 to 3.8, with 3.0 as the median. GPAs within the major ranged from 2.9 to 3.9, with 3.2 as the median.



2. ACS exams consistent with national averages

The Chemistry Department administers American Chemical Society (ACS) standardized exams at the end of all appropriate courses. This year we examined the exam scores in the areas of analytical and organic chemistry. This is the second year in a row that we have examined the scores in the analytical area, including Analytical Chemistry and Instrumental Analysis exams. These exams are administered at the end of CHEM 332 and CHEM 452, respectively. This is the first year that we have examined the scores in the organic area. The organic chemistry exam is administered at the end of CHEM 363. For each exam

the individual student cores were compared with the national mean and standard deviation provided by the ACS. Standardized exam scores for General Chemistry are included for comparison, as well as grades received by students in the courses in general, organic, and analytical chemistry. Average grades for the associated courses are shown in Table 2.

**Table 1.** Student scores on ACS standardized exams in comparison with national results

Area of Chemistry	Exam	2 std dev below mean	1 std dev below mean	1 std dev above mean	2 std dev above mean
General	General Chemistry*	0	7	2	1
Analytical	Analytical Chemistry	0	6	5	0
	Instrumental Analysis	2	4	4	1
Organic	Organic Chemistry	2	8	0	0

\*Scores not available for the transfer student.

**Table 2.** Average grade for courses in areas assessed

area	CHEM course(s)	average grade
General Chemistry*	181, 182, 183	3.03
	181Lab, 182Lab, 183Lab	3.42
Analytical Chemistry	332	3.21
	332Lab	3.27
	452	3.06
	452Lab	3.83
Organic Chemistry	361, 362, 363	2.75
	361Lab, 362Lab, 363Lab	3.36

\*Scores not available for the three transfer students.

- All students' portfolio components will be rated at satisfactory or higher.

Because we focused on the analytical and organic chemistry areas for this assessment period, we did not rate all portfolio components.

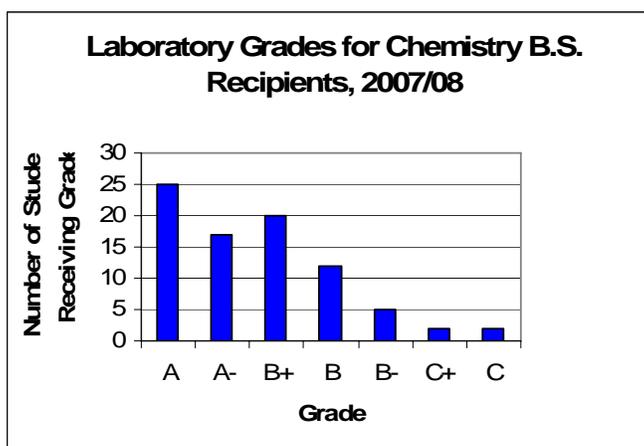
### **Student learning outcome 7**

*Work effectively in group situations.*

***Standard of mastery/criterion of achievement:***

1. All students receive a grade of C+ or better in laboratory courses.

Of the 84 laboratory grades recorded for this group of students, 81 were C+ or higher.



2. All research students receive a grade of B or better.

There were 48 research grades recorded for this group of students; all were A.

3. Satisfactory comments on exit survey.

In response to Question 2. What specific components of your education in chemistry do you think will best prepare you for the job market/graduate school?

"The high level of interaction between all students, faculty, and staff parallels the teamwork required in the industry."

In response to Question 3. If you performed research at CWU, do you feel it will help in your career? If so, please tell why.

"Yes, it will help because we had to work in a group setting plus needing to solve problems on own."

#### 4. Satisfactory comments on alumni survey.

##### Question 2.

"While I do not use the technical aspect of my major in my current position in the military. My research experience gave me necessary people skills along with a very broad understanding of how a large organization functions."

##### Question 3.

In your view, how well did your experience in the chemistry program at CWU prepare you for the following: (1 = did not prepare me; 5 = substantial preparation)

	1	2	3	4	5
Dealing with personnel and interpersonal communication issues in your current position	0	1	4	7.5	3.5

Average response = 3.8/5

Comment: "Interpersonal communication skills and ethical standards are very important in my current position as an officer in the military and I feel the chemistry department did their part in fortifying them within me during my time at Central."

### III. What was learned?

**Student Learning Outcome 1.** *Apply the standard technical information and perform experimental techniques of analytical, biochemistry, inorganic, organic, and physical chemistry.*

As required, all graduates maintained a higher than 2.0 overall gpa and a higher than 2.25 gpa for courses within the major. Half of last year's B.S. recipients maintained a major gpa of 3.2 or higher. According to this criterion, the B.S. recipients satisfied Student Learning Outcome 1.

This year we examined student scores on the ACS standardized exams in the area of analytical and organic chemistry, as well as introductory general chemistry. In general chemistry, all nine out of ten graduates had test scores within one standard deviation of the national mean. Three out of ten were above the national mean. The Analytical Chemistry exam is given at the end of Quantitative Analysis, an intermediate level chemistry course. Here, all student scores were within one standard deviation of the national mean; five of eleven scores were above the national mean. The Instrumental Analysis exam is given at the end of Instrumental Analysis, an advanced chemistry course. On this exam,

eight out of ten scores were within one standard deviation of the national mean and five of eleven scores were above the national mean. Our analytical chemistry series continues to serve this group of students well. Student performance on the standardized exams in the analytical area is comparable to student performance nationwide. Furthermore, for this group of students, performance in the analytical area was stronger than their performance in the general chemistry series.

The Organic Chemistry exam is given at the end of the year-long sequence in Organic Chemistry, an intermediate level series. Eight of the ten scores were within one standard deviation of the national mean. All of the scores were below the national mean. For this group of students the average performance in the organic area did not measure up to average student performance nationwide. Further, performance in this area was not as strong as performance by the same group in the analytical area.

#### **Student learning outcome 7. *Work effectively in group situations.***

Students are required to work in teams in nearly all chemistry laboratory courses. The fact that 75 out of 84 laboratory grades for this group of students were B or higher implies that they can effectively work in group situations. In the research laboratory, all 48 of the recorded grades were an A, again implying that these students can work as a member of a team.

There were several positive comments on the exit and alumni surveys concerning teamwork and interpersonal skills; there were no negative comments. Alumni gave the Chemistry Department fairly high marks (3.8/5) in preparing them to deal with "personnel and interpersonal communication issues".

#### **IV. What will the department do as a result of this information?**

No dramatic changes are planned for this degree program on the basis of the results presented here. Students are performing well in the area of analytical chemistry. Over the last several years, faculty teaching Quantitative Analysis have raised their expectations for student performance. Accordingly, the course number has been changed from CHEM 251 to CHEM 332. The general chemistry laboratory curriculum has been undergoing revision. As part of this revision, more emphasis is being placed on quantitative analysis. Our hope is that this will lead to further improvement in the upper level analytical chemistry courses.

Until this year, the Chemistry Department has been understaffed in the area of organic chemistry. With the hiring of two new organic chemists, students should have easier access to faculty members and should enjoy smaller lecture courses. We hope that this will lead to higher levels of student achievement in the organic chemistry series. The organic faculty members are also engaged in careful scrutiny of their expectations and teaching methods, and have started to

revise the laboratory curriculum. We will continue to assess student performance in the organic area over the next several years.

The Chemistry Department plans to continue to emphasize teamwork and communication skills in its laboratory and research curriculum.

#### **V. What did the department do in response to last year's assessment information?**

Several committee meetings and at least one full department meeting were devoted to a discussion of last year's assessment report. Most of the changes that we made were related to assessment rather than changes to curriculum, advising, or performance standards. For example, in last year's report it was noted that a number of students had not included research reports in their portfolios. As a result we have all agreed to be more vigilant in the collecting, reading, and filing of student research reports.

The Chemistry Department Undergraduate Curriculum Committee revised the student learner outcomes for all programs to include an understanding of the ethical treatment of scientific data. The committee also revised the alumni survey form, created and implemented a new exit survey for our graduates, and decided to implement an entrance survey. The entrance survey is in revision and will be implemented starting next year. The new exit survey addresses student attitudes towards safety, ethical treatment of data, and their ability to work as a member of a team.



3. In your view, how well did your experience in the chemistry program at CWU prepare you for dealing with personnel and interpersonal communication issues in your current position:

(1 = did not; 5 = substantial preparation)

1      2      3      4      5

Comments?

4. How do you feel your chemistry education compares with that of your peers from other institutions?

(1 = below that of peers; 5 = superior to that of peers)

1      2      3      4      5

Please comment on your choice:

5. We are gathering data for graduating seniors. If you will be starting employment immediately after graduation, would you be willing to share your starting salary with us?

6. If you would like information included in the Chemistry Chronicle Newsletter, which can be accessed on the web at [www.cwu.edu/~chem](http://www.cwu.edu/~chem), please indicate below.



**Central Washington University  
Assessment of Student Learning  
Department and Program Report**

**Academic Year of Report:** 2008/09      **College:** COTS  
**Department:** Chemistry      **Program:** B.S. in Chemistry, Biochemistry Emphasis

**I. Which student learning outcomes were assessed?** We have selected two learning outcomes to assess this year. These learning outcomes are related to the goals articulated by the Department of Chemistry, College of the Sciences, and Central Washington University as described below. The relevant goals are provided at the bottom of this section.

**Student Learning Outcome 1.** *Apply the standard technical information and perform experimental techniques of analytical, biochemistry, inorganic, organic, and physical chemistry.* This year we are assessing this outcome for the areas of analytical and organic chemistry. This is the second year that we have examined student learning outcomes in the area of analytical chemistry and the first year that we have examined outcomes in the organic chemistry area. In future years we will continue to expand our assessment efforts to the remaining examine areas of chemistry.

This departmental outcome is related to department goal #1, COTS goal #1, and to university strategic goal #1.

**Student Learning Outcome 7.** *Work effectively in group situations.* This is the second year that we have examined this learning outcome. The availability of alumni survey results prompted the examination of this outcome.

This departmental outcome is related to department goal #1 and goal #3, COTS goal #1 and goal #7, and university strategic goal #1 and goal #6.

**Relevant Goals**

Department of Chemistry:

- Goal #1. To provide quality education in chemistry through courses and programs on campus or off campus
- Goal #3. To facilitate this learning experience with modern equipment and laboratories, computer technology, cooperative research and service to the local community, the central Washington area and to the state

College of the Sciences:

- Goal #1. Provide for an outstanding academic and student experience in the College of the Sciences
- Goal #7. Create and sustain productive, civil, and pleasant learning environments

Central Washington University:

- Goal #1. Maintain and strengthen an outstanding academic and student life on the Ellensburg campus
- Goal #6. Build inclusive and diverse campus communities that promote intellectual inquiry and encourage civility, mutual respect, and cooperation.

**II. Who was assessed?** Students receiving a B.S. in Chemistry with Biochemistry Specialization during 2007/08. Eight students graduated with this degree during this time period. Three of these students entered our program with A.A. degrees, having already completed the general chemistry sequence.

### **III. How were student learning outcomes assessed?**

#### **Overview**

Our assessment of student learning outcomes is based on an examination of the portfolios of students who graduated in the preceding academic year, results of an exit survey, and results of an alumni survey. A brief description of each tool follows.

***Student portfolio.*** All chemistry majors are required to compile a portfolio before graduating. Completion of the portfolio is a requirement of CHEM 488, Undergraduate Colloquium. The portfolio includes an unofficial copy of their transcript, a compilation of all grades received on American Chemical Society (ACS) standardized exams, a copy of the abstract for their CHEM 488 oral presentation to the department, a copy of a laboratory report that showcases their ability to write in the style of the profession and their ability to use modern computer software, and a copy of a research report if undergraduate research was carried out.

***Exit survey.*** Students also complete an exit survey as part of CHEM 488. A copy of this survey is included as Appendix A.

***Alumni survey.*** Every five years the Chemistry Department administers a survey by mail to recent graduates. In March 2009 a survey was sent to students graduating with degrees in Chemistry during the period 2004–2008. A copy of the survey is included as Appendix B. The survey is anonymous; responses of those students graduating in 2008 cannot be isolated, neither can student responses be separated by degree type.

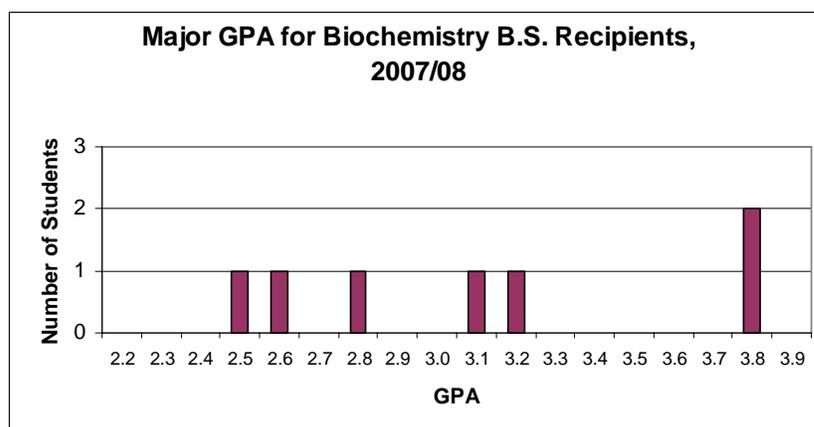
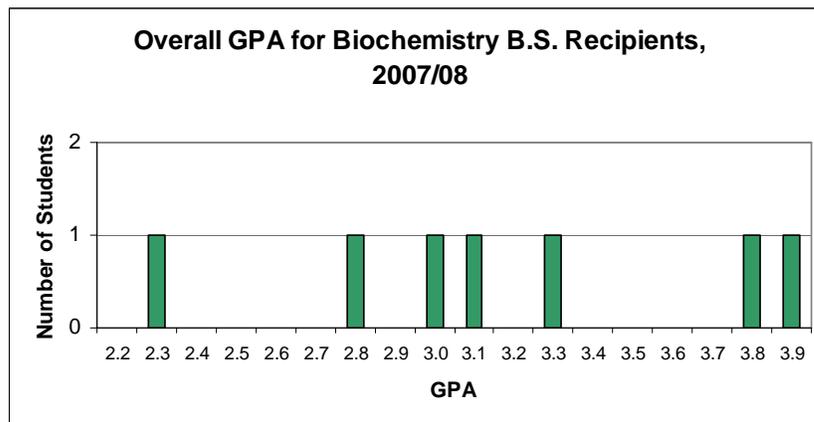
#### **Student Learning Outcome 1**

*Apply the standard technical information and perform experimental techniques of analytical, biochemistry, inorganic, organic, and physical chemistry.*

***Standard of mastery/criterion of achievement:***

1. Graduates maintain 2.0 gpa overall and 2.25 gpa within the major.

Overall GPAs for this group of students ranged from 2.3 to 3.9, with 3.1 as the median. GPAs within the major ranged from 2.5 to 3.8, with 3.1 as the median.



2. ACS exams consistent with national averages

The Chemistry Department administers American Chemical Society (ACS) standardized exams at the end of all appropriate courses. This year we examined the exam scores in the areas of analytical and organic chemistry. This is the second year in a row that we have examined the scores in the analytical area, including Analytical Chemistry and Instrumental Analysis exams. These exams are administered at the end of CHEM 332 and CHEM 452, respectively. Only those students earning a BS in Chemistry are required to take CHEM 452, Instrumental Analysis. This is the first year that we have examined the scores in the organic area. The organic chemistry exam is administered at the end of CHEM 363. For each exam the individual student cores were compared with the

national mean and standard deviation provided by the ACS. Standardized exam scores for General Chemistry are included for comparison, as well as grades received by students in the courses in general, organic, and analytical chemistry. Average grades for the associated courses are shown in Table 2.

**Table 1.** Student scores on ACS standardized exams in comparison with national results

Area of Chemistry	Exam	2 std dev below mean	1 std dev below mean	1 std dev above mean	2 std dev above mean
General	General Chemistry*	0	1	4	0
Analytical	Analytical Chemistry	0	3	5	0
	Instrumental Analysis	1	3	0	1
Organic	Organic Chemistry	2	3	3	0

\*Scores not available for three transfer students.

**Table 2.** Average grade for courses in areas assessed

area	CHEM course(s)	average grade
General Chemistry*	181, 182, 183	3.62
	181Lab, 182Lab, 183Lab	3.53
Analytical Chemistry	332	3.15
	332Lab	3.39
	452	3.20
	452Lab	3.74
Organic Chemistry	361, 362, 363	3.25
	361Lab, 362Lab, 363Lab	3.42

\*Scores not available for three transfer students.

- All students' portfolio components will be rated at satisfactory or higher.

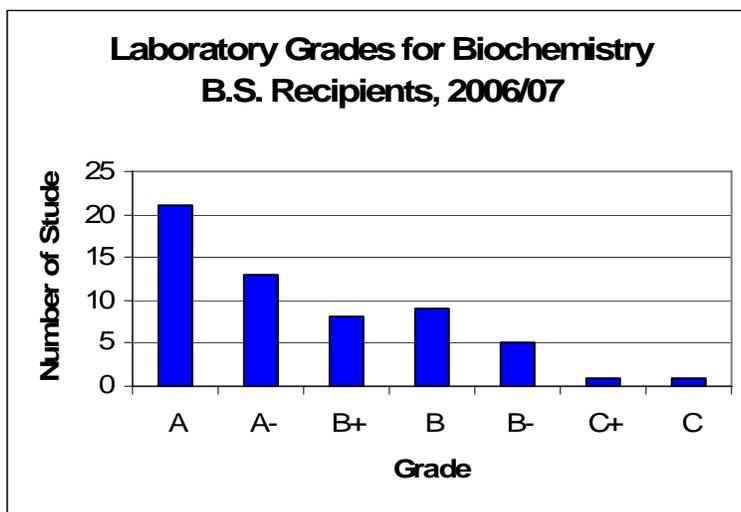
Because we focused on the analytical and organic chemistry areas for this assessment period, we did not rate all portfolio components.

### Student learning outcome 7

*Work effectively in group situations.*

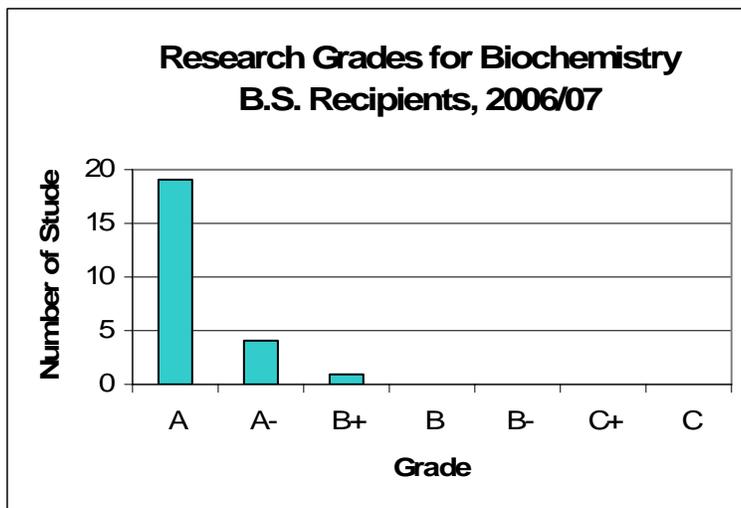
***Standard of mastery/criterion of achievement:***

1. All students receive a grade of C+ or better in laboratory courses.



Of the 58 laboratory grades recorded for this group of students, 57 were C+ or higher.

2. All research students receive a grade of B or better.



All research grades were B+ or higher.

3. Satisfactory comments on exit survey.

In response to Question 2. What specific components of your education in chemistry do you think will best prepare you for the job market/graduate school?

"The high level of interaction between all students, faculty, and staff parallels the teamwork required in the industry."

In response to Question 3. If you performed research at CWU, do you feel it will help in your career? If so, please tell why.

"Yes, it will help because we had to work in a group setting plus needing to solve problems on own."

4. Satisfactory comments on alumni survey.

Question 2.

"While I do not use the technical aspect of my major in my current position in the military. My research experience gave me necessary people skills along with a very broad understanding of how a large organization functions."

Question 3.

In your view, how well did your experience in the chemistry program at CWU prepare you for the following: (1 = did not prepare me; 5 = substantial preparation)

	1	2	3	4	5
Dealing with personnel and interpersonal communication issues in your current position	0	1	4	7.5	3.5

Average response = 3.8/5

Comment: "Interpersonal communication skills and ethical standards are very important in my current position as an officer in the military and I feel the chemistry department did their part in fortifying them within me during my time at Central."

**III. What was learned?**

**Student Learning Outcome 1.** *Apply the standard technical information and perform experimental techniques of analytical, biochemistry, inorganic, organic, and physical chemistry.*

As required, all graduates maintained higher than a 2.0 overall gpa and higher than a 2.25 gpa for courses within the major. Half of last year's B.S. recipients maintained a gpa of 3.1 or higher. According to this criterion, the B.S. recipients satisfied Student Learning Outcome 1.

This year we examined student scores on the ACS standardized exams in the area of analytical and organic chemistry, as well as introductory general chemistry. In general chemistry, all available test scores were within one standard deviation of the national mean. Four out of five scores were above the national mean. The Analytical Chemistry exam is given at the end of Quantitative Analysis, an intermediate level chemistry course. Here, all scores were within one standard deviation of the national mean; five out of eight were above the mean. The Instrumental Analysis exam is given at the end of Instrumental Analysis, an advanced chemistry course. While Instrumental Analysis is not required for this degree program, four out of eight students completed the course. Three out of five student scores are within one standard deviation of the mean; only one score is above the mean.

Student performance in the general chemistry sequence and analytical chemistry area compares favorable with student performance nationwide. Further, students in the B.S., Biochemistry Emphasis program performed better on the standardized exams in the analytical area than they did last year. This may be the result of increased expectations in our analytical chemistry courses, increased emphasis on quantitative techniques in general chemistry, and more laboratory exercises based on biological and environmental applications. However, the number of graduates in any given year is quite small and drawing conclusions based on one or two years of data is not justified. We do hope that this trend continues.

The Organic Chemistry exam is given at the end of the year-long sequence in Organic Chemistry, an intermediate level series. Student performance was comparable to student performance nationwide. Six of the eight scores were within one standard deviation of the national mean. Three of the eight scores were above the mean.

**Student learning outcome 7. *Work effectively in group situations.***

Students are required to work in teams in nearly all chemistry laboratory courses. The fact that 50 out of 57 laboratory grades for this group of students were B or higher implies that they can effectively work in group situations. In the research laboratory, 23 out of 24 grades were A- or higher, again implying that these students can work as a member of a team.

There were several positive comments on the exit and alumni surveys concerning teamwork and interpersonal skills; there were no negative comments. Alumni gave the Chemistry Department fairly high marks (3.8/5) in preparing them to deal with "personnel and interpersonal communication issues".

#### **IV. What will the department do as a result of this information?**

No dramatic changes are planned for this degree program on the basis of the results presented here. Students are performing quite well in the areas of analytical and organic chemistry. Over the last several years, faculty teaching Quantitative Analysis have raised their expectations for student performance. Accordingly, the course number has been changed from CHEM 251 to CHEM 332. The general chemistry laboratory curriculum has been undergoing revision. As part of this revision, more emphasis is being placed on quantitative analysis. Our hope is that this will lead to further improvement in the upper level analytical chemistry courses.

Until this year, the Chemistry Department has been understaffed in the area of organic chemistry. With the hiring of two new organic chemists, students should have easier access to faculty members and should enjoy smaller lecture courses. We hope that this will lead to higher levels of student achievement in the organic chemistry series.

The Chemistry Department plans to continue to emphasize teamwork and communication skills in its laboratory and research curriculum.

#### **V. What did the department do in response to last year's assessment information?**

Several committee meetings and at least one full department meeting were devoted to a discussion of last year's assessment report. Most of the changes that we made were related to assessment rather than changes to curriculum, advising, or performance standards. For example, in last year's report it was noted that a number of students had not included research reports in their portfolios. As a result we have all agreed to be more vigilant in the collecting, reading, and filing of student research reports.

The Chemistry Department Undergraduate Curriculum Committee revised the student learner outcomes for all programs to include an understanding of the ethical treatment of scientific data. The committee also revised the alumni survey form, created and implemented a new exit survey for our graduates, and decided to implement an entrance survey. The entrance survey is in revision and will be implemented starting next year. The new exit survey addresses student attitudes towards safety, ethical treatment of data, and their ability to work as a member of a team.



3. In your view, how well did your experience in the chemistry program at CWU prepare you for dealing with personnel and interpersonal communication issues in your current position:

(1 = did not; 5 = substantial preparation)

1      2      3      4      5

Comments?

4. How do you feel your chemistry education compares with that of your peers from other institutions?

(1 = below that of peers; 5 = superior to that of peers)

1      2      3      4      5

Please comment on your choice:

5. We are gathering data for graduating seniors. If you will be starting employment immediately after graduation, would you be willing to share your starting salary with us?

6. If you would like information included in the Chemistry Chronicle Newsletter, which can be accessed on the web at [www.cwu.edu/~chem](http://www.cwu.edu/~chem), please indicate below.

**Central Washington University  
Assessment of Student Learning  
Department and Program Report**

Please enter the appropriate information concerning your student learning assessment activities for this year.

Academic Year of Report: 2008-09

College: COTS

Department: Chemistry

Programs: B.A. Chemistry Teaching

**1. What student learning outcomes were assessed this year, and why?**

*In answering this question, please identify the specific student learning outcomes you assessed this year, reasons for assessing these outcomes, with the outcomes written in clear, measurable terms, and note how the outcomes are linked to department, college and university mission and goals.*

The Chemistry Department and Department of Science Education feel that it is important to assess chemistry teaching majors in such a way that ensures quality. To do so, seven Student Learning Outcomes (SLO) have been identified that provide a suitably detailed evaluation of student knowledge, skills, and disposition. Please refer to Appendix A for a report of Chemistry Teaching SLO, criterion of mastery, and assessment results.

Student Learning Outcomes:

1. Demonstrate an ability to individually and collaboratively engage in inquiry and integrate the nature of science. (SCED goal 1, 3, 4; COTS Goal 1, 4, 6; CWU Goal 1, 6)
2. Explain and apply fundamental science content concepts, principles, and methods.
3. Demonstrate an ability to effectively facilitate learning for all students. (SCED Goal 1, 3, 5; COTS Goal 1, 4, 6; CWU Goal 1, 6)
4. Create safe, effective learning environments that support inquiry, collaboration, intellectual risk-taking, ethical decision-making, and student construction of knowledge. (SCED Goal 2, 3, 4; COTS Goal 1, 6; CWU Goal 1, 6)
5. Demonstrate an ability to assess teaching and learning outcomes using multiple methods, effectively evaluate teaching and learning effectiveness, and improve practice based on reflection and data. (SCED Goal 1, 2, 3, 4; COTS Goal 1, 6, 7; CWU Goal 1, 6)
6. Demonstrate an ability to make science personally and socially relevant to individual and community by incorporating current events within collaborative and social networks. (SCED Goal 2, 3, 4, 7, 8; COTS Goal 1, 6; CWU Goal 1, 6)
7. Participate in a variety of activities that enhance professional development and improve teaching effectiveness. (SCED Goal 1, 2, 4; COTS Goal 1, 5, 6; CWU Goal 4, 6)

These SLO were chosen because they reflect the criteria necessary to become an effective chemistry teacher. The SLO were originally conceived through a consensus process by examining commonalities in three sets of professional standards; National Science Education Standards for Teaching, National Science Teacher Association Standards, and the Washington Competencies for Chemistry. By using this approach, performance within the program also provides some measure of how well students are able to meet professional standards.

## 2. How were they assessed?

*In answering these questions, please concisely describe the specific methods used in assessing student learning. Please also specify the population assessed, when the assessment took place, and the standard of mastery (criterion) against which you will compare your assessment results. If appropriate, please list survey or questionnaire response rate from total population.*

### A) What methods were used?

The Chemistry Teaching Program used a formative and summative assessment system comprised of several elements:

- 1) Performance-based, standards-aligned electronic portfolio
- 2) WEST-E and American Chemical Society content examinations
- 3) Entry and exit surveys

### Chemistry Teaching Portfolio

The Chemistry Teaching portfolio was used to assess student knowledge, skills, and dispositions relative to professional standards. The Chemistry Teaching Portfolio was built from a common template collaboratively designed and constructed by members of the Department of Science Education, with additional insight provided by content colleagues and K-12 teachers. The portfolio framework was based on the latest scientific research on how people learn (National Research Council, 2005), with assessment focused on: 1) determining student preconceptions, 2) engaging students in authentic scientific inquiry, 3) developing and applying robust content knowledge, and 4) promoting meta-cognitive awareness of teaching and learning process and critical thinking.

Each portfolio element, or dimension, required a reflection and was closely aligned to Chemistry Teaching SLO and professional standards. In an effort to promote critical thinking, students were required to supply evidence they deemed suitable rather than those prescribed by faculty. Students also had to justify their choice of evidence and progress toward meeting professional standards in each reflection. The dimensions of the Chemistry Teaching portfolio (including content strands) are indicated below:

- 1) Inquiry and Nature of Science
- 2) Content
  - a. Analytical/Instrumental Chemistry
  - b. Organic Chemistry
  - c. Biochemistry
  - d. Inorganic Chemistry
  - e. Physical Chemistry
  - f. Application of Mathematics and Physics to Chemistry

- 3) Teaching
- 4) Learning Environments
- 5) Assessment and Evaluation
- 6) Relevance
- 7) Professional Growth. The Content dimension is further subdivided into the major disciplinary themes in biological science, and included:

#### WEST-E and MFT Exams

Student content knowledge was assessed in Science Education (WEST-E) and American Chemical Society disciplines. Minimum scores were required for all exams. Each student had to post total and component scores in the Content dimension of the Chemistry Teaching Portfolio. These scores were also tracked in a separate spreadsheet to identify areas of strength and necessary development.

#### Entry and Exit Surveys

An entry to program survey was used to assess student demographics, disposition toward science education, and program learning expectations. An exit survey was used to evaluate program effectiveness, changes in disposition, and met/unmet learning expectations. A reflection comparing entry and exit survey results was also required in the Chemistry Teaching portfolio.

Prior to being allowed to student teach, portfolios were evaluated by chemistry teaching faculty using a standards-aligned rubric. Students had to demonstrate minimum proficiency for each portfolio dimension. An advising hold that could only be removed by a chemistry teaching or another Science Education faculty member was used to ensure compliance.

#### **B) Who was assessed?**

All eligible chemistry teaching majors, chemistry teaching certification, and endorsement students from the 2006-2007 academic year to date were assessed.

#### **C) When was it assessed?**

Upper division coursework during the academic year, with final portfolio due prior to student teaching. Portfolio was periodically evaluated during advising.

### 3. What was learned?

*In answering this question, please report results in specific qualitative or quantitative terms, with the results linked to the outcomes you assessed, and compared to the standard of mastery (criterion) you noted above. Please also include a concise interpretation or analysis of the results.*

Please refer to Appendix A for detailed assessment results. Several points of strength and areas for improvement emerged from assessment results, as follows:

- Five individuals from 2006-2007 academic year to date have completed the major program. As a whole, candidates provided exemplary/proficient evidence of performing at state benchmarks and have either graduated, gone on to student teach, or are currently employed. This suggests that 100% of graduating and student teaching candidates are currently meeting competency requirements as indicated by Chemistry Teaching portfolio results. These results are not entirely corroborated by the WEST-E pass rate for Chemistry Teaching candidates, since one major has had some difficulty in passing the Chemistry WEST-E several times over the past two years. Therefore the WEST-E pass rate average is artificially low with the reported 45.5%. Also, recurring difficulty in the areas of Solutions and Solubility/Acid-Base Chemistry and Nuclear Chemistry have been identified as an issue with both Chemistry Teaching Majors and Minors.
- American Chemical Society content exam results show the average of Chemistry Teaching students scores to be lower than the national percentile in most content areas. It should be noted that Physical Chemistry is observed as consistently above the national mean, 56.3%. Since several of the students assessed are transfer students, please note that these data are incomplete and there is not enough information to draw any significant conclusions.
- Generally, the assessment methods employed provided meaningful insight into Chemistry Teaching student knowledge, skills, and dispositions.
- SLO were closely aligned to department, college, and university goals, and covered a range of basic and advanced knowledge and skills. Disposition SLO were lacking.
- Portfolio reflection scores were lower than artifact scores indicating that students need more practice in writing reflections and describing how artifacts show that learning outcomes have been met.
- Survey results and advising discussion indicated that students achieved the majority of their learning goals. Insufficient experience with assessment and evaluation and classroom management were common criticisms. The relative absence of these and field teaching experiences, particularly in College of Education courses, was a common concern.

#### 4. What will the department or program do as a result of that information?

*In answering this question, please note specific changes to your program as they affect student learning, and as they are related to results from the assessment process. If no changes are planned, please describe why no changes are needed. In addition, how will the department report the results and changes to internal and external constituents (e.g., advisory groups, newsletters, forums, etc.).*

Based on collected data, the following revisions to the Chemistry Teaching program are proposed:

##### Improvements for Student Learning

- Add SLO that more explicitly address the development of professional values and dispositions.
- Continue to provide more opportunities for students to experience authentic scientific inquiry in introductory science courses. If inquiry is important in K-12 schools, then more content courses should model investigative science and focus on inquiry.
- Encourage submission of higher quality evidence in some content areas such as Solutions and Solubility/Acid-Base Chemistry and Nuclear Chemistry.
- Embed use of current events and community involvement to a greater extent in content and science education courses. We will consider the addition of SCED 354 to the Chemistry Teaching Major.
- Help students better connect evidence to developmental progress. Greater emphasis on metacognitive awareness will help students become better learners, which in turn should improve job performance as professional teachers. Improvement in this area will be important considering the increased emphasis on accountability in K-12 schools.
- Help students better learn how to assess and evaluate student learning. Students must have the ability to design, align, and employ effective methods of assessment as an integral part of K-12 accountability. Evidence indicates this is a deficit for many science education students, and they feel it should be emphasized more in College of Education courses. Regardless, greater emphasis on assessment can occur in science education methods courses.

##### Improvements in Assessment Process

- The artificially low pass rate for Chemistry Endorsement on the WEST-E is 45.5%. Such a low pass rate sent alarms to the Chemistry Department and Science Education Department. We promptly asked for and quickly received data in the Winter Quarter of 2007 that elucidated the situation for us. The low pass rate was due mainly to a single person who was taking and retaking the WEST-E Chemistry exam multiple times, 5 times in total. This act alone, with such a small number of students taking the Chemistry WEST-E from CWU, decreased the pass rate significantly. Since this time, Chemistry Teaching Advisors have communicated the importance of preparing for this exam with the majors and minors. Since this time, advisors have received WEST-E information after every offering state-wide so that we can be proactive in advising failing students to either better prepare for the exam or advise them into an alternate career path.

- Some aspects of the Chemistry Teaching portfolio need greater specificity and should be shared with students early in the program so they better understand what is expected.
- Since the Biology, Chemistry, Earth Science, and Physics Teaching portfolios are based on a common template, it would be useful to compare across these programs to identify overall trends in science teacher preparation.
- The LiveText software used to collect student data is disconnected from Blackboard, making it unnecessarily confusing for students and faculty. LiveText is limited in features, consistency, and availability of data. Exploration of new options for online assessment software is highly recommended.

## **5. What did the department or program do in response to last year's assessment information?**

*In answering this question, please describe any changes that have been made to improve student learning based on previous assessment results. Please also discuss any changes you have made to your assessment plan or assessment methods.*

This is the second year that annual assessment reports were required from each program at CWU. Systematic implementation of assessment has been occurring in Chemistry Teaching (and Science Education generally) for several years, partly in response to NCATE accreditation requirements, which has prompted the following:

- Changes to the Chemistry introductory CHEM 180 series lecture and lab were implemented in the 2008-2009 academic year. The CHEM 180 series scope and sequence now reflects a more appropriate progression of concepts. Also, lab manuals have been re-written to integrate skills and tools of an inquiry-based approach.
- Steps have been taken to incorporate Solutions and Solubility/Acid-Base Chemistry and Nuclear Chemistry into the general chemistry lecture and laboratory curriculum, after major and minor West-E exam scores slumped in this area in the Spring of 2008 (averaging 38.3% and 58% for majors, respectively). This information led to the Chemistry Department's Curriculum Committee adjusting our CHEM 180 series scope and sequence of content and incorporating more hands-on laboratory experimentation. Now, nuclear chemistry is taught that incorporates nuclear fission/fusion and radioisotopes in the first quarter, CHEM 181, and first order radioactive decay in the second quarter, CHEM 182, of general chemistry. Also, analytical chemists in the department were consulted about creating a two-part analytical chemistry laboratory that challenges students in solving for molar concentrations and acid-base equilibria. We hope that these changes to the curriculum will reflect positively in the West-E test scores and we will continue to monitor student success.
- The End of Program Portfolio was aligned to the new Washington competencies for Chemistry teachers.
- The new SCED senior seminar course (SCED 487) that was implemented in the 2007-2008 was a perceived success and continued the past academic year. Students completing this course consistently provided better evidence and reflections in each of the secondary science majors; however, the sample size is too small to draw any serious conclusions at this point. This course is recommended for Chemistry Teaching majors.

## 6. Questions or suggestions concerning Assessment of Student Learning at Central Washington University:

The Departments of Chemistry and Science Education recommend the following changes to student learning assessment at CWU:

- Provide more opportunities for chemistry and science education faculty to collaborate upon content and pedagogical courses so that the scope and sequence of coursework and practicum offer all teaching majors what they need to be successful teachers while meeting and exceeding national and state teaching standards.
- Provide more opportunities for training and professional development for how to conduct assessment. Graduate training typically does not include assessment; therefore it is important to not assume faculty know why or how to conduct assessment. Many faculty members may experience a steep learning curve.
- The due dates for the annual Assessment Plans should correspond more closely with annual departmental planning so that necessary changes have the greatest chance of being implemented.
- Provide necessary infrastructure for program assessment. This may include financial and intellectual resources including focused release time, collaboration, and dissemination of best practices across colleges and departments.
- Effective sharing of materials should minimize the reinvention of the wheel, as it were. Examples of rubrics (which will figure prominently in performance evaluations) should be shared as most faculty members are not highly familiar with the use of rubrics.
- Each department should have an assessment coordinator with reasonable workload release. This person should coordinate efforts, not remove assessment responsibility from other faculty.

### Appendix A – Chemistry Teaching Results Matrix

Student Learning Outcome	Criterion of Mastery	Assessment Results
<b>1. Demonstrate an ability to individually and collaboratively engage in inquiry and integrate the nature of science.</b>	<p>100% average score of Proficient or better for portfolio dimension 1 and associated reflection.</p> <p>100% average score of Proficient or better for relevant aspects of SCED 324 portfolio.</p> <p>Passing of WEST-E Chemistry exam.</p> <p>American Chemical Society content exam scores consistent with national averages.</p> <p>All standards met for WA Pedagogy Assessment.</p>	<p>Students assessed to date: 5</p> <p>Portfolio dimension 1 proficiency:</p> <ul style="list-style-type: none"> <li>• Inquiry Artifact: % 100</li> <li>• Nature of Science Artifact: 100%</li> <li>• Independent Research Artifact: 100%</li> <li>• Dimension 1 Reflection: 100%</li> </ul>

<p><b>2. Explain and apply fundamental science content concepts, principles, and methods.</b></p>	<p>100% average score of Proficient or better for portfolio Dimension 2 and associated reflection.</p> <p>100% average score of Proficient or better for relevant aspects of SCED 324 portfolio.</p> <p>Passing of WEST-E Chemistry exam.</p> <p>American Chemical Society content exam scores consistent with acceptable national mean averages.</p> <p>All standards met for WA Pedagogy Assessment.</p>	<p>Students assessed to date: 4</p> <p>Portfolio dimension 2 proficiency:</p> <ul style="list-style-type: none"> <li>• Analytical/Instrumental Chemistry Artifact: 100%</li> <li>• Organic Chemistry Artifact: 100%</li> <li>• Biochemistry Artifact: 100%</li> <li>• Inorganic Chemistry Artifact: 100%</li> <li>• Physical Chemistry: 100%</li> <li>• Application of Mathematics and Physics to Chemistry Artifact: 100%</li> <li>• Dimension 2 Reflection: 100%</li> </ul> <p>WEST-E passing scores: 45.5%, Passing is 150 and Total Mean for passing grades is 156.2 with a single Standard Dev. at +/-1.64</p> <p>American Chemical Society content exam scores are within acceptable National percentile averages:</p> <ul style="list-style-type: none"> <li>-General Chemistry: 45.7%</li> <li>-Organic Chemistry: 16.0%</li> <li>-Analytical: 21.33%</li> <li>-Biochemistry: n/a</li> <li>-Inorganic Chemistry: n/a</li> <li>-Instrum. Chemistry: n/a</li> <li>-Physical Chemistry: 56.3%</li> </ul>
<p><b>3. Demonstrate an ability to effectively facilitate learning for all students.</b></p>	<p>100% average score of Proficient or better for portfolio Dimension 3 and associated reflection.</p> <p>100% average score of Proficient</p>	<p>Students assessed to date: 4</p> <p>Portfolio dimension 3 proficiency:</p> <ul style="list-style-type: none"> <li>• SCED 324 Portfolio</li> </ul>

	<p>or better for relevant aspects of SCED 324 portfolio.</p> <p>Passing of WEST-E Chemistry exam.</p> <p>American Chemical Society content exam scores consistent with national averages.</p> <p>All standards met for WA Pedagogy Assessment.</p>	<p>Artifact: 100%</p> <ul style="list-style-type: none"> <li>• Other Teaching Experience Artifact: 100%</li> <li>• Dimension 3 Reflection: 100%</li> </ul>
<p><b>4. Create safe, effective learning environments that support inquiry, collaboration, intellectual risk-taking, ethical decision-making, and student construction of knowledge.</b></p>	<p>100% average score of Proficient or better for portfolio Dimension 4 and associated reflection.</p> <p>100% average score of Proficient or better for relevant aspects of SCED 324 portfolio.</p> <p>Passing of WEST-E Chemistry exam.</p> <p>American Chemical Society content exam scores consistent with national averages.</p> <p>All standards met for WA Pedagogy Assessment.</p>	<p>Students assessed to date: 4</p> <p>Portfolio dimension 4 proficiency:</p> <ul style="list-style-type: none"> <li>• Collaborative Learning Artifact: 100%</li> <li>• Diverse Learning Artifact: 100%</li> <li>• Technology Artifact: 100%</li> <li>• Safety Artifact: 100%</li> <li>• Dimension 4 Reflection: 100%</li> </ul>
<p><b>5. Demonstrate an ability to assess teaching and learning outcomes using multiple methods, effectively evaluate teaching and learning effectiveness, and improve practice based on reflection and data.</b></p>	<p>100% average score of Proficient or better for portfolio Dimension 5 and associated reflection.</p> <p>100% average score of Proficient or better for relevant aspects of SCED 324 portfolio.</p> <p>Passing of WEST-E Chemistry exam.</p> <p>American Chemical Society content exam scores consistent with national averages.</p> <p>All standards met for WA Pedagogy Assessment.</p>	<p>Students assessed to date: 4</p> <p>Portfolio dimension 5 proficiency:</p> <ul style="list-style-type: none"> <li>• Assessment of Student Learning Artifact: 80%</li> <li>• Self Assessment of Teaching Artifact: 100%</li> <li>• Dimension 5 Reflection: 100%</li> </ul>

<p><b>6. Demonstrate an ability to make science personally and socially relevant to individual and community by incorporating current events within collaborative and social networks.</b></p>	<p>100% average score of Proficient or better for portfolio Dimension 6 and associated reflection.</p> <p>100% average score of Proficient or better for relevant aspects of SCED 324 portfolio.</p> <p>Passing of WEST-E Chemistry exam.</p> <p>American Chemical Society content exam scores consistent with national averages.</p> <p>All standards met for WA Pedagogy Assessment.</p>	<p>Students assessed to date: 4</p> <p>Portfolio dimension 6 proficiency:</p> <ul style="list-style-type: none"> <li>• Incorporation of Current Events Artifact: 100%</li> <li>• Community Involvement Artifact: 100%</li> <li>• Dimension 6 Reflection: 100%</li> </ul>
<p><b>7. Participate in a variety of activities that enhance professional development and improve teaching effectiveness.</b></p>	<p>100% average score of Proficient or better for portfolio Dimension 7 and associated reflection.</p> <p>100% average score of Proficient or better for relevant aspects of SCED 324 portfolio.</p> <p>Passing of WEST-E Chemistry exam.</p> <p>American Chemical Society content exam scores consistent with national averages.</p> <p>All standards met for WA Pedagogy Assessment.</p>	<p>Students assessed to date: 4</p> <p>Portfolio dimension 7 proficiency:</p> <ul style="list-style-type: none"> <li>• Professional Membership Artifact: 100%</li> <li>• Dimension 7 Reflection: 100%</li> </ul>

**CWU CHEMISTRY DEPARTMENT ~ EXIT SURVEY (used 2004-2008)**

Which program will you graduate from (circle one): BA BA Chem Teaching  
BS BS Biochem MS

1. Employment or graduate school information: (Please include current position title, employment/school name, and a brief position description.)

2. What specific components of your education in chemistry do you think will best prepare you for the job market/graduate school?

3. If you performed research at CWU, do you feel it will help in your career? If so, please tell why. If you did not conduct research at CWU, do you wish you had done so? Please elaborate.

4. How do you feel your chemistry education compares with that of your peers from other institutions?

5. In what areas would you suggest changes to improve the CWU Chemistry program?

6. We are gathering data for graduating seniors. Would you be willing to share your starting salary with us?

7. If you would like information included in the Chemistry Chronicle Newsletter, which can be accessed on the web at [www.cwu.edu/~chem](http://www.cwu.edu/~chem), please indicate below.

**CWU CHEMISTRY DEPARTMENT ~ EXIT SURVEY**

*(transitioned to this survey in Chem 488, 2008-2009)*

Which program will you graduate from (circle one):

BA      BA Chem Teaching      BS      BS (ACS certified)      BS Biochem      MS

1. If you already know your employment or graduate school plans, please indicate position title, employer / school name, and a brief position description.

2. For the specific components of your education in chemistry that are listed below, please rank each in terms of how well you believe it has prepared you for employment or graduate school:

1 = did not significantly contribute to my preparation / skill set;

5 = essential to my preparation / skill set

Lecture Courses	1	2	3	4	5	
Laboratory Courses	1	2	3	4	5	
Research Experience	1	2	3	4	5	n/a
Serving as a Teaching Assistant	1	2	3	4	5	n/a
Working with Faculty Advisor	1	2	3	4	5	
Other? _____	1	2	3	4	5	

If you wish, please use the space below to comment specifically on your choices above:

3. In your view, how well did the chemistry curriculum improve the following skills:  
(1 = did not improve; 5 = substantial improvement)

Oral Communication	1	2	3	4	5
Written Communication	1	2	3	4	5
Working as part of a team	1	2	3	4	5
Observing safety protocols	1	2	3	4	5

If you wish, please use the space below to comment specifically on your choices above:

4. As a future chemist, how much do you value the following:  
(1 = do not value; 5 = regard as extremely important):

Ethical handling / reporting of data	1	2	3	4	5
Safe handling and proper disposal of chemicals and waste	1	2	3	4	5
Interpersonal communication	1	2	3	4	5

If you wish, please use the space below to comment specifically on your choices above:

5. We are gathering data for graduating seniors. If you will be starting employment immediately after graduation, would you be willing to share your starting salary with us?
6. Let us know what you are doing! If you have exciting news for us to include in the annual alumni newsletter, Periodic News, please email it to [chemistry@cwu.edu](mailto:chemistry@cwu.edu).

**CWU CHEMISTRY DEPARTMENT**  
**EXIT SURVEY RESULTS 2004-2005 GRADUATES**

Graduating seniors responding to this survey:

Bachelor of Arts	0
Bachelor of Arts: Teaching	1
Bachelor of Science	6
Bachelor of Science: Biochemistry	7
Master of Science	0

1. Employment or graduate school information: (Please include current position title, employment/school name, and a brief position description.)
  - Applying to med school
  - In the near future I hope to be working towards my doctorate in geochemistry.
  - I don't have a job and I'm not going to grad school
  - Most likely UW grad school (physical inorganic). Definitely a grad school somewhere.
  - Not sure
  - Accepted to CWU grad program- deny admissions... moving to Glendale, AZ to begin teaching career. No job as of yet.
  - None
  - N/A
  - Sand Lab Technician
  - Plan on going to grad school at Central and get an MS in chemistry
  - No job yet. Might go to grad school eventually. Just looking for work.
  - Do not know what I will be doing next year. I will probably find a job and study to take the MCAT's (for medical school). Eventually, medical school is the goal.
  - Will be applying to medical school for the 2006 school year.

2. What specific components of your education in chemistry do you think will best prepare you for the job market/graduate school?
  - Direct instrumentation contact.
  - Strong emphasis on developing problem solving skills. Research and laboratories because they introduce you to a variety of instruments and give you a hands on learning to conceptual chemistry. Chem 388/488 and formal lab write-up prepare students for future research.
  - My research experiences
  - Research and writing skills (although I hate to say it writing will be very, very important.) I feel that the close contacts with the professors helped a lot as well.
  - Lab experience and writing abilities

- General chem. 180 series. Friendly, helpful, caring faculty who aided every step of the process.
- The lab work
- Lab work
- Basic knowledge of chemicals and their interactions with each other. Inorganics and engineering.
- Learned to use many of the instruments
- Research and hands on work, T.A.
- Specifically, biochemistry and organic chemistry were the most beneficial components in terms of a career in medicine. However, I took something away from every chemistry class I took.
- Laboratory work
- The various lab procedures performed.

3. If you performed research at CWU, do you feel it will help in your career? If so, please tell why. If you did not conduct research at CWU, do you wish you had done so? Please elaborate.

- The research I conducted provides invaluable experience. It was also a great experience.
- Research experience here and at my summer internship had tremendous influence on my overall understanding of chemistry and introduction to applying my education to productive applied chemistry that class lab can't compare with.
- My research I think will help my career, because I was able to get to know professors and show that I work hard. I don't believe the same smartest and best students get the highest grades all the time.
- I participated in several research projects, but none in the chemistry department. I really wish that I had done so.
- Yes, because it gives me a perspective of expectations
- Yes, it was a great experience.
- I conducted research outside of CWU. I would have liked to some at CWU but there just wasn't enough opportunity.
- I only was able to do one quarter of research and I still think it will help. It gave me some independent lab experience.
- I wish I had done so. I would like to have had research experience before graduating.
- N/A
- Yes, I learned how to use several instruments such as GC/MS and NMR.
- I performed research at CWU and I feel it was very beneficial in that it allowed me to deepen my knowledge of a specific field I was interested in.
- I wish that I would have done research but felt as if the opportunity was not there. I guess I felt as though I was unaware of research until very late in my education.
- The research helped me learn certain lab techniques I might not have learned.

4. How do you feel your chemistry education compares with that of your peers from other institutions?

- Par
- I am grateful for my one on one communications and learning with the professors and the undergraduate research opportunities not usually available at bigger schools. I do feel, however, my lack of graduating from a more influential school hurts my future opportunities.
- I hear Western has a good program so to them ours may be lacking somewhat. But truthfully I don't know.
- Yes. I have met many other students from other schools, and find that for the most part we all learned the same thing.
- Fairly well
- Similar, due to my interest in it. I feel I was able to come away with more.
- No idea
- I don't know anyone from other schools in chemistry.
- I don't know
- The education here is equal or above most of my peers from other institutions
- Don't know any other chem. students from other schools.
- I feel my chemistry education is equal or better than peers from other institutions.
- I do not know anyone in chemistry from other institutions.
- None of my friends outside of CWU are science majors but I feel that CWU chem. did an excellent job.

5. In what areas would you suggest changes to improve the CWU Chemistry program?

- More money, bigger facilities, and better places to sleep.
- Make labs worth more credit, especially quant and instrumental because the class as a whole is based on lab; more time is spent on lab for certain.
- More math requirements and the calc-based physics required as well.
- I would allow for more electives, while, at the same time requiring more mathematics for courses or simply using more math in the classroom. By more I mean allowing electives more freedom of class choice, i.e. no biochem for no biochemists.
- Not sure
- More upper level electives, such as 2<sup>nd</sup> quarter inorganic or more environmental.
- More chem. elective classes to choose from especially in spring
- Better labs
- Independent study labs that can be taken in quarters that the lab or class are not offered (sic)
- I think their needs to be more elective classes such as an advanced organic chemistry class.
- Chemistry tutors, study aides available
- Nothing that I can think of.
- I think that the chemistry department at CWU provides a very positive atmosphere for students. I feel as though everyone in the department was interested in student success. So, no changes so far.

- Becoming ACS certified and offering more opportunities for technical writing and giving seminars.

6. We are gathering data for graduating seniors. Would you be willing to share your starting salary with us?

- No
- Right now my starting salary is \$0 per year.
- \$22,000
- Maybe
- Yes, starting salaries in the Glendale area for teachers are between \$29,000-\$33,000.
- Unknown at this time
- Sure
- Yes
- When I have a job, yes ([andrews778@aol.com](mailto:andrews778@aol.com)) e-mail me and I'll let you know
- Sure
- Yes
- No
- I would like to have a starting salary.

**CWU CHEMISTRY DEPARTMENT**  
**EXIT SURVEY RESULTS 2005-2006 GRADUATES**

Graduating seniors responding to this survey:

Bachelor of Arts	2
Bachelor of Arts: Teaching	0
Bachelor of Science	3
Bachelor of Science: Biochemistry	10

1. Employment or graduate school information: (Please include current position title, employment/school name, and a brief position description.)

- I don't know yet. I try to apply for Chiropractic School.
- City of Mountlake Terrace: Water Safety Instructor. Teach swimming & water aerobic lessons.
- Entry-level chemist, AmTest Laboratories, Inc. Basic bench chemistry, running analytical instruments, testing water samples.
- I will be attending George Washington University in Washington D.C. for a Masters in Forensic Science.
- I am going to graduate school here at CWU under Carin Thomas researching the effects of ultrafine particles on mitochondria.
- Graduate student, Central Washington University.
- No formal commitment after graduation.
- I have applied to graduate school, for a masters or Ph.D. in medicinal chem, but it is too early to tell.
- Nursing school, unsure of specific school as of yet.
- N/A
- Pharmacy school – still going through interviews, so don't know where yet.
- I have applied to the UW Physics Ph.D. program, but have not yet received a response.
- Bastyr University for graduate program in Acupuncture and Oriental Medicine.

2. What specific components of your education in chemistry do you think will best prepare you for the job market/graduate school?

- Organic lab and theory. Physical chem lab and theory.
- I have a very competitive degree which I can compete in job market.
- Education in organic chemistry, biochemistry and various biology classes.
- I think instrumental was very helpful because no matter what kind of chemistry work you go into you'll need to know how to work different kinds of instruments.
- The lab work and the breadth of information.

- The labs that are associated with the classes best prepare people for the job market/graduate school because they are what you do after school.
- High degree of work ethic, always having been mentally challenged.
- The laboratory experiments.
- Maybe knowledge of chemistry. I don't know for sure yet.
- Undergraduate research at CWU, laboratory experiments in lab classes, and being a Teaching Assistant.
- The pathways of chemicals and process of metabolism will help me with understanding the body better for nursing.
- The research that I did helped me tremendously because it was medicinal research and I'm going into pharmaceutical sales.
- Organic chemistry, biochemistry concepts.
- The labs and lab reports will help me write technical papers later on in my career.
- I think the biochemistry class will be useful for my graduate program.

3. If you performed research at CWU, do you feel it will help in your career? If so, please tell why. If you did not conduct research at CWU, do you wish you had done so? Please elaborate.

- I think the lab in physical chem and biochem class provide a lot already.
- Yes, I wish I had done one research. But my classes and study times already make me too busy.
- It would have been fun but not essential for me in particular. There are some people who would need to have it on their resume and it's fine that they were able to do it over me.
- Of course! It teaches about the scientific method and how to fail as well as how to succeed.
- I do believe research helped in my career. It helped me get into graduate school and will help me prepare for the job market.
- I did not perform research at CWU.
- Yes, I performed research at CWU. I believe that it will prepare me w/ jobs that I am or planning to apply for.
- Yes, employers like that research stuff.
- Yes. Gave me practical experience for a future in medicinal chemistry.
- Research would have been a great opportunity, but I don't regret not doing it because I want to work with people, not just instruments in a lab.
- The research that I did helped me tremendously because it was medicinal research and I'm going into pharmaceutical sales.
- I do wish I had done research – it would have prepared me for research at my future school, which I hope to be actively involved in.
- My research was in the Physics Department. I feel that the emphasis on thesis writing, note taking, and presentation will benefit me greatly, regardless of whatever science-oriented career I choose.

- I think I'm not interested in doing any research at CWU. I want to do some medical research eg. cancer or herbal medicine analysis.

4. How do you feel your chemistry education compares with that of your peers from other institutions?

- Depend on each student.
- Chemistry education can go to more field than other institutions.
- O.K. I feel that schools on a semester schedule may be able to get in a little more information during their course of a year.
- I think the professors are very helpful and the classes are thorough so I'm sure the department measures up well against others.
- I don't know any other chemistry students.
- I believe that here there are more teacher to student relationships for better learning that is hard to achieve at larger institutions.
- Central offered a better program in many aspects – small class sizes and having professors that know their students!
- I think that the one on one interaction between students & professors is the key at this institution.
- Top notch.
- Other schools learn more in general chem. However I feel the upper division is just as good if not even better.
- I am unsure. I do not know the program or people from other schools in the chemistry field.
- I don't know anyone else that has a major in chem, but it seems comparable educationally with other who have minors in chemistry.
- I feel my chemistry education is comparable, if not better – small class size & prof availability → more personal learning & solidified knowledge of concepts.
- Since I do not know any chem majors from other schools, I do not have a proper reference for comparison.
- I think I do improve my chemistry knowledge the professors were good in teaching.

5. In what areas would you suggest changes to improve the CWU Chemistry program?

- I think everything is very well, don't need change.
- More classes are available every quarter.
- More math and physics required.
- Maybe if the profs could coordinate the tests a little more so we don't have 3 tests in 2 days!
- More faculty with more interests, but I know that is a funding issue. Otherwise, nothing.
- I would suggest classes that deal with real-world issues more to incorporate laboratory research better to the real world.

- Less labs in every lab class. I feel that students only push out lab reports while not really learning.
- Hire enough faculty to teach students & offer more variety in courses. Hire someone to help students (chem) with their 4-year plans!
- I cannot think of anything at this time.
- Make Calc. 4 a requirement for the 2<sup>nd</sup> quarter of Pchem. Give more credits for Pchem!!
- Hire more professors so classes aren't cancelled. Schedule classes w/ biology department so labs don't conflict as much.
- Perhaps Quantitative Analysis (251) should have a higher number. It is rather labor-intensive for a 200 class. It may even be desirable to offer instrumental before quant.
- The upper level class should offer more or every quarter.

6. We are gathering data for graduating seniors. Would you be willing to share your starting salary with us?

- I don't know much about it.
- Hmm...\$10.89 per hour in City of Mountlake Terrace.
- \$11/hour to start, to be increased after a 3-month probation period.
- As soon as I have a starting salary...
- I am going to grad school.
- No.
- Yes.
- N/A I am not going out into the work force right away, I have more schooling first.
- Sure, when I get a job!
- Yes, but I'm going to pharmacy school first!

**CWU CHEMISTRY DEPARTMENT**  
**EXIT SURVEY RESULTS 2006-2007 GRADUATES**

Graduating seniors responding to this survey:

Bachelor of Arts	0
Bachelor of Arts: Teaching	1
Bachelor of Science	2
Bachelor of Science: Biochemistry	13

1. Employment or graduate school information: (Please include current position title, employment/school name, and a brief position description.)

- N/A
- University of Arizona Pharmacy School.
- I have applied for grad school at CWU in Biology.
- Oregon State University.
- University of Washington Laboratory Medicine graduate program (MS).
- Graduate school at University of California Santa Barbara.
- Currently looking for a position.
- Taking time off.
- Material Science Institute Masters Program in Advanced Organic Chemistry, University of Oregon.
- University of Oregon Master-Internship Program.
- None.
- N/A
- None as of yet (I still have a year). This question removes some anonymous aspects of the survey.
- I will not graduate until Dec. so I don't know yet. I plan on working with a pharmaceutical company.
- I have not yet applied to graduate school. Employment: Phlebotomist, Kittitas Valley Community Hospital.

2. What specific components of your education in chemistry do you think will best prepare you for the job market/graduate school?

- I feel the opportunity to work closely with the professors provided an open dialogue for problem solving.
- The labs and also being able to write an effective science type of paper.
- Biochem and overall scientific process.
- Research experience, small classes, group projects and lots of interaction with professors.

- The close contact I've had with the professors (especially Pchem) has established me as a real chemist.
- Working in a research lab.
- The use of machines like UV-Vis Spec and IR. The lectures were also great, over the years I learn a lot to which I can apply.
- Instrumentation. Knowledge.
- It is a chemistry Masters Program so my year of organic chemistry will be useful.
- Problem solving skills developed in labs & lectures.
- Critical thinking training, laboratory skills and organic chemistry.
- Research. Lab techniques. Making connections with scientists in the field.
- I would have to say the labs/hands-on experiments.
- Teaching assistant course. Laboratory experience.
- I feel the labs will prepare me for my future career.
- Working with others, work ethic and dedication to a goal will prove most important, wherever I end up.

3. If you performed research at CWU, do you feel it will help in your career? If so, please tell why. If you did not conduct research at CWU, do you wish you had done so? Please elaborate.

- I felt the self motivation to progress in a field and provide you with professional poise was very rewarding.
- I did not conduct research. I think it would have been nice to do a little research. However, I had very little between all my classes and extra curricular activities.
- I did not conduct laboratory research at Central. I wish I would have, but it was hard with the credit load.
- Yes I worked for Dr. Diaz for over a year and had a blast. I learned an incredible amount about solid state chemistry, a whole field of chemistry that is not covered in lecture classes.
- Yes it will help tremendously. I've been able to really learn specific lab skills that are applicable to a job.
- Yes, because it prepares you for graduate school and the job market. The experience taught me how to be self-motivated.
- No.
- Yes and I think it will look good when trying to get a job but I don't think what I did really fits with my field I'm going into.
- Yes, I was unsure what I wanted to do after college but doing research helped me realize that is what I want to do.
- My research experience will give me a solid foundation for any lab work I do in my future.
- Yes, it will help; it provided me with a wealth of laboratory skills and scientific writing experience.
- Research allows students the opportunity to experience science that has not yet been perfected, thus a more exploratory effect, which is not easy, but beneficial if

chemistry is what they want to do as a career. It forms problem solving skills necessary for the real world.

- Yes it did. I learned more about chem ed-related materials, which is what I need for my future career (to be a teacher).
- I have not yet however I will next quarter. It will prepare me for working with others & to understand the field more.
- I wish I would have done research, because I feel it would have benefited my future career.
- My research experience was not preparing me for graduate school – it only solidified the thought that I did not want to go into research.

4. How do you feel your chemistry education compares with that of your peers from other institutions?

- I feel that small class sizes hold you more accountable for your education.
- I feel my education is comparable to anyone else's chemistry education, maybe even a little bit better.
- I have no comparisons.
- On par.
- Definitely equal. Although the close contact with my professors is better by far than other institutions.
- Very comparable.
- Don't really know but it is the same if not better.
- I feel like others from more prestigious colleges (i.e. UW, WSU, etc) have a better education, but maybe they should, they paid for it!
- I feel very prepared, I am confident in my knowledge, and even though other colleges may be rated better I think I got a great education.
- Don't know, I haven't compared with people of my field.
- Comparable if not better.
- I feel our education here at Central is much more nurturing than most universities, which makes it fairly appealing. However, refinement of certain topics may be also beneficial for growth.
- N/A
- I feel a lot of other schools learn a lot more in gen chem. Also they have someone who is willing to write 4-year plans with students.
- I feel I worked harder than other majors on campus and am better prepared for life after college.
- Comparable; we have a very nice facility that caters to "hands-on" learning.

5. In what areas would you suggest changes to improve the CWU Chemistry program?

- More diverse class offerings.
- The one aspect of the chemistry education I hated the most was you never gave first priority for classes to chemistry majors. I have been waitlisted for nearly

every chemistry class I have ever taken here. This school has made it nearly impossible to complete a degree in 4 years.

- More biochemistry classes.
- Maybe more elective options per quarter.
- Offering seminars on specific instrumentation rather than just the instrumental analysis class.
- Begin to emphasize conceptualization earlier in the program.
- The use of machines to improve skill in analyzing in all labs.
- More instrumentation use & more regularly. Industry wants you to be able to run lots of instruments.
- Just try to keep growing the program and try to not lose too many of the great faculty members you have.
- More guidance. I would have liked to meet more often with my advisor and have them be able to help with job applications and resumes.
- Removal of conflicts with biology department and more non-standard chem classes.
- Upper-division level course refinement. Integration of quantitative techniques in gen chem labs. More hands-on techniques with instruments.
- Lecture times.
- Write sample 4-year plans. Offer quant, biochem, pchem more than fall quarter (maybe 1 each quarter, Pchem → Fall, Biochem → Winter, Quant → Spring). More elective upper-level classes!
- Make sure teachers prepare students for the ACS exams.
- More integrated labs – labs that supplement the lecture course.

6. We are gathering data for graduating seniors. Would you be willing to share your starting salary with us?

- N/A
- I'm going to be a student for the next 4 years at pharmacy school so I won't really have one.
- Yes, but it may be a few years (~\$40,000)
- Sure.
- I don't know how much annually but I'll make about \$22/hour.
- Tuition + ~\$20,000/year stipend at UCSB.
- No thanks.
- I don't have one yet.
- Yes, however I don't intend to work in my field for another few years.
- I don't know it yet!
- Not sure – have one more year of school yet.

**CWU CHEMISTRY DEPARTMENT**  
**EXIT SURVEY RESULTS 2007-2008 GRADUATES**

Graduating seniors responding to this survey:

Bachelor of Arts	1
Bachelor of Arts: Teaching	1
Bachelor of Science	10
Bachelor of Science: Biochemistry	7

1. Employment or graduate school information: (Please include current position title, employment/school name, and a brief position description.)

- Possibly graduate school, Central Washington University?
- Not currently employed in Chemistry.
- Department of Chemistry, CWU (MS)
- I will be attending CWU graduate school in fall of 2008.
- Possibly Brown & Haley (Tacoma) or Metagenics (Gig Harbor)
- Masters internship student at University of Oregon.
- Pacific Northwest National Laboratory. Technician in glass working on Hanford Waste Clean-up by vitrification.
- I will be employed as a second lieutenant in the Idaho National Guard, located in Boise, as an attack helicopter pilot. I hope to attend Boise State University where I plan to obtain a graduate degree in material science.
- Don't know yet but I applied to CWU-WATERS Program at Ellensburg, WA and the Department of Fish and Wildlife Large Lakes Research Team at Ellensburg, WA.
- Physical Science Teacher at Eisenhower High School in Yakima, WA. I teach 9<sup>th</sup> grade physical science, 2 sections of regular classes, and 3 sections of at Risk Students. (IPOD)
- Not yet employed and hope to attend medical school in 2009.
- Still applying for grad school, not yet accepted.
- Unknown, I am currently looking for a job.
- Applying for both at the time.
- Accepted to graduate school at the University of Oregon.

2. What specific components of your education in chemistry do you think will best prepare you for the job market/graduate school?

- Laboratory experience and research work.
- Experience with instruments and lab equipment.
- The high level of interaction between all students, faculty, and staff parallels the teamwork required in the industry.

- The most helpful component for job market preparation was the instrumental and analytical chemistry classes. I think taking Chem 555 nanotech/micro fluidics has prepared me for graduate school.
- Undergraduate research & science honors program.
- Lab experience, learning to focus.
- Good general chemistry education.
- The research I performed as part of the Science Honors Program gave me a feel for “real world” research while making me more competitive when it comes to applying for graduate school.
- The hands on lab experience plus research.
- The laboratory components to the lecture where knowledge and experience of modern day analytical instruments and methods was obtained.
- 1. SCED 324 w/Dr. Q → Inquiry and Critical thinking, 2. CHEM 180 series, 3. Environmental Chem.
- The laboratory work and the basic understanding of instrumentation, mechanisms, and research habits.
- I think I will benefit from lab classes the most.
- The range of chemistry classes I took has given me a good background. The instrumental class I took taught me to use a lot of chemistry equipment. That would make me very competitive in the job market.
- Microbiology from Pinkart and Biochemistry from Thomas. Both classes apply to my future studies and both professors are excellent teachers who set high yet achievable standards.
- I think all the classes I took were beneficial some more so than others. I do not have a job so I can't say yet if they have helped me.
- Genetics and Biochemistry. My teachers really paved the way on how to soak it all in.
- Undergraduate research.

3. If you performed research at CWU, do you feel it will help in your career? If so, please tell why. If you did not conduct research at CWU, do you wish you had done so? Please elaborate.

- Research gives me experience in chemistry which almost all jobs require.
- Yes, I learned and experienced things not available in undergrad coursework. I gained experience with computational software.
- My research experience helped me develop the ability to work/think independently in a research lab setting which has a direct impact on my future graduate studies and intended career path as a research chemist.
- It has given me the opportunity to learn a topic that isn't normally in lecture. I don't know how it will affect my career but I am even more grateful for the experience of the research.
- My research along with the science honors program is what will distinguish me from other candidates.
- Yes, research helped develop my patience and reasonable expectations for the development process.

- I performed research for a total of five quarters. I enjoyed the experience very much as I found it forced me to apply what I learned in class to “real world” problems. I will continue to use this type of critical thinking as I perform in my career whether military or chemistry related.
- Yes, it will help because we had to work in a group setting plus needing to solve problems on own.
- Performing research at CWU was perhaps one of the most important events in my career at CWU. It gave me so much experience in a research setting and helped me better understand the value of time management & literary research.
- I do not feel that it will help me. I wish I would have done more involved research.
- I do wish I had done research to further enhance my skills. I wish that research was more advocated by advisors.
- I have not conducted any research, but I wish I did do that it would have given me some experience.
- I did research with Dr. Fabry. It was a very interesting process and allowed me to experience the scientific method in a very in-depth manner. It is also a great resume builder and will make me more competitive candidate for school or work.
- No research.
- I did not conduct research, but I think it is a great thing. I am glad I did not do research though because then I would not have been able to be involved with the other stuff I did.
- I haven't taken research yet, that's next quarter.
- I do wish I could have done research here but I felt I didn't have the time to do so.
- I have three years of undergraduate research I believe it helped very much on getting into grad school. My experience as an undergrad at CWU was wonderful; there were lots of available undergraduate research opportunities.

4. How do you feel your chemistry education compares with that of your peers from other institutions?

- I don't know other institutions programs, no comparisons.
- I expect the class sizes and instructor availability are better at a smaller school/department like Central's.
- The relatively small size of the department (compared to WSU OR UW) allows for more student/teacher interaction which is a huge advantage over other programs, but this also limits course offerings.
- As I have not had much interaction with peer from other institutes, I feel that I cannot quantify an answer.
- I feel more prepared because of the small class sizes and the willingness of the professors to provide extra help.
- I think Central has better student to teacher ratios, newer science building.
- In talking with students from other universities I feel the education Central Chemistry Department gives us is on the same level as other institutions. I feel participating in Central's Science Honors Program takes the education to a higher level.

- I think I had a higher education level compared to UW or WSU because my friends there didn't get the one on one attention with professors and is easy excess to research.
- None of my peers are in the Chemistry field, but from what I have heard Central has a much better student to professor ratio for the beginning chem. courses and the professor's care whether students learn.
- I feel that the chemistry part of my education was excellent, but the Ed. degree was very low in comparison.
- I think that physical chemistry is the most challenging course I've heard of.
- I have checked the requirements for programs at other institutions and they are similar to CWU. I have no worries about it.
- I feel that I have experienced a superior chem. education program. The professors are wonderful, I was able to experience undergrad research, and the small class sizes allowed me to get to know my peers and professors very well.
- Fairly even.
- I don't know chem. students from other schools but I am satisfied with my education.
- Equally.
- Let's just say I know my teachers much better than they do. The teachers here know all of us and are willing to help.
- Equal.

5. In what areas would you suggest changes to improve the CWU Chemistry program?

- None
- Expanding the department (i.e. adding a few faculty positions) will enable the program to offer more electives while still maintaining the personal interactions I cited earlier.
- I recognize that organic chemistry is important, but I would like to see more stress put on classes such as analytical, instrumental, and inorganic.
- It would be helpful to make instrumental analysis long than a quarter.
- Make sure teachers are competent. I felt cheated by my PChem 2<sup>nd</sup> and 3<sup>rd</sup> quarters.
- More credit for labs.
- I would suggest removing the first quarter of biochemistry from the BS Plan. The chemistry major is already a large major compared too many other majors and one quarter of biochemistry does not reinforce any of the major concepts learned in the overall BS Plan. I would also like to see more department research opportunities advertized to younger students.
- No more visiting professors!
- To change the instrumental analysis to a 2<sup>nd</sup> quarter course, as I feel this is one of the important classes in the chemistry program and it felt too rushed.
- Have Science Ed (SCED 324) be a 2 quarter series, one focused on research of pedagogy and one focused on implementing in the class room.
- The advisors should be more informative.

- I felt it was hard at times to learn everything when working with groups. Most of the time, we assign each member to a specific role for the whole lab. Most people do not want to rotate since they just want to get the lab period over with.
- The biggest problems I had were time conflicts with biology classes. The two departments need to work together better. Also, more professors were needed for popular classes (OChem, BioChem, etc)
- Find some stability! I had to change professors in the middle of a series 3 times in 4 years and had to take a lab one year after completing the class. It's not fair to the student.
- More help from advisors, help with finding jobs, and using more experienced professors to teach the upper division classes.
- A higher standard of the temporary professors the department brings in → better P-Chem professors.
- More hands on in the first few years would draw more people, basically more lab time.
- Make sure there are always enough labs for students in lecture. I had great personal relationships with my teachers, and I respected most all of my teachers. However, I only have 2 complaints over the last 4 years. 1. Many students had to take O-Chem lab a year late cause of lab shortages, and 2. I am not learning much of anything in CHEM 382 due to Dr. Rittenhouse's teaching style. Otherwise things were great at CWU. Ps. Lisa is awesome!

6. We are gathering data for graduating seniors. Would you be willing to share your starting salary with us?

- None
- Yes, once I have one!
- ~ \$24,000. Graduate assistantship.
- I would be willing to give the information after I finish graduate school.
- \$2,500 -\$3,200/month
- Yes, not 100%. Haven't met for official offer yet. 36-40k.
- I will be serving as a second lieutenant in the army which has a start salary of \$30,000.
- Yes.
- Yes, once I get a job.
- \$33,000
- ~ \$50,000
- Yes.
- Yes, but I probably won't have a salary for another 5 years.
- I would love to if I had one.
- I don't know.
- No.
- Yes, anything for Central.
- At UO = \$22,500

**CWU CHEMISTRY DEPARTMENT**  
**EXIT SURVEY RESULTS 2008-2009 GRADUATES – PART ONE**

Graduating seniors responding to this survey:

Bachelor of Arts	0
Bachelor of Arts: Teaching	4
Bachelor of Science	1
Bachelor of Science: Biochemistry	1

1. Employment or graduate school information: (Please include current position title, employment/school name, and a brief position description.)

- Currently applying to CWU Masters' Program.
- Student, Central Washington University.
- I don't have a job yet.
- I plan on teaching.
- None yet (still have to do student teaching). Searching for chemistry teaching in the high school.

2. What specific components of your education in chemistry do you think will best prepare you for the job market/graduate school?

- Undergraduate research.
- The research experience & lab experience.
- Lab work from 180/360 series and Quant lecture/lab.
- My education will prepare me to teach high school chemistry.
- Nothing in particular.
- The TA experience was the best prep I could've had for teaching. The higher-level classes were good for learning, but I will be using gen chem the most.

3. If you performed research at CWU, do you feel it will help in your career? If so, please tell why. If you did not conduct research at CWU, do you wish you had done so? Please elaborate.

- Yes, it but my "classroom learning" into context and helped me develop skills I would have otherwise not had the chance to develop.
- Yes, I feel my research experience helped me understand a lot about how the real work environment will be like.
- I did research with a professor who has a lot of knowledge and experience and I learned a lot from her. It will help my career because I learned personal management skills.
- I have not yet done research.
- Yes. I would have liked to have done additional research in order to refresh my skills.
- Yes! Chem Ed research with Dr. Sorey was a great experience; I'm hoping to continue communication with him throughout my teaching career.

4. How do you feel your chemistry education compares with that of your peers from other institutions?

- Yes, for the most part. Specifically, I don't feel as if I understand the first thing about Quantum Mechanics, but after talking to students from other schools, this seems quite normal after 1 quarter of undergrad quantum.
- I feel that although sometimes getting into classes was hard, I had more one on one experience with teachers which enhanced learning.
- At CWU things are constantly changing. I think it is detrimental to students that we have so many professors that come and go.
- My chemistry education is wonderful.
- It's not quite as in-depth due to the quarter program.
- I don't really know much about other universities, but I know there are probably areas that need improvement (like the SCED department).

5. In what areas would you suggest changes to improve the CWU Chemistry program?

- My only idea would be to try and replace most of the non-tenure track instructors, which is already being done.
- More frequent offerings of classes.
- CWU should place more importance on teaching (effective teaching) rather than research.
- Patience in professors.
- Additional training for new TAs, i.e. practical instruction on conducting and grading a lab.
- SCED department. Also, preparing teachers earlier for graduation. I hate how little time and help there was with the portfolio. Foreign chem. professors are extremely difficult to work with.

6. We are gathering data for graduating seniors. Would you be willing to share your starting salary with us?

- Yes, when I get a job.
- Yes.
- No.
- Starting teaching salary? Not much, probably ~\$35-40,000/yr.

**CWU CHEMISTRY DEPARTMENT**  
**EXIT SURVEY RESULTS 2008-2009 GRADUATES – PART TWO**

Graduating seniors responding to this survey:

Bachelor of Arts	1
Bachelor of Arts: Teaching	0
Bachelor of Science	2
Bachelor of Science: Biochemistry	8

1. If you already know your employment or graduate school plans, please indicate position title, employer / school name, and a brief position description.

- I'm planning to go to pharmacy school.
- University of Washington, Ph.D. program, Teaching Assistantship.
- Unknown.
- I am planning to either attend graduate school at Central next fall or take a year off.
- UC Santa Cruz, Ph.D. candidate in Earth & Planetary Sciences.
- Graduate student at the University of Notre Dame in the Computer Science & Engineering Department. Likely studying bioinformatics.
- Entering chemical sales field. Chempart in Washington.
- I will be attending the Oregon Health and Science University's School of Dentistry in the fall.

2. For the specific components of your education in chemistry that are listed below, please rank each in terms of how well you believe it has prepared you for employment or graduate school:

1 = did not significantly contribute to my preparation / skill set;

5 = essential to my preparation / skill set

	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>n/a</b>
Lecture Courses			2	5	4	
Laboratory Courses				5	6	
Research Experience			1	1	7	2
Serving as a Teaching Assistant		1	1	1	4	4
Working with Faculty Advisor			2	2	7	
Other? Teaching SI				1		

If you wish, please use the space below to comment specifically on your choices above:

- The lecture courses support the laboratory courses which contribute to the research experience so they are all interdependent!
- I think that more experience with instruments would be nice.
- Most of the professors in the department are great and very helpful. I believe I will be well prepared for a career.
- I don't think I could have gotten into Notre Dame without the research experience.
- I would like the 388 or 488 classes to be more career opportunity oriented.

3. In your view, how well did the chemistry curriculum improve the following skills:  
(1 = did not improve; 5 = substantial improvement)

	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>
Oral Communication		3	4	4	
Written Communication		1	5	2	3
Working as part of a team			2	7	2
Observing safety protocols			2	4	5

If you wish, please use the space below to comment specifically on your choices above:

4. As a future chemist, how much do you value the following:  
(1 = do not value; 5 = regard as extremely important):

	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>
Ethical handling / reporting of data				2	9
Safe handling and proper disposal of chemicals and waste				2	9
Interpersonal communication			1	1	9

If you wish, please use the space below to comment specifically on your choices above:

5. We are gathering data for graduating seniors. If you will be starting employment immediately after graduation, would you be willing to share your starting salary with us?
- I will be continuing my education.
  - Yes, but I don't know what it is yet.



3. In your view, how well did your experience in the chemistry program at CWU prepare you for the following (1 = did not prepare me; 5 = substantial preparation)

Dealing with personnel and interpersonal communication issues in your current position:

1      2      3      4      5

Applying appropriate ethical standards in the handling and reporting of data:

1      2      3      4      5

Safe handling and proper disposal of chemicals and waste

1      2      3      4      5

If you wish, please use the space below to comment specifically on your choices above:

4. How do you feel your chemistry education compares with that of your peers from other institutions? (1 = below that of peers; 5 = superior to that of peers)

1      2      3      4      5

Please comment on your choice:

5. We are gathering data for graduates of our programs. Would you be willing to share your starting salary with us?

6. Let us know what you are doing! If you have exciting news for us to include in the annual alumni newsletter, Periodic News, please email it to [chemistry@cwu.edu](mailto:chemistry@cwu.edu).

## **CWU CHEMISTRY DEPARTMENT ~ 2004-2008 ALUMNI SURVEY RESULTS**

*Survey was mailed March 2009*

Alumni responding to this survey:

Bachelor of Arts	2
Bachelor of Arts: Teaching	1
Bachelor of Science	5
Bachelor of Science: Biochemistry	5
Master of Science	3

1. Employment or graduate school information: (Please include current position title, employer/school name, and a brief position description.)
  - Chemistry Teacher – Glendale High School, Glendale High School Union District, Graduate Student – School Administration – Arizona State University
  - Graduate Student – Central Washington University, Secretary Senior – Central Washington University
  - Molecular Basis of Disease Fellow at Georgia State University. Should graduate with PhD in Fall 2009
  - Lab Technician/Chemist – City of Yakima – Wastewater Division
  - Sterling Reference Labs. I review toxicology reports and release them to clients after I ensure all the information is correct
  - Eli Lilly & Co. Neuroscience Sales Representative
  - First year doctorate student at the University of Oregon
  - Research Tech, Fred Hutchinson Cancer Research Center processing whole blood samples to isolate and culture B-cells/extract DNA and run genome tests
  - Lab Technician at U.S. Oil and Refining. I do quality control of all the products and biproducts.
  - Environmental Health Supervisor, Kittitas County Public Health
  - Graduate Student – Materials Science/Surface Chemistry
  - Graduate Program – University of California Santa Barbra
  - Assistant Manager of the North Star Casteel Products Inc. I do what the management team tells me to do.
  - Currently Second Lieutenant in the US Army. I'm attending Flight School at Fort Rueter, AL. I have plans to attend Boise State University to pursue an advanced degree in Material Science.
  - Colorado School of Mines – Geochemistry Program in Chemistry Department – 1 year leave of absence from PhD degree. Current employment of Norwest Applied Hydrology as an aqueous geochemist (Geochemist title position). Enviro Consultant – includes hydro chemistry basin evaluations for energy companies: sampling QA/QC; data validation and interpretation ground water modeling.

- Science Teacher, Yakima School District, Eisenhower High School and track coach. I teach 9<sup>th</sup> grade physical science (1/2 chem, 1/2 physics.) 2 regular sections and 3 sections of at risk students who are very involved in gangs/drugs. I am also on the science instructional leadership team.

2. For the components of your education in chemistry that are listed below, please rank each in terms of how well you believe it has prepared you for your current position:  
 1 = did not significantly contribute to my preparation / skill set;  
 5 = essential to my preparation / skill set

	1	2	3	4	5	n/a
Lecture courses	0	2	4.5	5.5	4	
Laboratory courses	0	1	4	6	5	
Research experience	1	1	0	2	9	3
Serving as a TA	0	0	3	5	5	3
Working with faculty advisor	1	0	4.5	4.5	6	
Other?				1		

If you wish, please use the space below to comment specifically on your choices above:

- Overall the teaching was very effective. The one thing that may improve lecture courses at CWU is to require students to go to the board and work through problems. This is the one way to involve studying and internalization of information.
- Research to working with all types of analytical instrumentation helped the most to prepare me for my current position. I wished I would have taken advantage of internships – these are so important in developing “connections” for job opportunities.
- The research I performed with Dr. Fabry was essential in obtaining my current position and also has been helpful in my career with a pharmaceutical company.
- I enjoyed my time at CWU and my research opportunities. The faculty and office staff were wonderful and I miss the cohesive feeling of the chemistry department at CWU vs. where I am now.
- While I do not use the technical aspect of my major in my current position in the military. My research experience gave me necessary people skills along with a very broad understanding of how a large organization functions.
- The chemistry program at CWU was great but could use an Environmental Chemistry Specialization! Maybe joint degree with Geology Department? I would not be where I am today with out lecture/lab/research experience gained from both the chemistry and geology departments. Thank you.
- When you are going into the teach profession, it is better to gain practice in the teaching position than taking classes where you are just another student. Being responsible for grades and lab safety is essential to learn before entering a classroom (as a teacher). I can learn any amount of science I want, but that won't make me a good teacher. Being mentored on how to teach makes good teachers.

3. In your view, how well did your experience in the chemistry program at CWU prepare you for the following: (1 = did not prepare me; 5 = substantial preparation)

	1	2	3	4	5
Dealing with personnel and interpersonal communication issues in your current position	0	1	4	7.5	3.5
Applying appropriate ethical standards in the handling and reporting of data	0	0	2.5	5.5	8
Safe handling and proper disposal of chemicals and waste	0	1	4.5	1.5	9

If you wish, please use the space below to comment specifically on your choices above:

- I would like to have received more training in the handling, use and disposal of chemicals.
- These were all taught very well at CWU.
- Need more education on disposal and haz of Chemical Waste, it seemed like I had almost none.
- Interpersonal communication skills and ethical standards are very important in my current position as an officer in the military and I feel the chemistry department did their part in fortifying them within me during my time at Central.
- There needs to be a specific class dealing with ordering, storing and disposing of chemicals and lab waste. High school teachers are solely responsible for this and a paper exercise on designing a storage room is simply not enough and does not count as training.

4. How do you feel your chemistry education courses compare with that of your peers from other institutions? (1 = below that of peers; 5 = superior to that of peers)

1	2	3	4	5
0	2	5	7	3

Please comment on your choice:

- Right now I am studying with several individuals from around the world. I think my education is better than most students that went to larger universities.
- Seems to be at parity.
- I feel that the quality of the education was excellent. It would have been very helpful if there were a wider array of classes to choose from. Additional inorganic and materials type classes would have aided in my preparation for grad school greatly.

- I see and work with many other lieutenants that have graduated from other universities all across the country, I have yet to meet another chemistry major, but I feel my problem solving skills and ability to analyze the situation exceeds their ability.
  - Smaller class sizes, professors who made learning fun, and my research experiences were invaluable. I would like to recognize the geology department for their flexibility in which classes contributed to my geology minor. Made my class and research experience more geochemistry specialization.
  - Diaz is an excellent teacher and Fabry also teaches good courses, these professors make the content very challenging, but reasonable to grasp if you do what is expected.
5. We are gathering data for graduates of our programs. Would you be willing to share your starting salary with us?
- Starting - \$36,000 and Now - \$40,000
  - \$25,000/year
  - Grad school stipend \$23,000 but was soon raised to \$25,000.
  - Starting \$34,000/yr, currently \$48,000/yr.
  - \$40,000
  - Starting Salary - \$52,000 plus bonus, Current Salary - \$59,000 plus bonus
  - Yearly stipend \$22,500.
  - QC - \$40,000 (1<sup>ST</sup> JOB), Research - \$36,000 (Current Job)
  - \$40,000
  - \$40,000 starting
  - \$21,000
  - \$44,000/year
  - \$43,000
  - \$52,500 + 20% year bonus (upon performance evaluation). → This starting salary includes maters in environmental Geochemistry.
  - \$32,000

# Faculty Vitae



# GIL BELOFSKY

Department of Chemistry  
Central Washington University  
400 E. University Way  
Ellensburg, WA 98926-7539

phone: 509-963-2882  
fax: 509-963-1050  
e-mail: [belofskyg@cwu.edu](mailto:belofskyg@cwu.edu)

## AREAS OF SPECIALIZATION

*Natural Products Chemistry* – extraction, isolation, and characterization of new chemical compounds from biological sources; focusing on selection of promising candidates for study of their interactions with pharmacologically important receptors, and coordinating evaluation for potential as drugs or supplements.

*Organic/Analytical Chemistry* - chromatography and spectroscopy of organic compounds

## EDUCATION

**The University of Iowa**, Iowa City, IA, **Ph.D. Organic Chemistry**, advisor: Dr. James B. Gloer May 1996  
**Colorado State University**, Fort Collins, CO, **M.S. Organic Chemistry**, advisor: Dr. Frank R. Stermitz Oct. 1987  
**Carnegie Mellon University**, Pittsburgh, PA, **B.S. Chemistry** Jun. 1985

## RESEARCH EXPERIENCE

**Central Washington University**, Ellensburg, WA, **Assistant Professor of Chemistry** Sept. 2008 - present  
Primary investigator in a natural products research program

**Efficas, Inc.**, Boulder, CO, **Director, Natural Products Research** July 2005 – Jan. 2008  
Bioactives from food and plant extracts for health and nutritional management of disease

**The University of Tulsa**, Tulsa, OK, **Assistant Professor of Chemistry** Jan. 1999 – June 2005  
Primary investigator in a botanical natural products research program

**Scripps Institution of Oceanography**, La Jolla, CA, **Postdoctoral Research Fellowship** Feb. 1996 - Jun. 1998  
Original research in marine natural products chemistry, advisor Dr. William Fenical

**Bristol-Myers Squibb Company**, Wallingford, CT, **Associate Research Scientist** Jan. 1989 - May 1991  
Conducted original research in antitumor natural products chemistry

**Harvard University**, Cambridge, MA, **Research Assistant** Jan. 1988 - Dec. 1988  
Research in biological oceanography

## TEACHING EXPERIENCE

**Central Washington University**, Ellensburg, WA, **Assistant Professor of Chemistry** Sept. 2008 - present  
Organic Chemistry Lecture and Laboratories and special topics/advanced courses

**The University of Tulsa**, Tulsa, OK, **Assistant Professor of Chemistry** Jan. 1999 – Jun. 2005  
Organic Chemistry I and II Lecture and Laboratories  
Qualitative Organic Analysis Lecture/Laboratory, Natural Products Chemistry (new course)

**The University of Iowa**, Iowa City, IA, **Teaching Assistant** Aug. 1991 - May 1992  
Organic Chemistry Laboratory, including short lectures

**Colorado State University**, Fort Collins, CO, **Teaching Assistant** Aug. 1985 - May 1986  
General Chemistry Laboratory, including short lectures

## PROFESSIONAL SOCIETIES

Active member of:

American Society of Pharmacognosy  
American Chemical Society

## PROFESSIONAL SERVICE

American Chemical Society

Secretary, Tulsa Section, ACS

Jan. 1999 – Dec. 1999

Chair-Elect, Tulsa Section, ACS

Jan. 2000 – Dec. 2000

Chair, Tulsa section ACS

Jan. 2001 - Dec. 2001

American Society of Pharmacognosy

ASP Web Site Development Committee

Jan. 2001 - May. 2002

## PUBLICATIONS IN REFEREED JOURNALS

Marsella R.; Messinger L.; Zabel S.; Rosychuk R.; Griffin C.; Cronin P.O.; Belofsky G.; Lindemann J.; Stull D. "A randomized, double blind, placebo controlled study to evaluate the effect of EFF1001, an *Actinidia arguta* (hardy kiwi) preparation, on CADESI score and pruritus in dogs with mild to moderate atopic dermatitis" **2009** *Veterinary Dermatology*, in press.

Lindemann, J.; Pampe, E.D.; Peterkin, J.J.; Orozco-Cronin, P.; Belofsky, G.N.; Stull, D.P. "A Medical Food that Reduces Leukotriene Synthesis Improves Quality of Life in Adult Subjects with Asthma" **2008**, *Submitted to The Journal of Allergy and Clinical Immunology*.

Belofsky, G.; Carreno, R.; John, D.T.; Goswick, S.M. "Activity of Isoflavans of *Dalea aurea* (Fabaceae) against the Opportunistic Ameba *Naegleria fowleri*" *Planta medica*, **2006**, *72*, 383-386.

Belofsky, G.; Carreno, R.; Lewis, K.; Ball, A.R.; Casadei, G.; Tegos, G.P. "Metabolites of the 'Smoke Tree' *Dalea spinosa* Potentiate Antibiotic Activity against Multi-Drug Resistant (MDR) *Staphylococcus aureus*" *Journal of Natural Products*, **2006**, *69*, 261-264.

Belofsky, G.; Percivill, D.; Lewis, K.; Tegos, G.P.; Ekart, J. "Phenolic Metabolites of *Dalea versicolor* that Enhance Antibiotic Activity Against Model Pathogenic Bacteria," *Journal of Natural Products*, **2004**, *67*, 481-484.

Belofsky, G.; French, A.F.; Wallace, D.R.; Dodson, S.L. "New Geranyl Stilbenes from *Dalea purpurea* with *in vitro* Opioid Receptor Affinity," *Journal of Natural Products*, **2004**, *67*, 26-30.

Belofsky, G.N.; Anguera, M.; Jensen, P.R.; Fenical, W.; Köck, M. "Oxepinamides A-C and Fumiquinazolines H-I: Bioactive Metabolites from a Marine Isolate of a Fungus of the Genus *Acremonium*," *Chemistry, A European Journal* **2000**, *6*, 1355.

Belofsky, G.N.; Jensen, P.R.; Fenical, W., "Sansalvamide A: A New Cytotoxic Cyclic Depsipeptide Produced by a Marine Isolate of a Fungus of the Genus *Fusarium*," *Tetrahedron Letters* **1999**, *40*, 2913.

Belofsky, G.N.; Jensen, P.R.; Renner, M.K.; Fenical, W., "New Cytotoxic Sesquiterpenoid Nitrobenzoyl Esters from a Marine Isolate of the Fungus *Aspergillus versicolor*," *Tetrahedron* **1998**, *54*, 1715.

Belofsky, G.N.; Gloer, K.B.; Gloer, J.B.; Wicklow, D.T.; Dowd, P.F., "New *p*-Terphenyl and Polyketide Metabolites from the Sclerotia of *Penicillium raistrickii*," *Journal of Natural Products* **1998**, *61*, 1115.

Belofsky, G.N.; Gloer, J.B.; Wicklow, D.T.; Dowd, P.F., "Shearamide A: A New Cyclic Peptide from the Ascostromata of *Eupenicillium shearii*," *Tetrahedron Letters* **1998**, 39, 5497.

Krasnoff, S.B.; Gibson, D.M.; Belofsky, G.N.; Gloer, K.B.; Gloer, J.B., "New Destruxins from the Entomopathogenic Fungus *Aschersonia* sp.," *Journal of Natural Products* **1996**, 59, 485.

Belofsky, G.N.; Gloer, J.B.; Wicklow, D.T.; Dowd, P.F., "Antiinsectan Alkaloids: Shearinines A-C and a New Paxilline Derivative from the Ascostromata of *Eupenicillium shearii*," *Tetrahedron* **1995**, 51, 3959.

Matson, J.A.; Colson, K.L.; Belofsky, G.N.; Blieberg, B.B., "Sandramycin, A Novel Antitumor Antibiotic Produced by a *Nocardioides* sp. II. Structure Determination," *Journal of Antibiotics* **1993**, 46, 162.

Stermitz, F.R.; Belofsky, G.N.; Ng, D.; Singer, M.C., "Quinolizidine Alkaloids Obtained by *Pedicularis semibarbata* (Schrophulariaceae) from *Lupinus fulcratus* (Leguminosae) Fail to Influence the Specialist Herbivore *Euphydryas editha* (Lepidoptera)," *Journal of Chemical Ecology* **1989**, 15, 2521.

Belofsky, G.N.; Bowers, M.D.; Janzen, S.; Stermitz, F.R., "Iridoid Glycosides of *Aureolaria flava* (Schrophulariaceae) and their Sequestration by *Euphydryas phaeton* (Nymphalidae) Butterflies," *Phytochemistry* **1989**, 28, 1601.

Belofsky, G.N.; Stermitz, F.R., "10-trans-Cinnamoylmelittoside and other Iridoids from *Castilleja wightii*," *Journal of Natural Products* **1988**, 51, 614.

## PATENT

Indole Antiinsectan Metabolites from the Ascostromata of *Eupenicillium shearii*, Belofsky, G.N.; Gloer, J.B.; Wicklow, D.T.; Dowd, P.F., U.S. Patent #5,492,902, issued Feb. 20, 1996.

## PROFESSIONAL PRESENTATIONS

(oral presentations unless otherwise noted)

### Invited Presentations

*Mesa State College*, "Natural Products, from Biosynthesis to Novel Drug Targeting," Belofsky, G., April 25, 2008, Grand Junction, Colorado.

*USDA, ARS, WRRC, Plant Mycotoxin Research Unit*, "Plant and Fungal Secondary Metabolites: Implications for Chemical Ecology, Antiinsectan Activity, and Inhibition of Resistance Mechanisms in Microorganisms," Belofsky, G., January 9, 2006, Albany, California.

*Presented as part of the Biomedical Sciences Seminar Series, Oklahoma State University, Center for Health Sciences*, "Natural Products Chemistry at The University of Tulsa, Neuropharmacological and Chemical Studies of Plant and Fungal Sources," Belofsky, G., January 31, 2003, Tulsa, Oklahoma.

*Presented to the  $\beta\beta\beta$  Biological Honor Society, University of Tulsa*, "Natural Products Studies of the Plant Genus *Dalea*," Belofsky, G.; Ekart, J.A.; French, A.N.; Dodson, S.L.; Stermitz, F.R.; Lewis, K.; Wallace, D.R., Sept. 25, 2001, Tulsa, Oklahoma.

*Presented to the Department of Chemistry Faculty and Students of Northeastern State University*, "Natural Products Chemistry at the University of Tulsa," Belofsky, G., April 18, 2001, Talequah, Oklahoma.

*American Chemical Society, Oklahoma Section, 45<sup>th</sup> Pentasectional Meeting*, "Screening of Plant and Fungal Extracts for Neuropharmacological Activity," Belofsky, G.; Wallace, D.R., April 15, 2000, Oklahoma State University, Stillwater, Oklahoma.

## Submitted Presentations

*Annual Meeting of the American Academy of Allergy, Asthma & Immunology*, "A Medical Food that Reduces Leukotriene Synthesis Improves Quality of Life in Adult Subjects with Asthma" Lindemann, J.; Pampe, E.D.; Peterkin, J.J.; Orozco-Cronin, P.; Belofsky, G.N.; Stull, D.P., March 18, 2008, Philadelphia, Pennsylvania - poster presentation.

*2007 North American Veterinary Dermatology Forum*, "A Randomized, double blind, placebo controlled study to evaluate the use of EFF1001 to decrease CADESI score and/or pruritus of atopic dogs" Marsella, R.; Messinger, L.; Zabel, S.; Rosychuk, R.; Griffin, C.; Cronin, P.O.; Belofsky, G.; Lindemann, J.; Stull, D., April 18-22, 2007, Lihue, Kauai, Hawaii - poster presentation.

*The 46<sup>th</sup> Annual Meeting of the American Society of Pharmacognosy* "Concentrates of Aqueous Preparations of *Actinidia arguta* (Actinidiaceae) Regulate the Expression of Cytokines and Other Immunological Markers *In Vitro*" Belofsky, G.; Antczak, M.; Stull, D., August 6<sup>th</sup>, 2006, Arlington, Virginia - poster presentation.

*The 46<sup>th</sup> Annual Meeting of the American Society of Pharmacognosy*, "Anti-Amebic Metabolites of *Dalea aurea* (Fabaceae)," Belofsky, G., Carreno, R.; John, D.T., Goswick, S.M., July 26<sup>th</sup>, 2005, Corvallis, Oregon - poster presentation.

*2004 International Congress on Natural Products Research*, "Biologically Active Phenolic Metabolites of the 'Smoke Tree' *Dalea spinosa* (Fabaceae)" Belofsky, G.; Carreno, R.; Lewis, K.; Ball, A.R.; Tegos, G.P., August 1<sup>st</sup>, 2004, Phoenix, Arizona - poster presentation.

*The 44<sup>th</sup> Annual Meeting of the American Society of Pharmacognosy*, "Some of the Chemistry and Biological Activity of Secondary Metabolites from *Dalea versicolor* (Fabaceae)," Belofsky, G.; Percivill, D.; Ekart, J., July 13<sup>th</sup>, 2003, Chapel Hill, North Carolina - poster presentation.

*American Chemical Society, Rocky Mountain Regional Meeting*, "Biologically Active Natural Products from *Dalea* (Fabaceae) Species," Belofsky, G.; Omara, N.; Dodson, S.L.; French, A.N.; Azadi, K.A.; Wallace, D.R., October 13, 2002, Albuquerque, New Mexico.

*The 42<sup>nd</sup> Annual Meeting of the American Society of Pharmacognosy*, "The Biological Activity and Chemistry of the Plant Genus *Dalea*," Belofsky, G.; Ekart, J.A.; French, A.N.; Dodson, S.L.; Stermitz, F.R.; Lewis, K.; Wallace, D.R., July 16, 2001, Oaxaca, Mexico.

*The 41<sup>st</sup> Annual Meeting of the American Society of Pharmacognosy*, "Establishing a Collaborative Program in Pharmacognosy at the University of Tulsa – Screening and Preliminary Results," Belofsky, G.; Dodson, S.L.; Ekart, J.A.; McConnell, J.W.; Levetin, E.; Wallace, D.R., July 23, 2000, Seattle, Washington.

*2000 Years of Natural Products Research – Past, Present, And Future*, "New Fumiquinazolines from a Marine Isolate of a Fungus of the Genus *Acremonium*," Belofsky, G.N.; Anguera, M.; Jensen, P.R.; Fenical, W., Jul. 28, 1999, Vrije Universiteit, Amsterdam, The Netherlands - poster presentation.

*14th Annual Rocky Mountain Regional Meeting of the American Chemical Society*, "Sansalvamide A: A New Cytotoxic Cyclic Depsipeptide Produced by a Marine Fungus," Belofsky, G.N.; Jensen, P.R.; Fenical, W., March 15-18, 1998, Tucson, Arizona.

*Thirty-Sixth Annual Meeting of the American Society of Pharmacognosy*, "The Shearamides: New Cyclic Peptides from the Ascostromata of *Eupenicillium shearii*," Belofsky, G.N.; Gloer, J.B.; Wicklow, D.T.; Dowd, P.F., Jul. 25, 1995, The University of Mississippi, Oxford, Mississippi - poster presentation.

*International Congress on Natural Products Research*, "Shearamide A: A New Cyclic Peptide from the Ascostromata of *Eupenicillium shearii*," Belofsky, G.N.; Gloer, J.B.; Wicklow, D.T.; Dowd, P.F., Aug. 4, 1994, Halifax, Nova Scotia, Canada.

*The Mona Symposium on Natural Products and Medicinal Chemistry*, "New Bioactive Indole Alkaloids from the Ascostromata of *Eupenicillium shearii*," Belofsky, G.N.; Gloer, J.B.; Wicklow, D.T.; Dowd, P.F., Jan. 6, 1994, University of the West Indies, Mona, Jamaica.

**Student Presentations, University of Tulsa** (poster presentations unless otherwise noted)

229<sup>th</sup> *American Chemical Society National Meeting*, "Biologically Active Phenolic Metabolites of *Dalea aurea* (Fabaceae)," Carreno, R.; Belofsky, G.; John, D.T.; Goswick, S.M., March 14, 2005, San Diego, California.

229<sup>th</sup> *American Chemical Society National Meeting*, "Phenolic Metabolites of *Dalea schottii* (Fabaceae)," Bridge, C.; Belofsky, G., March 14, 2005, San Diego, California.

227<sup>th</sup> *American Chemical Society National Meeting*, "Biologically Active Phenolic Metabolites of *Dalea spinosa* (Fabaceae)," Carreno, R.; Belofsky, G.; Lewis, K.; Ball, A.; Casadei, G.; Tegos, G., March 29, 2004, Anaheim, California.

227<sup>th</sup> *American Chemical Society National Meeting*, "Plant Derived Inhibition of Mycotoxin Production in *Myrothecium cinctum*," Leib, R.; Belofsky, G.; Azadi, K.; Levetin, E., March 29, 2004, Anaheim, California.

225<sup>th</sup> *American Chemical Society National Meeting*, "Isolation of Fungal Metabolites from Biologically Active Extracts of *Myrothecium cinctum* and *Gliocladium* sp.," Azadi, K.; Belofsky, G.; Wallace, D.R.; Levetin, E., March 24, 2003, New Orleans, Louisiana.

225<sup>th</sup> *American Chemical Society National Meeting*, "Isolation and Characterization of Natural Products from *Dalea versicolor* (Fabaceae)," Percivill, D.; Belofsky, G.; Lewis, K.; Tegos, G.P.; Ekart, J., March 24, 2003, New Orleans, Louisiana.

225<sup>th</sup> *American Chemical Society National Meeting*, "Chemistry-guided Fractionation of Plant Natural Products," Monroe, C.; Belofsky, G.

223<sup>rd</sup> *American Chemical Society National Meeting*, "Isolation and Characterization of Compounds from Bioactive Extracts of *Monarda citreodora*," Dodson, S.L.; Belofsky, G.; Wallace, D.R., April 8, 2002, Orlando, Florida.

223<sup>rd</sup> *American Chemical Society National Meeting*, "Isolation of Natural Products from Biologically Active Extracts of Fungi," Azadi, K.; Belofsky, G.; Dodson, S.L.; Wallace, D.R.; Levetin, E., April 8, 2002, Orlando, Florida.

223<sup>rd</sup> *American Chemical Society National Meeting*, "Opioid Receptor Binding Activity of Compounds from *Dalea purpurea* (Fabaceae)," French, A.N.; Belofsky, G.; Dodson, S.L.; Wallace, D.R., April 8, 2002, Orlando, Florida.

36<sup>th</sup> *Annual Midwest Regional American Chemical Society Meeting*, "Natural Products Studies of Biologically Active Extracts of *Penicillium expansum*," Dentis, J.D.; Dodson, S.L.; Belofsky, G.; Wallace, D.R., October 11, 2001, Lincoln, Nebraska.

221<sup>st</sup> *American Chemical Society National Meeting*, "Isolation and Characterization of Components from Biologically Active Extracts of the Fungus *Cladosporium cladosporioides*," McConnell, J.W.; Belofsky, G.; Levetin, E.; Price III, J.A., April 2, 2001, San Diego, California.

221<sup>st</sup> *American Chemical Society National Meeting*, "Isolation and Characterization of Natural Products from Neuropharmacologically Active Extracts of *Dalea purpurea*," French, A.N.; Belofsky, G.; Wallace, D.R., April 2, 2001, San Diego, California.

221<sup>st</sup> *American Chemical Society National Meeting*, "Natural Products from the Desert Plant *Dalea versicolor* with the Potential to Overcome Antibiotic Resistance," Ekart, J.; Belofsky, G.; Lewis, K.; Hsiang, P.; Stermitz, F.R., April 2, 2001, San Diego, California.

221<sup>st</sup> American Chemical Society National Meeting, "Screening of Plant Extracts for Neuropharmacological Activity," Dodson, S.L.; Belofsky, G.; Wallace, D.R., April 2, 2001, San Diego, California.

219<sup>th</sup> American Chemical Society National Meeting, "Chemical Composition of Extracts of the Desert Plant *Dalea versicolor* (Fabaceae)," Ekart, J. and Belofsky, G., March 27, 2000, San Francisco, California.

219<sup>th</sup> American Chemical Society National Meeting, "Isolation and Characterization of Components from Biologically Active Extracts from a *Botrytis* sp. of Fungus," McConnell, J.W. and Belofsky, G., March 27, 2000, San Francisco, California.

## RESEARCH PROPOSALS

### Internal Proposals, University of Tulsa

*Student Research Grant Program, The University of Tulsa*, "Plant Derived Inhibition of Mycotoxin Production in *Mycrothecium cinctum*" October 1, 2003, award: \$500 – Mr. Ryan Leib.

*Faculty Development Summer Fellowship Program, The University of Tulsa*, November 26, 2002, award: two months of summer salary and \$500 for supplies.

*Faculty Development Summer Fellowship Program, The University of Tulsa*, November 30, 2001, award: two months of summer salary and \$500 for supplies.

*Student Research Grant Program, The University of Tulsa*, "Biologically Active Compounds from a *Gliocadium* Species of Fungus," February 5, 2001, award: \$400 - Mr. Kavon Azadi

*Student Research Grant Program*, "Dopamine Active Constituents of the Fungus *Penicillium expansum*," February 5, 2001, award: \$380 - Ms. Jennifer Dentis

*Faculty Development Summer Fellowship Program, The University of Tulsa*, December 8, 2000, award: two months of summer salary and \$500 for supplies.

*Student Research Grant Program, The University of Tulsa*, "Chemical Composition of Extracts of the Desert Plant *Dalea versicolor*," February 16, 2000, award: \$300 – Ms. Julie Ekart.

*Student Research Grant Program, The University of Tulsa*, "Isolation and Characterization of Compounds from Biologically Active Extracts of a *Botrytis* sp. of Fungus," February 16, 2000, award: \$300 – Mr. Jason McConnell.

*Faculty Development Summer Fellowship Program, The University of Tulsa*, November 30, 1999, award: two months of summer salary and \$500 for supplies.

*Faculty Development Summer Fellowship Program, The University of Tulsa*, November 24, 1998, award: two months of summer salary and \$500 for supplies.

### External Proposals, Central Washington University (GB is the primary investigator unless otherwise noted)

*Bill and Melinda Gates Foundation, Grand Challenges Explorations Round 2 – Create Drugs and Delivery Systems to Limit Drug Resistance*, "Use of Natural Products to Enhance the Activity of Current Treatments for Multi-Drug Resistant Tuberculosis," \$100,000 (1.5 years), submitted November, 2008; **decision pending**.

### External Proposals, University of Tulsa (GB is the primary investigator unless otherwise noted)

*The National Institutes of Health, National Center for Complementary and Alternative Medicine*, "Neuropharmacological Activity of Native American Plants," \$288,200 (2 years), submitted May, 2002; **not funded**. Primary investigator: D.R. Wallace, Postdoctoral Fellow: J. Paulson, Department of Pharmacology, The Oklahoma State University, College of Osteopathic Medicine.

*The Research Corporation, Cottrell College Science Awards*, "Natural Products Chemistry and the Neurosciences - Plants with Receptor Binding Activity from the Nature Conservancy's Tallgrass Prairie Preserve," \$31,724 (2 years), November, 2001; **granted**.

*The National Institutes of Health, National Center for Complementary and Alternative Medicine*, "Natural Product Protection Against CNS HIV Neurotoxicity," \$375,240 (2 years), submitted April, 2001; **not funded**. Primary investigator: D.R. Wallace, Department of Pharmacology, The Oklahoma State University, College of Osteopathic Medicine. Co-investigator: R.M. Booze, Department of Anatomy and Neurobiology, The University of Kentucky.

*The Nature Conservancy - Tallgrass Prairie Preserve, Application for Research Permit*, "Natural Products Chemistry - Plants with Medicinal Potential from the Tallgrass Prairie Preserve," January, 2001; **granted**.

*Merck - AAAS Undergraduate Science Research Program*, "Isolation and Characterization of Biologically Active Natural Products from Fungi and Bioremediation of Acid Mine Drainage by a Subsurface Flow Treatment System," \$60,000 (3 years), submitted November 2000; **not funded**. Co-investigators: T. Harris, Department of Chemistry and Biochemistry, The University of Tulsa; E. Levetin; W. Rosche, Department of Biological Science, The University of Tulsa.

*The American Society of Pharmacognosy Member Travel Grant*, "Establishing a Collaborative Program in Pharmacognosy at the University of Tulsa - Screening and Preliminary Results," \$500, June, 2000; **funded**.

*Oklahoma Center for the Advancement of Science and Technology*, "Development of Selective Opioid Receptor Ligands," \$135,000 (1 year), submitted January, 2000; **not funded**. Primary investigators: J.C. DiCesare, Department of Chemistry and Biochemistry, The University of Tulsa; D.R. Wallace, Department of Pharmacology, The Oklahoma State University, College of Osteopathic Medicine.

*The American Society of Pharmacognosy Research Starter Grant*, "Isolation and Characterization of Secondary Metabolites of Airborne and Soil Fungi," \$5000; June, 1999; **funded**.

*American Chemical Society/Eli Lilly & Company Women Chemists Committee Travel Award*, "Screening of Plant and Fungal Extracts for Neuropharmacological Activity," \$1205; March 2000; **not funded**. Student investigator: S. Dodson, Department of Chemistry and Biochemistry, The University of Tulsa.

## INSTITUTIONAL ADVANCEMENT AT THE UNIVERSITY OF TULSA

Coordinated donation of Varian Unity Plus NMR instrument from **Pfizer Global Research**, La Jolla, CA estimated value: \$125,000.

Coordinated donation of HPLC equipment from **Boeringer-Ingelheim Pharmaceuticals**, Danbury, CT. estimated value: \$2,000.

Coordinated donation of laboratory equipment from **Searle-Monsanto**, St. Louis, MO. estimated value: \$1700.

## REVIEWING ACTIVITIES

### **Book review, *Journal of Natural Products*:**

Belofsky, G. *J. Nat Prod.*, **2003**, *66*, 902-903, for Hollis, J.M., Basic Atomic and Molecular Spectroscopy, John Wiley and Sons, Inc., New York, NY, and The Royal Society of Chemistry, UK, 2002.

### **Review of papers for the following journals:**

*Journal of Natural Products*  
*Phytochemistry*  
*Tetrahedron Letters*  
*Journal of Chemical Ecology*  
*Phytochemical Analysis*

**Review of research proposals for the following organizations:**

*National Science Foundation  
The Research Corporation  
Jeffress Memorial Trust*

**ACTIVITIES AT CENTRAL WASHINGTON UNIVERSITY**

**Dept. of Chemistry, Biochemistry Faculty Search Committee** Sept. 2008 – present

**Dept. of Chemistry, Pre-Pharmacy Advisor** Sept. 2008 – present

**Undergraduate Student Research Mentoring**

J. Eric Inions (2009)  
Marshall Crabtree (2009)  
John Schrieber (2009)  
Victoria Eisenberg (2009)

**ACTIVITIES AT THE UNIVERSITY OF TULSA**

**Undergraduate Student Research Mentoring**

R. Carreno*	(2003-2005)	J. Dentis*	(2000-2002)
C. Bridge	(2003-2005)	D. Johnson	(2000-2002)
R. Leib*	(2003-2004)	K. Adjip	(1999-2000)
C. Monroe*	(2002-2003)	J. Ekart*	(1998-2001)
D. Percivill*	(2002-2004)	J. McConnell*	(1998-2001)
K. Azadi*	(2000-2004)	R. Wilson	(1998-2000)
S. Dodson*	(2000-2003)	A. Sumner	(1998-2000)
A. French*	(2000-2003)		

\*Indicates recipients of Student Travel Grants, University of Tulsa (internal, \$100 awards)

**University of Tulsa, Premedical Evaluation Committee** 2002 – 2005

**University Senate/Faculty Senate** Jan. - Dec. 2001

# Stephen Chamberland

Department of Chemistry  
Central Washington University  
400 East University Way  
Ellensburg, Washington 98926-7539

Office: Science 302H  
Phone: (509) 963-1126  
Fax: (509) 963-1050  
Email: chambers@cwu.edu

- Education**
- 2005**      **University of California, Irvine**, Irvine, California  
*Ph.D. Organic Chemistry, GPA: 3.9/4.0*
- 1999**      **Boston College**, Chestnut Hill, Massachusetts  
*B.S. Biochemistry, Minor in Chemistry, cum laude, GPA: 3.6/4.0*
- Professional Experience**
- 2008–present**      **Central Washington University**, Ellensburg, Washington  
*Assistant Professor of Chemistry*  
Teaching Interests: Introductory Organic Chemistry, Organic Reaction Mechanisms, Advanced/Synthetic Organic Chemistry  
Research Interests: Methodology Development, Synthetic Organic Chemistry, Computational Chemistry
- 2005–2008**      **Colorado State University**, Fort Collins, Colorado  
*Postdoctoral Research Associate of Professor Robert M. Williams*
- Prepared complex putative early (7 steps) and late-stage (approx. 25 steps) biosynthetic intermediates of mitomycin C as well as *N*-acetylcysteamine thioester derivatives of these compounds which were analyzed by collaborators in Professor David H. Sherman's group (University of Michigan) using over-expressed mitomycin C biosynthetic enzymes
  - Developed a rationale to explain the high selectivity observed in Mukaiyama aldol hydroxymethylation reactions (step 19 of approx. 25 steps) used in the preparation of eight-membered ring containing putative late-stage biosynthetic intermediates of mitomycin C, identified relevant conformations of the intermediates in these reactions, and quantified energy differences between them using Spartan '06 modeling software
  - Synthesized a bioconjugate of anticancer antibiotic FR900482 and biotin for use in gene pull-down assays by collaborators
- 1999–2005**      **University of California, Irvine**  
*Graduate Research Associate of Professor Keith A. Woerpel*
- Enlisted a variety of synthetic methods (Yamaguchi lactonization, radical atom-transfer cyclization, *8-endo* radical cyclization, and ring-closing metathesis) to construct eight-membered ring lactones possessing a single remote alkyl or alkoxy substituent at C-3, C-4, or C-5 (lactone carbon = C-1). Each synthesis was four to ten chemical steps in length.
  - Exploited remote stereocontrol to achieve diastereoselective nucleophilic substitution reactions of lactone-derived eight-membered ring oxocarbenium ions prepared from acetate acetal precursors
  - Developed a computational method that, in tandem with experimental results, established a paradigm for understanding the structure, stereoelectronic interactions, through-space electrostatic effects, and conformational preferences of charged monosubstituted eight-membered ring oxocarbenium ion intermediates
  - Devised and initiated the preparation and computational, spectroscopic, and crystallographic analysis of C-4 alkyl- and alkoxy-substituted, semi-stable dioxocarbenium ion salts to understand the general conformational preferences of charged tetrahydropyrylium ion intermediates in comparison with neutral structures
- 1995–1999**      **Boston College**, Chestnut Hill, Massachusetts  
*Scholar of the College with Professor T. Ross Kelly*
- Scholar of the College Honors Thesis Title: Total Synthesis of Luotonin A and Studies Directed Toward the Total Syntheses of Louisianins C and D, and Ulupyrinone

## Publications

- **Chamberland, S.**; Grüschow, S.; Sherman, D. H.; Williams, R. M. *Synthesis of Potential Early-Stage Intermediates in the Biosynthesis of FR900482 and Mitomycin C*. *Org. Lett.* **2009**, *11*, 791–794.
- Namiki, H. N.; **Chamberland, S.**; Gubler, D. A.; Williams, R. M. *Synthetic and Biosynthetic Studies of FR900482 and Mitomycin C: An Efficient and Stereoselective Hydroxymethylation of an Advanced Benzazocane Intermediate*. *Org. Lett.* **2007**, *9*, 5341–5344.
- **Chamberland, S.**; Ziller, J. W.; Woerpel, K. A. *Structural Evidence that Alkoxy Substituents Adopt Electronically Preferred Pseudoaxial Orientations in Six-Membered Ring Oxocarbenium Ions*. *J. Am. Chem. Soc.* **2005**, *127*, 5322–5323.
- **Chamberland, S.**; Woerpel, K. A. *Using Nucleophilic Substitution Reactions to Understand How a Remote Alkyl or Alkoxy Substituent Influences the Conformation of Eight-Membered Ring Oxocarbenium Ions*. *Org. Lett.* **2004**, *6*, 4739–4741.
- Kelly, T. R.; **Chamberland, S.**; Silva, R. A. *The Total Synthesis of Luotonin A*. *Tetrahedron Lett.* **1999**, *40*, 2723–2724.

## National Presentations

- *Preparation of complex putative early- and late-stage intermediates in mitomycin and FR-900482 biosynthesis*. **Chamberland, S.**; Williams, R. M.; Sherman, D. H. 234th American Chemical Society National Meeting, Boston, MA, United States, August 19–23, 2007, Poster Presentation, BIOL-073.
- *Preparation of complex putative early- and late-stage intermediates in mitomycin and FR-900482 biosynthesis*. **Chamberland, S.**; Williams, R. M.; Sherman, D. H. 8<sup>th</sup> Winter Conference on Medicinal and Bioorganic Chemistry, Steamboat Springs, CO, United States, January 21–25, 2007, Poster #3.
- *Synthesis and nucleophilic substitution reactions of eight-membered ring oxocarbenium ion precursors containing a remote alkyl or alkoxy substituent*. Woerpel, K. A.; **Chamberland, S.** 227th American Chemical Society National Meeting, Anaheim, CA, United States, March 28–April 1, 2004, ORGN-020.

## Invited Lectures

Brigham Young University, Provo, UT, Department of Chem. and Biochem. – December 2007  
Kennesaw State University, Kennesaw, GA, Department of Chemistry – November 2007  
Bard College, Annandale-on-Hudson, NY, Division of Science and Mathematics – November 2007  
Central Washington University, Ellensburg, WA, Department of Chemistry – October 2007  
California State University, Northridge, Department of Chemistry – October 2007

## External Funding Activity

- *Developing a Greener, More General Catalytic Asymmetric Aziridination Reaction Using Recyclable Hypervalent Iodine(III) Reagents*, 2008 Undergraduate New Investigator (UNI) Grant Application, American Chemical Society Petroleum Research Fund, Submitted August 2008, Denied February 2009.
- *Using HOMO-Raising Chiral Auxiliaries to Engender Stereoselective Diels-Alder Reactions: Toward the Synthesis of Alkaloids Used in the Pharmacotherapy of Drug Addiction*, Early Career Award in Chemistry of Drug Abuse and Addiction (ECHEM) – National Institute on Drug Abuse, PAS-07-327, National Institutes of Health R03 Grant Application, Submitted October 2008, Denied February 2009.
- *Quest to Develop a Greener, More General Catalytic, Asymmetric Aziridination Reaction Using Recyclable Hypervalent Iodine Reagents*, Cottrell College Science Award Application, Research Corporation, Full proposal submitted November 2008, Denied April 2009
- *The Development of a General, Environmentally Friendly Strategy for the Catalytic, Asymmetric Aziridination of Aliphatic Olefins*, 2008 Dreyfus Faculty Start-Up Award Application, Camille and Henry Dreyfus Foundation, Inc., Submitted May 2008, Denied July 2008

## Internal Funding Activity

- *Developing an Environmentally Friendly and Industrially Useful Chemical Reaction Reaction Using Recyclable Iodine(III) Reagents*, Application for the 2009 Summer Research Grant Competition, Submitted February 2009, Denied March 2009
- *An Air- and Moisture-Free Workstation for Chemistry Research and Teaching at CWU*, Application for the Spring 2008 Equipment Grant Competition sponsored by the Office of Graduate Studies and Research, Submitted April 2008, Denied June 2008

- *Safe and Reliable Solvent Purification for Chemistry Research and Teaching Labs at CWU*, Application for the Spring 2008 Equipment Grant Competition sponsored by the Office of Graduate Studies and Research, Submitted April 2008, Denied June 2008
- *Development of a General and Environmentally Friendly Catalytic, Asymmetric Aziridination Reaction Using Recyclable Iodine(III) Reagents*, Application for the 2008 Summer Research Grant Competition, Submitted February 2008, Denied March 2008

### Honors and Awards

- Scholar of the College, Boston College, 1999 (one of only 23 students to receive this honor)
- Dean's List, Boston College, 1995–1999
- Member of the Boston College Chapter of the Golden Key National Honor Society, 1998–present

### Teaching Experience

- **Central Washington University**
  - Course instructor for CHEM 363LAB.001 and CHEM 363LAB.003 (Spring 2008)
  - Course instructor for CHEM 361.001 lecture and CHEM 361LAB.002 (Fall 2008)
  - Course instructor for CHEM 362.001 lecture and CHEM 361LAB.001 (Winter 2009)
  - Course instructor for CHEM 363.001 lecture, CHEM 363LAB.004 (Spring 2009) and CHEM 565 (Organic Synthesis I) – a new course I created at CWU
- **Colorado State University** (2006–2008)  
Served as a departmental tutor of organic chemistry
- **University of California, Irvine** (1999–2001)  
Teaching assistant for undergraduate organic chemistry laboratories (CH 51LA and 51LB) for four academic quarters, a general chemistry laboratory (CH 1B), and head teaching assistant for an undergraduate organic chemistry lecture (CH 51A, taught by Professor Gregory A. Weiss, Department of Chemistry, University of California, Irvine)

### Undergraduate Researchers Mentored

- **Fall Quarter 2008:** Miss Kellie Mullen and Mr. Joshua Burwell
- **Winter Quarter 2009:** Miss Kellie Mullen and Miss Sarah Clark
- **Spring Quarter 2009:** Miss Sarah Clark (2009-2010 Science Honors Program Scholar), Mrs. Maria Godinez (2009-2010 Ronald E. McNair Scholar), Mr. Tim Ausink

### Professional Activities

- Member of the American Chemical Society (Division of Organic Chemistry) since 1999
- Served as referee for manuscripts submitted to the journals *Tetrahedron*, *Organic Letters*, and the *European Journal of Organic Chemistry*
- Attended POGIL (Process Oriented Guided Inquiry Learning) workshop at the 2008 ACS Northwest/Rocky Mountain Combined Regional Meeting (June 2008, Park City, UT)

### University Service

- Undergraduate Assessment Committee, CWU Chemistry Department (September 2008–present)
- Graduate Committee, CWU Chemistry Department (September 2008–present)
- Academic Advisor, CWU Chemistry Department (September 2008–present)

## Anthony Lee Diaz

Department of Chemistry  
Central Washington University  
Ellensburg, WA 98926

tel: 509-963-2818  
email: diaza@cwu.edu

### Education

Ph.D. Solid-State Chemistry, Oregon State University, September 1996 (GPA 4.00)  
M.S. Surface Chemistry, Western Washington University, June 1993 (GPA 4.00)  
B.S. Chemistry, University of Washington, June 1991 (GPA 3.91)  
Undergraduate Studies, University of California, Berkeley, 8/86 – 12/89 (GPA 2.88)

### Teaching/Research Experience

Assistant Professor of Chemistry, Central Washington University (9/00 – 6/05)

Associate Professor of Chemistry, Central Washington University (9/05 – present)

Provide instruction in general, inorganic and physical chemistry at the undergraduate and graduate level. Mentor graduate and undergraduate research in the area of solid-state luminescence.

Principal Scientist, Lamp Phosphor Research, OSRAM SYLVANIA (10/96 – 8/00)

Developed new luminescent materials for lighting and display applications. Modified/improved existing materials, including the development of novel synthetic methods. Conducted fundamental research on the physics and chemistry of solid-state phosphors.

### Honors and Awards

Excellence in Teaching Award, Alumni Association, Central Washington University, 2001

Benedict Award, Outstanding Second Year Graduate Student, Department of Chemistry,  
Oregon State University, 1994 – 1995

Oregon Sports Lottery Scholarship, Oregon State University, 1994 – 1995

Ingram Award, Outstanding First Year Graduate Student, Department of Chemistry, Oregon  
State University, 1993 – 1994

Laboratory Teaching Assistant Award, Dept. of Chemistry, Oregon State University, 1994

Outstanding Master's Thesis Award, Western Association of Graduate Schools, 1993

American Vacuum Society Student Prize, 39<sup>th</sup> National Symposium, Chicago, IL, 1992

Paul C. Cross Award, Physical Chemistry Student of the Year, Dept. of Chemistry, University  
of Washington, 1990

## **External Research Grants**

### National Science Foundation – Research at Undergraduate Institutions

*Investigation of Surface Loss Processes in Nano-scale Luminescent Materials*

\$145,463 – Applied 10/30/08. **Awarded** 5/09.

### Coherent, Inc. – Private Research Contract

*Phosphors for Laser Power and Energy Sensors*

**Original award** \$18,000 for 1/1/06 – 12/31/06

**Renewed** for \$28,000 for 1/1/07 – 12/31/07

**Renewed** for \$28,000 for 1/1/08 – 12/31/08

### National Science Foundation – Research at Undergraduate Institutions

*Electron Transport and Trapping Processes in Luminescent Materials*

\$125,315 – Applied 10/30/06. Not funded.

### American Chemical Society – Petroleum Research Fund

*Energy Flow and Trapping Processes in Luminescent Materials Under Vacuum Ultraviolet Excitation*

\$50,000 (plus \$2,000 CWU matching funds) – Applied 4/05, **awarded** 6/06 PRF# 43841- B10.

### National Science Foundation – Research at Undergraduate Institutions

*Electron Transport and Trapping Processes in Luminescent Materials Under VUV Excitation*

\$141,902 – Applied 10/30/05. Not funded.

### OSRAM SYLVANIA, Inc.

*Research collaboration between Professor Anthony Diaz, Department of Chemistry, Central Washington University and the Phosphor Research and Development Group of OSRAM SYLVANIA, Towanda, PA - 10/3/02*

Requested \$36,851 10/03, **awarded** \$16,545 4/03.

### Research Corporation- Cottrell College Science Award (Renewal)

*Fundamental Investigations of the Vacuum Ultraviolet Properties of New Luminescent Materials*

\$23,846 (plus \$7,515 CWU matching funds)- Applied 11/15/02, **awarded** 5/01 as CC5851

### OSRAM SYLVANIA, Inc.

*Proposed research collaboration between Professor Anthony Diaz, Department of Chemistry, Central Washington University and the Phosphor Research and Development Group of OSRAM SYLVANIA, Towanda, PA*

\$40,000 – Applied 10/00, **awarded** 5/01.

### Research Corporation- Cottrell College Science Awards

*Fundamental Studies of Vacuum Ultraviolet Damage Processes in Luminescent Materials*

\$36,763 (plus \$21,692 CWU matching funds) – Applied 11/00, **awarded** 5/01 as CC5347

**Publications** (undergraduate co-authors appear in bold. 1 – 8 are independent contributions of the PI from work at Central Washington University)

1. **R. Atkins** and A. L. Diaz, "Investigation of host-to-activator energy transfer and surface losses in  $\text{SrY}_2\text{O}_4:\text{Eu}^{3+}$  under VUV excitation", *Journal of Luminescence*, **128** 1463 – 1470 (2008).
2. **T. Watrous-Kelley** (CWU Masters student), A. L. Diaz and T. A. Dang, "Quantitative Determination of Non-Radiative Host-to-Activator Energy Transfer Efficiencies in  $\text{YBO}_3:\text{Eu}^{3+}$  and  $\text{Y}_2\text{O}_3:\text{Eu}^{3+}$  Under VUV Excitation", *Chemistry of Materials*, **18** 3130 – 3136 (2006).
3. **B. Dawson** and A. L. Diaz, "Crystal Chemistry, Defect Chemistry, and Degradation Processes in  $\text{BaMgAl}_{10}\text{O}_{17}:\text{Eu}^{2+}$ ", *Proceedings of the 12<sup>th</sup> International Display Workshops*, **1** 509 – 512 (2005). Invited.
4. **B. Dawson, M. Ferguson**, G. Marking and A. L. Diaz, "Mechanisms of VUV Damage in  $\text{BaMgAl}_{10}\text{O}_{17}:\text{Eu}^{2+}$ ", *Chemistry of Materials*, **16** 5311 – 5317 (2004).
5. **B. Howe** and A. L. Diaz, "Characterization of Host Lattice Emission and Energy Transfer in  $\text{BaMgAl}_{10}\text{O}_{17}$ ," *Journal of Luminescence*, **109** 51 – 59 (2004).
6. A. L. Diaz, "Semiconductors," *Chemistry: Foundations and Applications*, J. J. Lagowski, ed. Macmillan Reference USA (2004) pp. 117 - 123.
7. **V. Pike, S. Patraw**, A. L. Diaz and B. G. DeBoer, "Defect Chemistry and VUV Optical Properties of the  $\text{BaMgAl}_{10}\text{O}_{17}:\text{Eu}^{2+}$  -  $\text{Ba}_{0.75}\text{Al}_{11}\text{O}_{17.25}:\text{Eu}^{2+}$  Solid Solution," *Journal of Solid State Chemistry*, **173** 359 – 366 (2003).
8. **D. B. Bolstad** and A. L. Diaz, "Synthesis and Characterization of Nanocrystalline  $\text{Y}_2\text{O}_3:\text{Eu}^{3+}$  Phosphor: An Upper-Division Inorganic Chemistry Laboratory," *Journal of Chemical Education*, **79** 1101 - 1104 (2002).
9. A. L. Diaz, B. G. DeBoer and C. F. Chenot, "Effect of Stoichiometry on the Luminescence and Thermal Stability of  $\text{BaMgAl}_{10}\text{O}_{17}:\text{Eu}^{2+}$ ," *19<sup>th</sup> International Display Research Conference Proceedings*, 65 – 68 (1999).
10. D. A. Keszler and A. L. Diaz, " $\text{Eu}^{2+}$  Luminescence Color: A Structure-Property Relationship," *Materials Research Society Symposium Proceedings*, **453** 247 – 252 (1997).
11. A. L. Diaz and D. A. Keszler, " $\text{Eu}^{2+}$  Luminescence in the Borates  $\text{X}_2\text{Z}(\text{BO}_3)_2$  (X = Ba, Sr; Z = Mg, Ca)," *Chemistry of Materials*, **9** 2071 – 2077 (1997).
12. A. L. Diaz and D. A. Keszler, "Red, Green, and Blue  $\text{Eu}^{2+}$  Luminescence in Solid State Borates: A Structure-Property Relationship," *Materials Research Bulletin*, **31** 147 – 151 (1996).
13. A. L. Diaz, C. Radzewich and M. Wicholas, "Synthesis and  $^1\text{H}$  VT-NMR Conformational Analysis of Bis( $\eta^5$ -cyclopentadienyl) Titanium Pentasulfide: An Experiment for an Integrated, Advanced Laboratory Course," *Journal of Chemical Education*, **72** 937 – 938 (1995).
14. A. L. Diaz, W. W. C. Quigley, H. D. Yamamoto and M. E. Bussell, "Infrared Spectroscopy and Temperature Programmed Desorption Study of CO on  $\text{Rh}/\text{Al}_2\text{O}_3$  Catalysts: Probing Overlayer and Support Sites," *Langmuir*, **10** 1461 – 1471 (1994).
15. A. L. Diaz and M. E. Bussell, "An Infrared Spectroscopy and Temperature Programmed Desorption Study of CO on  $\text{MoO}_3/\text{Al}_2\text{O}_3$  Catalysts: Quantitation of the Molybdena Overlayer," *Journal of Physical Chemistry*, **97** 470 – 477 (1993).

16. M. B. Hugenschmidt, A. L. Diaz and C. T. Campbell, "Interaction of Cyclohexadiene with Pt(111) Studied by BPTDS and HREELS," *Journal of Physical Chemistry*, **96** 5974 – 5978 (1992).
17. F. C. Henn, A. L. Diaz, M. E. Bussell, M. E. Domagala, M. B. Hugenschmidt and C. T. Campbell, "The Decomposition of Cyclohexene on Pt(111): A BPTDS, HREELS Study," *Journal of Physical Chemistry*, **96** 5965 – 5974 (1992).

### U.S. Patents

1. #6,303,051 A. L. Diaz and C. F. Chenot, "Phosphate Treated Silicate Phosphor", Oct. 16, 2001.
2. #6,149,839 A. L. Diaz and J. A. Yurchisin, "Cation-treated Silicate Phosphor", Nov. 21 2000.
3. #5,976,413 A. L. Diaz, C. F. Chenot and S. A. Sonner, "Method of Preparing a Lead and Manganese Co-activated Calcium Metasilicate Phosphor", Nov. 2 1999.

### Presentations

1. A. L. Diaz, "Studies of host-to-activator energy transfer in luminescent materials," **invited**, *233<sup>rd</sup> National Meeting of the American Chemical Society*, Chicago, IL, 3/28/07
2. A. L. Diaz, "Optoelectronic devices made simple: LEDs, solar cells, and flat displays," **invited**, *Central Washington University Natural Science Seminar*, Ellensburg, WA, 5/5/06.
3. B. Dawson and A. L. Diaz, "Crystal Chemistry, Defect Chemistry, and Degradation Processes in BaMgAl<sub>10</sub>O<sub>17</sub>:Eu<sup>2+</sup>," **invited**, *12<sup>th</sup> International Display Workshops*, Takamutsu, Japan, 12/7/05.
4. B. Dawson, M. Ferguson, B. Howe and A. L. Diaz, "Mechanisms of VUV Damage in the Plasma Display Blue Phosphor BaMgAl<sub>10</sub>O<sub>17</sub>:Eu<sup>2+</sup>," *227<sup>th</sup> National Meeting of the American Chemical Society*, Anaheim, CA, 3/31/04.
5. A. L. Diaz, "Materials Science Puzzles in Display and Lighting Technologies," **invited**, *Central Washington University Natural Science Seminar*, Ellensburg, WA, 2/22/02.
6. A. L. Diaz, "Phosphor Development for Large Area Flat Panel Displays," **invited**, *Meeting of the Corning Region of the American Chemical Society*, Sayre, PA, 1/7/00.
7. A. L. Diaz, C. F. Chenot and B. G. DeBoer, "Effect of Stoichiometry on the Luminescence and Thermal Stability of BaMgAl<sub>10</sub>O<sub>17</sub>:Eu<sup>2+</sup>," *19<sup>th</sup> International Display Research Conference*, Berlin, Germany, 9/7/99.
8. A. L. Diaz and D. A. Keszler, "Structure-Property Relationships in Eu<sup>2+</sup> Luminescence in Solid State Borates," *51<sup>st</sup> Northwest Regional Meeting of the American Chemical Society*, Corvallis, OR, 6/22/96.

# Levente Fabry-Asztalos, Ph.D.

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## Education:

- 1997 – 2001 Washington State University Pullman, WA  
**Ph.D. in Chemistry** (Organic) - 2001  
Thesis Title: “Asymmetric synthesis of organoboron compounds bearing peptides and other nitrogen containing substituents”  
Advisor: Professor Donald S. Matteson
- 1997-2000 Washington State University Pullman, WA  
**M.S. in Chemistry** - 2000  
Advisor: Professor Donald S. Matteson
- 1995-1997 Washington State University Pullman, WA  
**B.A. in Anthropology** - 1997  
**B.S. in Biochemistry** - 1996
- 1992 - 1994 Vasile Goldis University Arad, Romania  
**School of Medicine**  
M.D. Degree Program

## Professional Experience:

- 2003-Present Central Washington University Ellensburg, WA  
Department of Chemistry  
**Assistant Professor**  
*Teaching specialty:* organic chemistry, medicinal chemistry.  
*Research interests:* design and synthesis of inhibitors against enzymes responsible for the proliferation of disease states such as cancer and HIV; asymmetric synthesis; molecular modeling, computational chemistry.
- Summer of 2008 Central Washington University Ellensburg, WA  
College of the Sciences  
**Interim Science Honors Program Director**
- ◆ Monitored research student progress and student/mentor relationship; provided needed advising and counseling
  - ◆ Scheduled and coordinated weekly meetings of research students and faculty mentors
  - ◆ Worked with the fiscal technician to oversee the budget and keep track of spending
- 2001-2003 University of Wisconsin Madison, WI  
Department of Chemistry and School of Pharmacy  
**Post-doctoral Research Associate**  
Advisor: Professor Daniel H. Rich

- ◆ Developed syntheses and designed novel non-peptide peptidomimetic aspartic protease  $\beta$ -secretase inhibitor scaffolds
- ◆ Designed novel metalloprotease anthrax lethal factor inhibitors

1999 – 2001 Washington State University Pullman, WA  
Department of Chemistry

**Research Assistant**

- ◆ Developed a synthetic method for the asymmetric synthesis of boron modified peptides which have HIV-1 protease dual mode inhibitory activity. Synthesized peptidyl boronic acids and a new class of boron compounds, peptidyl boronate chelates.
- ◆ Developed a new method for the synthesis of alkylhaloborane-amine complexes and diol sulfites

1996 – 1999 Washington State University Pullman, WA  
Department of Chemistry

**Teaching Assistant; Head Teaching Assistant from 08/98**

- ◆ Trained, coordinated, and supervised teaching assistants
- ◆ Performed laboratory instruction of undergraduate organic chemistry laboratory classes
- ◆ Performed substitute teaching for undergraduate organic chemistry classes when professors had other commitments

1995 – 1999 Washington State University Pullman, WA  
Student Advising and Learning Center

**Preceptor**

- ◆ Taught organic chemistry at all levels for undergraduates

**Awards:**

2007 Included in the 2007 national edition of *Who's Who Among America's Teachers*.

2007 Received merit based performance adjustment at Central Washington University

2006 Included in the 2006 national edition of *Who's Who Among America's Teachers*.

2005 One of my students at Central Washington University made a gift in my honor to the Senior Gift Scholarship Campaign, May 2005.

2004 Nominated for Most Inspirational Educator, Central Washington University

1999 Outstanding Service as a Peer Tutor, Washington State University

1998 Outstanding Service as a Peer Tutor, Washington State University

1996 Tutor of the Year, Washington State University

**Research Student Awards:**

2008 SOURCE at CWU, Amanda Blackmore, undergraduate student. Oral presentation received Outstanding Student Presentation Award.

2008 SOURCE at CWU, Badi' Abdul-Wahid and Grant Barker, undergraduate and graduate student, respectively. Oral presentation received Outstanding Student Presentation Award.

- 2006 IEEE International Joint Conference on Neural Networks, Razvan Andonie, Levente Fabry-Asztalos, Sarah Abdul-Wahid, Catharine J. Collar, Nicholas Salim. Oral presentation received Best Session Presentation Award.
- 2005 SOURCE at CWU, Heather N. Biles undergraduate and Catharine J. Collar graduate students. Poster received Honorary Mention.
- 2004 SOURCE at CWU, Meagan L. Ansingh, Gayle H. Smith, and Catharine J. Collar, undergraduate students. Poster received Honorary Mention.

#### Courses taught at Central Washington University:

CHEM 564	(3 Credits)	Medicinal Organic Chemistry
CHEM 505	(1 Credit)	Current Topics in Chemistry: Medicinal Chemistry
CHEM 503	(1 Credit)	Introduction to Research
CHEM 488	(1 Credit)	Chemistry Colloquium
CHEM 388	(1 Credit)	Chemistry Colloquium
CHEM 363	(3 Credits)	Organic Chemistry III
CHEM 363Lab	(2 Credits)	Qualitative Organic Chemistry Laboratory
CHEM 362	(3 Credits)	Organic Chemistry II
CHEM 361	(3 Credits)	Organic Chemistry I
CHEM 361Lab	(2 Credits)	Organic Chemistry Laboratory
CHEM 111	(4 Credits)	Introduction to Chemistry
CHEM 111Lab	(1 Credit)	Chemistry Laboratory

#### Master's Theses Directed at Central Washington University:

##### As Committee Chair:

- Catharine J. Collar Independent Studies, *Molecular Modeling of Four Aspartic Protease Enzymes and Their Inhibitors*. Thesis Advisor, 09/04-05/06.
- Yinshan Jia Chemistry, *Investigation of Potential Boronated HIV-1 Protease Inhibitory Compounds*. Thesis Advisor, 09/03-05/06.
- Grant I. Barker Chemistry, *Computer modeling and neural networks used in the design and synthesis of novel  $\beta$ -secretase inhibitors for the therapeutic treatment of Alzheimer's disease*. Thesis Advisor, 09/06-Present.
- Pei-Mien Chen Chemistry, *Synthesis of Cyclic Boronates as Potential HIV-1 Protease Inhibitors*. Thesis Advisor, 09/06-Present.
- Jesse L. Nye Chemistry, *Synthesis of 5,6-Dihydropyran-2-ones and Cyclic Boronates as Potential HIV-1 Protease Inhibitors*. Thesis Advisor, 09/08-Present.

##### As Committee Member:

- Nathaneal G. Palmatier Chemistry, *Computational Study of Carbenoid Derived Aromatic Compounds*. 06/04-02/05.
- Amy A. Diaz Chemistry, *Quantitative Analysis of Total Hydroxyl Radical Produced in Mitochondria Under Conditions of Oxidative Stress*. 11/04-07/06.

Ryan Jorgensen                      Chemistry, *Preparation and Characterization of a Template Imprinted Silica Gel Surface*. 04/06-05/08.

**Undergraduate Research Projects Directed at Central Washington University:**

Gayle H. Smith                      *Molecular and Statistical Analysis of Known and Newly Designed HIV-1 Protease Inhibitors*. 09/03-12/04.

Meagan L. Ansingh                      *Molecular and Statistical Analysis of Known and Newly Designed HIV-1 Protease Inhibitors*. 09/03-03/06.

Catharine J. Collar                      *Molecular Modeling and Statistical Analysis of HIV-1 Protease Inhibitors*. 09/03-06/04.

Trung H. Ke                              *The Importance of Boronates as Enzyme Inhibitors*. 09/03-06/04.

Nicholas Salim                              *Application of a Fuzzy Neural Network to Predict IC<sub>50</sub> Values of Potential HIV-1 Protease Inhibitors. Synthesis of Novel Potential HIV-1 Protease Inhibitors*. 03/04-08/06. **Science Honors student.**

Kaori Noridomi                              *Matrix Metallo Protease Inhibitors. Synthesis of a precursor for 5,5-dihydropyran-2-ones as potential HIV-1 protease inhibitors*. 03/04-05/06.

Cheryl Ermev                              *The Role of Proteasome Inhibitors in Cancer Therapy. Synthesis of Dimethyl Benzyl Boronate*. 03/04-03/05.

Erin B. Eichler                              *Cathepsin D and Alzheimer's*. 03/04-06/04.

Heather N. Biles                              *Analyzing Force Field and Charge Conditions to Enhance Biological Activity Predictions of Cathepsin D Inhibitors*. 08/04-05/06. **Science Honors student.**

Michael W. Ellis                              *Creating a Model for Cathepsin D Inhibitors Using Computational and Statistical Software*. 08/04-03/06.

Faith Winslow                              *Synthesis of 1,3-Azaborine Precursors*. 01/05-03/05.

Jonathan Schwab                              *Molecular and Statistical Analysis of Known and Newly Designed HIV-1 Protease Inhibitors*. 01/05-06/05.

Elizabeth F. Scott                              *Molecular and Statistical Analysis of Known and Newly Designed HIV-1 Protease Inhibitors*. 03/05-03/06.

Jessica A. McAbee                              *Design of Novel Structures Targeting Enzymes Involved in Cancer Cell Proliferation*. 07/05-03/06.

Tajinder S. Heer                              *Synthesis of 1,3-Azaborines as Novel HIV-1 Protease Inhibitors*. 03/05-06/07. **Science Honors student.**

David V. Nguyen                              *Synthesis of Novel 1,3-Azaborine Heterocycles as Potential HIV-1 Protease Inhibitors*. 07/05-05/07.

Tracy K. O'Connell                              *Organic Synthesis of a Precursor to a Potential HIV-1 Protease Inhibitor*. 09/05-05/07.

Christopher Badi' Abdul-Wahid                              *The Rational Design of Novel Plasmodium falciparum Plasmepsin IV Inhibitors, Aided by a Fuzzy Neural Network*. 09/05-Present. **Science Honors student.**

Amanda C. Blackmore                              *Synthesis of Novel Cyclic Boronated Potential HIV-1 Protease Inhibitors*. 09/06-06/08. **Science Honors student.**

Jesse L. Nye                                      *Synthesis of 5,6-dihydropyran-2-ones as potential inhibitors of HIV-1 protease*. 01/07-08/08. **Science Honors student.**

Scott A. Palmer                              *Synthesis of Four Novel 5,6-Dihydropyran-2-ones as Potential HIV-1 Protease Inhibitors*. 01/07-06/08.

Lee Ream                                      *Synthesis of Novel 1,3-Azaborine Heterocycles as Potential HIV-1 Protease Inhibitors*. 07/07-Present.

Elizabeth P. Nikolaeva                              *Synthesis of Novel Cyclic Boronated Potential HIV-1 Protease*

	<i>Inhibitors</i> . 03/08-Present.
Donald R. Clayton	<i>Synthesis of Novel Cyclic Boronated Potential HIV-1 Protease Inhibitors</i> . 03/08-Present.
Christopher Marshall	<i>The Study and Synthesis of Novel Cathepsin D Inhibitors</i> . 01/09-Present.
Jeffrey Nelson	<i>The Study and Synthesis of Novel Cathepsin D Inhibitors</i> . 01/09-Present.
Matthew McCammant	<i>Synthesis of Novel Cyclic Boronated Potential HIV-1 Protease Inhibitors</i> . 04/09-Present.

**Refereed Publications:**

“A Quantitative Structure-Activity Relationship Study of HIV-1 Protease Inhibitors Using a Small Molecular Dataset” Razvan Andonie, Levente Fabry-Asztalos, Christopher B. Abdul-Wahid, Grant I. Barker, Lukas Magill, Sarah Abdul-Wahid, *IEEE/ACM Transactions on Computational Biology and Bioinformatics*, accepted.

“Fuzzy ARTMAP Rule Extraction in Computational Chemistry” Razvan Andonie, Levente Fabry-Asztalos, Bogdan Crivat, Sarah Abdul-Wahid, Christopher B. Abdul-Wahid *Proceedings of the IEEE International Joint Conference on Neural Networks (IJCNN 2009)*, accepted.

“Synthesis of a ( $\beta$ -Acetamido- $\alpha$ -acetoxyethyl)boronic Ester via Azido Boronic Esters” Matteson, D. S.; Maliakal, D.; Fabry-Asztalos, L. *Journal of Organometallic Chemistry*, **2008**, 693, 2258-2262.

“A Genetic Algorithm Optimized Fuzzy Neural Network Analysis of the Affinity of Inhibitors for HIV-1 Protease” Levente Fabry-Asztalos, Razvan Andonie, Catharine J. Collar, Sarah Abdul-Wahid, Nicholas Salim *Bioorganic & Medicinal Chemistry*, **2008**, 6, 2903-2911.

“A New Fuzzy ARTMAP Approach for Predicting Biological Activity of Potential HIV-1 Protease Inhibitors” Razvan Andonie, Levente Fabry-Asztalos, Lukas Magill, Sarah Abdul-Wahid *Proceedings of the IEEE International Conference on Bioinformatics and Biomedicine (BIBM 2007)*, **2007**, 56-61.

“An Integrated Soft Computing Approach for Predicting Biological Activity of Potential HIV-1 Protease Inhibitors” Andonie, R.; Fabry-Asztalos, L.; Abdul-Wahid, S.; Collar, C. J.; Salim, N. *Proceedings of the IEEE International Joint Conference on Neural Networks (IJCNN 2006)*, **2006**, 7495-7502.

“Neuro-fuzzy Prediction of Biological Activity and Rule Extraction for HIV-1 Protease Inhibitors” Andonie, R.; Fabry-Asztalos, L.; Collar, C. J.; Abdul-Wahid, S.; Salim, N. *Proceedings of the IEEE Symposium on Computational Intelligence in Bioinformatics and Computational Biology (CIBCB 2005)*, San Diego, **2005**, 113-120.

“Glass Catalyzed Conversion of Boronic Esters of Asymmetric Diols to Diol Sulfites and Amine Complexes of Boron Halides” Matteson, D.S.; Hiscox, W.C.; Fabry-Asztalos, L.; Kim, G.; Siems, W.F. III. *Organometallics*, **2001**, 20, 2920-2923.

“Efficient Syntheses of Fluorinated Aryl Alcohols of High Enantiomeric Purity via Boronic Esters” Singh, R. P.; Twamley, B.; Fabry-Asztalos, L.; Matteson, D. S.; Shreeve, J. M. *J.*

“Inhibition of HIV-1 Protease by a Boron-Modified Polypeptide” Pivazyan, A. D.; Matteson, D. S.; Fabry-Asztalos, L.; Singh, R. P.; Lin, P.; Blair, W.; Guo, K.; Robinson, B.; Prusoff, W. H. *Biochem. Pharma.*, **2000**, 60, 927-936.

**Patent:**

“Preparation of borinic acid peptide derivatives as protease inhibitors” Matteson, D. S.; Fabry-Asztalos, L.; Prusoff, W. H.; Pivazyan, A. D. PCT Int. Appl. **2003**, 50 pp., CODEN:PIXXD2 WO 0315706 A2 20030227 CAN 138:188075 AN 2003: 154193.

**Invited Seminars/Presentations:**

- September 2008 “Towards the Synthesis of Novel Boronates as Potential HIV-1 Protease Inhibitors,” XXth International Symposium on Medicinal Chemistry, Vienna, Austria, poster presentation.
- June 2007 “Towards the Synthesis of Novel Borinic Acids as Potential HIV-1 Protease Inhibitors,” 88<sup>th</sup> Annual Meeting of the Pacific Division of the American Association for the Advancement of Science, Boise, ID.
- February 2007 “Design and Synthesis of Novel Aspartic Protease Inhibitors,” Natural Sciences Seminar Series, Central Washington University, Ellensburg, WA.
- July 2006 “A Comparative Study of Global Education.” Central Washington University, Des Moines Center, Des Moines, WA.
- July 2005 “A Comparative Study of Global Education.” Central Washington University, Des Moines Center, Des Moines, WA.
- April 2005 “Design and Synthesis of Novel Aspartic Protease Inhibitors,” Willamette University, Salem, OR.
- October 2004 “Design and Synthesis of Novel Aspartic Protease Inhibitors,” Boise State University, Boise, ID.
- July 2004 “A Comparative Study of Global Education.” Central Washington University-SeaTac Center, SeaTac, WA.
- March 2004 “Towards Alzheimer's Disease Therapies. Design and Synthesis of Potential  $\beta$ -Secretase Inhibitors,” Washington State University, Pullman, WA.

**Student Research Presentations:**

“Synthesis Towards 5,6-Dihydropyran-2-ones as Potential Inhibitors of HIV-1 Protease” Jesse Nye, Levente Fabry-Asztalos\*, oral presentation at the Pacific Northwest Undergraduate Research Symposium on Organic Chemistry, Corvallis, OR, August 11, 2008.

”Synthesis Towards Novel 1,3-Azaborine Heterocycles as Potential Dual-Mode HIV-1 Protease Inhibitors” Amanda Blackmore, Levente Fabry-Asztalos\*, oral presentation at CWU-

”Synthesis of 5,6-Dihydropyran-2-ones as Potential Inhibitors of HIV-1 Protease” Jesse Nye, Levente Fabry-Asztalos\*, oral presentation at CWU-SOURCE 2008, Ellensburg, WA, May 15, 2008.

”Computer Modeling and Neural Networks Used in the Design of Novel HIV-1 Protease Inhibitors for the Therapeutic Treatment of HIV/AIDS” Grant Barker, Levente Fabry-Asztalos\*, Razvan Andonie\*, oral presentation at CWU-SOURCE 2008, Ellensburg, WA, May 15, 2008.

”Ordered Fuzzy ARTMAP for Predicting HIV-1 Protease Inhibitor Activity” Badi’ Abdul-Wahid, Grant Barker, Razvan Andonie\*, Levente Fabry-Asztalos\*, oral presentation at CWU-SOURCE 2008, Ellensburg, WA, May 15, 2008.

”Synthesis of Novel 1,3-Azaborines as Potential Dual-Mode HIV-1 Protease Inhibitors for the Treatment of HIV/AIDS” Pei-Mien Chen, Lee Ream, Levente Fabry-Asztalos\*, poster presentation at CWU-SOURCE 2008, Ellensburg, WA, May 15, 2008.

”Synthesis of Four Novel 5,6-Dihydropyran-2-ones as Potential HIV-1 Protease Inhibitors” Scott Palmer, Levente Fabry-Asztalos\*, poster presentation at CWU-SOURCE 2008, Ellensburg, WA, May 15, 2008.

”Prediction of Novel Inhibitors Targeting Malarial *Plasmodium Falciparum* Plasmepsin IV” Badi’ Abdul-Wahid, Levente Fabry-Asztalos\*, Razvan Andonie\*, poster presentation at CWU-SOURCE 2008, Ellensburg, WA, May 15, 2008.

”Solvent [BMIM][OTF]: New Life for a Classic Transformation” Kelley Brown, Casey Kellar, Paul Charlton, Viorel D. Sarca\*, Levente Fabry-Asztalos\*, poster presentation at CWU-SOURCE 2008, Ellensburg, WA, May 15, 2008.

”Synthesis of 5,6-Dihydropyran-2-ones as Potential Inhibitors of HIV-1 Protease” Jesse Nye, Scott Palmer, Levente Fabry-Asztalos\*, poster presentation at the 2008 American Chemical Society Puget Sound Section Undergraduate Research Symposium, Olympia, WA, April 26, 2008.

”Synthesis towards novel 1,3-azaborine heterocycles as potential dual-mode HIV-1 protease inhibitors” Amanda C. Blackmore, Pei-Mien Chen, Lee Ream, Levente Fabry-Asztalos\*, poster presentation at the 2008 American Chemical Society Puget Sound Section Undergraduate Research Symposium, Olympia, WA, April 26, 2008.

”Ordered Fuzzy ARTMAP for Predicting HIV-1 Protease Inhibitor Activity” C. Badi’ Abdul-Wahid, Grant I. Barker, Razvan Andonie, Levente Fabry-Asztalos\*, oral presentation at the 2008 American Chemical Society Puget Sound Section Undergraduate Research Symposium, Olympia, WA, April 26, 2008.

”Synthesis towards novel 1,3-azaborine heterocycles as potential dual-mode HIV-1 protease inhibitors” Amanda C. Blackmore, Levente Fabry-Asztalos\*, poster presentation at the 235th American Chemical Society National Meeting, New Orleans, LA, April 6-10, 2008.

“A New Fuzzy ARTMAP Approach for Predicting Biological Activity of Potential HIV-1 Protease Inhibitors” Razvan Andonie\*, Levente Fabry-Asztalos\*, Lukas Magill, Sarah Abdul-Wahid, oral presentation at *IEEE International Conference on Bioinformatics and Biomedicine (BIBM 2007)*, Silicon Valley, CA, November 2, 2007.

“Synthesis of 5,6-Dihydropyran-2-one as Potential Inhibitors of HIV-1 Protease” Jesse L. Nye, Levente Fabry-Asztalos\*, poster presentation at the 16<sup>th</sup> Regional Murdock Conference on Undergraduate Research, Salem, OR, November 2, 2007.

“Synthesis of Novel Cyclic Boronated Potential HIV-1 Protease Inhibitors” Amanda C. Blackmore, Levente Fabry-Asztalos\*, poster presentation at 16<sup>th</sup> Regional Murdock Conference on Undergraduate Research, Salem, OR, November 2, 2007.

”Synthesis Towards Novel Straight Chain Borinic Acid Potential HIV-1 Protease Inhibitors” Tajinder Heer, Levente Fabry-Asztalos\*, oral presentation at CWU-SOURCE 2007, Ellensburg, WA, May 17, 2007.

”Dimensional abstraction: Generating novel potential inhibitors of Malarial Plasmeprin IV using computational methodologies” Christopher B. Abdul-Wahid, Sarah Abdul-Wahid, Levente Fabry-Asztalos\*, Razvan Andonie\*, oral presentation at CWU-SOURCE 2007, Ellensburg, WA, May 17, 2007.

“Synthesis Towards 1,3-Azaborine Heterocycles as Potential HIV-1 Protease Inhibitors” David V. Nguyen, Tracy K. O’Connell, Pei-Mien Chen, Amanda C. Blackmore, Levente Fabry-Asztalos\*, poster presentation at CWU-SOURCE 2007, Ellensburg, WA, May 17, 2007.

”Fuzzy ARTMAP with Relevances with Genetic Algorithm Optimization for Predicting Properties of HIV-1 Protease Inhibitors” Luke Magill, Razvan Andonie\*, Levente Fabry-Asztalos\*, oral presentation at CWU-SOURCE 2007, Ellensburg, WA, May 17, 2007.

“Synthesis Towards Novel Straight Chain and Cyclic Borinic Acid Potential HIV-1 Protease Inhibitors” Tajinder S. Heer, David V. Nguyen, Tracy K. O’Connell, Levente Fabry-Asztalos\*, poster presentation at the 2007 American Chemical Society Puget Sound Section Undergraduate Research Symposium, Tacoma, WA, May 12, 2007.

“Generating novel potential inhibitors of Malarial Plasmeprin IV using computational methodologies” Badi’ Adbul-Wahid, Sarah Abdul-Wahid, Levente Fabry-Asztalos\*, Razvan Andonie\*, poster presentation at the 2007 American Chemical Society Puget Sound Section Undergraduate Research Symposium, Tacoma, WA, May 12, 2007.

“Synthesis of Novel Borinic Acids as Potential HIV-1 Protease Inhibitors” Yinshan Jia, Tajinder Heer, David Nguyen, Tracy K. O’Connell, Levente Fabry-Asztalos\*, poster presentation at the 233<sup>rd</sup> American Chemical Society National Meeting, Chicago, IL, March 25-29, 2007.

“*In silico* study of *Plasmodium falciparum* proteases Plasmeprin II and IV: Prediction of biological activity of newly designed inhibitors” Badi’ Adbul-Wahid, Sarah Abdul-Wahid, Levente Fabry-Asztalos\*, Razvan Andonie\*, poster presentation at the 233<sup>rd</sup> American Chemical Society National Meeting, Chicago, IL, March 25-29, 2007.

“Synthesis of Novel Borinic Acids as Potential HIV-1 Protease Inhibitors” Tajinder Heer, Nicholas Salim, Tracy K. O’Connell, David Nguyen, Levente Fabry-Asztalos\*, poster presentation at 15<sup>th</sup> Regional Murdock Conference on Undergraduate Research, Portland, OR October 20, 2006.

“Synthesis of 5,6-Dihydropyran-2-one Analogues as Potential HIV-1 Protease Inhibitors” Nicholas Salim, Kaori Noridomi, Tracy O’Connell, Levente Fabry-Asztalos\*, poster presentation at CWU-SOURCE 2006, Ellensburg, WA, May 18, 2006.

“Synthesis of Novel Boronated HIV-1 Protease Dual-mode Inhibitors” Tajinder Heer, David Nguyen, Yinshan Jia, Levente Fabry-Asztalos\*, poster presentation at CWU-SOURCE 2006, Ellensburg, WA, May 18, 2006.

”An Integrated Computational Intelligence Approach for Predicting Biological Activity of Potential HIV-1 Protease Inhibitors” Sarah Abdul-Wahid, Catharine Collar, Nicholas Salim, Razvan Andonie\*, Levente Fabry-Asztalos\*, oral presentation at CWU-SOURCE 2006, Ellensburg, WA, May 18, 2006.

”Analyzing Force Field and Charge Conditions to Enhance Biological Activity Predictions of Cathepsin D Inhibitors” Heather Biles, Levente Fabry-Asztalos\*, Catharine Collar, Michael Ellis, oral presentation at CWU-SOURCE 2006, Ellensburg, WA, May 18, 2006.

“Fuzzy-neural Network Predictions of IC<sub>50</sub> Values for Potential HIV-1 Protease Inhibitors”, Nicholas Salim, Catharine J. Collar, Levente Fabry-Asztalos\*, poster presentation at the 2006 American Chemical Society Puget Sound Section Undergraduate Research Symposium, Bellingham, WA, May 6, 2006.

“Analyzing Force Field and Charge Conditions to Enhance Biological Activity Predictions of Cathepsin D Inhibitors”, Heather Biles, Catharine J. Collar, Levente Fabry-Asztalos\*, poster presentation at the 2006 American Chemical Society Puget Sound Section Undergraduate Research Symposium, Bellingham, WA, May 6, 2006.

“Application of a Fuzzy-Neural Network to Predict IC<sub>50</sub> Values for Potential HIV-1 Protease Inhibitors” Nicholas Salim, Sarah Abdul-Wahid, Catharine J. Collar, Levente Fabry-Asztalos\*, Razvan Andonie\*, poster presentation at the 331<sup>th</sup> American Chemical Society National Meeting, Atlanta, GA, March 26-30, 2006.

“Application of a Fuzzy-Neural Network to Predict IC<sub>50</sub> Values for Potential HIV-1 Protease Inhibitors” Nicholas Salim, Sarah Abdul-Wahid, Catharine J. Collar, Levente Fabry-Asztalos\*, Razvan Andonie\*, poster presentation at the 331<sup>th</sup> American Chemical Society National Meeting, Atlanta, GA, March 26-30, 2006.

“Analyzing Force Field and Charge Conditions to Enhance Biological Activity Predictions of Cathepsin D Inhibitors” Heather Biles, Michael Ellis, Catharine J. Collar, Levente Fabry-Asztalos\*, poster presentation at the 331<sup>th</sup> American Chemical Society National Meeting, Atlanta, GA, March 26-30, 2005.

“Modeling Bioactivity for Aspartic Protease Inhibitors Using Bioavailability and Physicochemical Molecular Descriptors” Catharine J. Collar and Levente Fabry-Asztalos\*,

poster presentation at the 331<sup>th</sup> American Chemical Society National Meeting, Atlanta, GA, March 26-30, 2005.

“Molecular modeling of cathepsin-D inhibitors; A comparative study with pepstatin” Heather N. Biles, Catharine J. Collar, Levente Fabry-Asztalos\*, poster presentation at 14<sup>th</sup> Regional Murdock Conference on Undergraduate Research, Nampa, ID, November 12, 2005.

“Application of fuzzy neural networks to predict IC50 values of novel HIV-1 protease inhibitors” Nicholas Salim, Catharine J. Collar, Sarah Abdul-Wahid, Levente Fabry-Asztalos\*, Răzvan Andonie\*, oral presentation at 14<sup>th</sup> Regional Murdock Conference on Undergraduate Research, Nampa, ID, November 12, 2005.

“Explicit Knowledge Extraction from Properties of Chemical Structures” Sarah Abdul-Wahid, Catharine J. Collar, Nicholas Salim, Razvan Andonie\*, Levente Fabry-Asztalos\*, poster presentation at CWU-SOURCE 2005, Ellensburg, WA, May 19, 2005.

“Regression Analysis for Biological Affinity of Cathepsin D Inhibitors in Relation to Molecular Structure and Energy” Michael W. Ellis, Catharine J. Collar, Levente Fabry-Asztalos\*, poster presentation at CWU-SOURCE 2005, Ellensburg, WA, May 19, 2005.

“Force Field and Charge Comparisons for Cathepsin-D Inhibitors” Heather N. Biles, Catharine J. Collar, Levente Fabry-Asztalos\*, poster presentation at CWU-SOURCE 2005, Ellensburg, WA, May 19, 2005. Poster received Honorary Mention.

”The Investigation of Potential Boronated HIV-1 Protease Inhibitory Compounds” Yinshan Jia, Levente Fabry-Asztalos\*, oral presentation at CWU-SOURCE 2005, Ellensburg, WA, May 19, 2005.

”Neuro-Fuzzy and Multiple Regression IC50 Prediction of HIV-1 Protease Inhibitors” Catharine Collar, Sarah Abdul-Wahid, Nicholas Salim, Levente Fabry-Asztalos\*, Razvan Andonie\*, oral presentation at CWU-SOURCE 2005, Ellensburg, WA, May 19, 2005.

”Predicting Biological Activity of HIV-1 Protease Inhibitors Using Multi-Variable Molecular Mathematical Modeling” Catharine Collar, Levente Fabry-Asztalos\*, oral presentation at CWU-SOURCE 2005, Ellensburg, WA, May 19, 2005.

“Predicting Biological Affinity of HIV-1 Protease Inhibitors Using a Neuro-Fuzzy Network” Sarah Abdul-Wahid, Nicholas Salim, Catharine J. Collar, Razvan Andonie\*, Levente Fabry-Asztalos\*, poster presentation at the 2005 American Chemical Society Puget Sound Section Undergraduate Research Symposium, Seattle, WA, April 23, 2005.

“Prediction of HIV-1 Protease Inhibitors through Molecular Modeling and Statistical Analysis” Catharine Jane Collar and Levente Fabry-Asztalos\*, poster presentation at the 229<sup>th</sup> American Chemical Society National Meeting, San Diego, CA, March 13-17, 2005.

“Molecular and statistical analysis of known and newly designed HIV-1 protease inhibitors” Meagan L. Ansingh, Gayle H. Smith, Levente Fabry-Asztalos, oral presentation at the 13<sup>th</sup> Regional Murdock Conference on Undergraduate Research, Portland, OR, November 19, 2004.

“Force fields and charges; do they really make a difference?” Gayle H. Smith, Meagan L. Ansingh, Levente Fabry-Asztalos, poster presentation at the 13<sup>th</sup> Regional Murdock Conference on Undergraduate Research, Portland, OR, November 19, 2004.

“Discovery towards novel HIV/AIDS therapies: molecular modeling of HIV-1 protease inhibitors” Meagan Ansingh, Gayle Smith, Catharine Collar, Levente Fabry-Asztalos, poster presentation at CWU-SOURCE 2004, Ellensburg, WA, May 20, 2004.

”Molecular modeling and statistical analysis of HIV-1 protease inhibitors.” Catharine Collar, Levente Fabry-Asztalos, seminar presentation at CWU-SOURCE 2004, Ellensburg, WA, May 20, 2004.

“Molecular Modeling and Statistical Analysis of HIV 1 Protease Inhibitors” Catharine Jane Collar and Levente Fabry-Asztalos, poster presentation at the 2004 American Chemical Society Puget Sound Section Undergraduate Research Symposium, Ellensburg, WA, April 24, 2004.

**Grants Written:**

PI – CWU SOAR Grant

New Drug Therapies for HIV/AIDS – 03/16/09  
Requested \$8,500 summer salary – not funded.

PI – CWU College of the Sciences Faculty Summer Research Grant

New Drug Therapies for HIV/AIDS – 02/06/09  
Requested \$3,000 for summer salary – not funded.

PI – CWU Faculty Research Appointment (FRA) Grant

New Drug Therapies for HIV/AIDS – 01/15/09  
Requested a Research Appointment for Fall 2009 – not funded.

PI – National Science Foundation – Faculty Early Career Development (CAREER) Grant

CAREER: Synthesis and Study of Cyclic and Straight-Chain Borinic Acids –  
07/24/08  
Requested \$601,349 (\$477,149 direct and \$124,200 indirect costs) – not funded.

Proposal Initiator – CWU Equipment Grant

Multidisciplinary Computational Modeling and Simulation Lab Initiative – 04/08/08  
Other proposal initiators are Drs. Razvan Andonie (Computer Science) and Lixing Sun (Biological Sciences). Requested \$36,180 – not funded.

PI – CWU Spheres of Distinction Grant

Establishing an Interdepartmental Computational Chemistry Research Center at  
Central Washington University – 03/14/08  
Grant written in collaboration with Dr. Razvan Andonie from the Computer Science  
Department Requested \$62,685 for the first year, \$6,000 for continuing years – not  
funded.

PI – CWU College of the Sciences Faculty Summer Research Grant

New Drug Therapies for HIV/AIDS – 02/07/08  
Requested \$3,000 for summer salary – funded.

## PI – CWU SOAR Grant

New Drug Therapies for HIV/AIDS – 01/15/08  
Requested \$8,500 summer salary – funded.

## PI – CWU Spheres of Distinction Grant

Establishing an Interdepartmental Computational Chemistry Research Center at  
Central Washington University – 02/28/07  
Grant written in collaboration with Dr. Razvan Andonie from the Computer Science  
Department  
Requested \$88,870 for the first two year, \$6,000 for continuing years – not funded.

## PI – CWU College of the Sciences Faculty Summer Research Grant

Predicting Biological Activities of Known and Novel HIV-1 Protease Inhibitors –  
02/23/07  
Requested \$3,000 for summer salary – not funded.

## PI - IBM

Establishing a Computational Chemistry Research Laboratory – 05/23/06  
Grant written in collaboration with Dr. Razvan Andonie from the Computer Science  
Department  
Requested \$35,200 – pending.

## PI – CWU Spheres of Distinction Grant

Establishing an Interdepartmental Computational Chemistry Research Center at  
Central Washington University – 05/09/06  
Grant written in collaboration with Dr. Razvan Andonie from the Computer Science  
Department  
Requested \$53,385 – not funded.

## PI – National Institutes of Health: Academic Research Enhancement Award (AREA)

Discovery of HIV-1 Protease Inhibitors Using Computational Intelligence – 12/30/05  
Co-PI is Dr. Razvan Andonie from the Computer Science Department  
Requested \$150,000 direct and \$53,974 indirect – not funded.

## PI - Research Corporation: Cottrell College Science Award

Novel 1,3-Azaborine Heterocycles as Aspartic Protease Inhibitors – 12/02/05  
Requested \$58,228 (\$38,828 plus \$19,400 CWU match) – funded.

## PI – CWU SOAR Grant

Using Computational Intelligence Techniques in the Design and Analysis of HIV-1  
Protease Enzyme Inhibitors – 05/16/05  
Grant written in collaboration with Dr. Razvan Andonie from the Computer Science  
Department at Central Washington University  
Requested \$4,250 summer salary – not funded.

## PI – CWU Essential Instructional/Research Equipment Grant

Establishing an Interdepartmental Computational Chemistry Research Center at  
Central Washington University – 05/16/05  
Grant written in collaboration with Dr. Razvan Andonie from the Computer Science

Curriculum Vitae – Levente Fabry-Asztalos, Ph.D.  
Department at Central Washington University  
Requested \$22,685 – not funded.

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PI – CWU Seed Grant  
Molecular Modeling of Inhibitors for Therapeutically Important Enzymes – 01/18/05  
Requested \$2,000 – funded.

PI - Research Corporation: Cottrell College Science Award  
Novel 1,3-Azaborine Heterocycles as Aspartic Protease Inhibitors – 12/01/04  
Requested \$34,828 plus \$19,400 CWU match – not funded.

PI – CWU Essential Instructional/Research Equipment Grant  
Molecular Modeling of Lead Compounds for Drug Development – 04/19/04  
Requested \$8,700 – not funded.

PI – CWU College of the Sciences Faculty Summer Research Grant  
Drug Discovery Towards Novel HIV/AIDS Therapies – 02/02/04  
Requested \$3,000 – not funded.

PI - Research Corporation: Cottrell College Science Award  
New 1,3-Azaborine Heterocycles as Protease Inhibitors – 11/24/03  
Requested \$42,218 plus \$14,400 CWU match – not funded.

PI - The Camille and Henry Dreyfus Foundation: Faculty Start-up Grant for Undergraduate Institutions  
Design and synthesis of 1,3-azaborines as novel HIV-1 protease inhibitors - 05/15/03  
Requested \$19,973 – not funded.

**Research Student Grants:**

Catharine J. Collar – CWU Office of Undergraduate Research Grant  
Molecular Modeling for HIV-1 Protease Inhibitors – 01/20/04  
Requested \$500 – funded \$300.

Catharine J. Collar – CWU COTS Undergraduate Research Grant  
Molecular Modeling for HIV-1 Protease Inhibitors – 02/18/04  
Requested \$500 – funded.

Gayle H. Smith – CWU Office of Undergraduate Research Grant  
Computer Design and Synthesis of Potential HIV-1 Protease Inhibitory Compounds – 01/20/04  
Requested \$500 – funded \$300.

Gayle H. Smith – CWU COTS Undergraduate Research Grant  
Computer Design and Synthesis of Potential HIV-1 Protease Inhibitory Compounds – 02/18/04  
Requested \$500 – funded.

Meagan L. Ansingh – CWU COTS Undergraduate Research Grant  
Molecular Modeling and Synthesis of a Potential HIV-1 Protease Inhibitor – 02/20/04  
Requested \$500 – funded.

Catharine J. Collar – CWU Thesis Research Grant  
Molecular Modeling of Protease Enzymes and Their Inhibitors – 11/15/04  
Requested \$695 – funded \$695.

Yinshan Jia – CWU Thesis Research Grant

Investigation of potential Boronated HIV-1 Protease Inhibitors – 11/15/04

Requested \$699.82 – funded \$699.82.

Catharine J. Collar – National Science Foundation (NSF) Graduate Research Fellowship Grant

A Biochemical, Mathematical, and Computerized Study of Macromolecules and Micromolecules – 11/16/04

Requested \$40,500 annually – not funded.

Nicholas Salim – CWU Science Honors Research Program

New techniques for molecular modeling; using neural networks and Sybyl to predict biological activity – 11/18/04

Requested \$1500 (plus \$3000 summer stipend) – accepted and funded.

Heather Biles – CWU Science Honors Research Program

The effects of Force Field and Charge on Molecular Modeling: A Volumetric Study to Find the Perfect Model for Cathepsin-D Ligands – 11/18/04

Requested \$1500 (plus \$3000 summer stipend) – accepted and funded.

Meagan L. Ansingh – CWU Science Honors Research Program

Design of Novel HIV-1 Protease Inhibitors – 11/18/04

Requested \$1500 (plus \$3000 summer stipend) – not funded.

Michael Ellis – CWU Science Honors Research Program

Creating a Model for Cathepsin D Inhibitors Using Statistical and Computational Software – 11/18/04

Requested \$1500 (plus \$3000 summer stipend) – not funded.

Nicholas Salim – CWU Office of Undergraduate Research Grant

Using neural networks and Sybyl for molecular modeling – 01/21/05

Requested \$500 – funded \$300.

Heather Biles – CWU Office of Undergraduate Research Grant

The effects of Force Field and Charge on Molecular Modeling; Finding the Perfect Model for Cathepsin-D Inhibitors – 01/21/05

Requested \$500 – funded \$400.

Michael Ellis – CWU Office of Undergraduate Research Grant

Creating a Model for Cathepsin D Inhibitors Using Computational and Statistical Software – 01/21/05

Requested \$500 – not funded.

Heather Biles – CWU COTS Undergraduate Research Grant

The effects of Force Field and Charge on Molecular Modeling: A Volumetric Study to Find the Perfect Model for Cathepsin-D Ligands – 02/18/05

Requested \$500 – not funded.

Nicholas Salim – CWU COTS Undergraduate Research Grant

Using neural networks and Sybyl for molecular modeling – 02/18/05

Requested \$500 – not funded.

Catharine J. Collar – CWU Graduate Student Summer Research Grant

Molecular Mathematical Modeling for Aspartic Protease Inhibitors – 04/13/05

Requested \$2,500 summer stipend – funded.

Yinshan Jia – CWU Graduate Student Summer Research Grant

Investigation of potential Boronated HIV-1 Protease Inhibitory Structures – 04/13/05

Requested \$2,500 summer stipend – not funded.

Tajinder Heer – CWU Science Honors Research Program

Synthesis of Novel Borinic Acid HIV-1 Dual-Mode Protease Inhibitors– 12/02/05

Requested \$1500 (plus \$3000 summer stipend) – accepted and funded.

Christopher Badi Abdul-Wahid – CWU Science Honors Research Program

The Rational Design of Novel *Plasmodium falciparum* Plasmeprin IV Inhibitors, Aided by a Fuzzy Neural Network – 12/02/05

Requested \$1500 (plus \$3000 summer stipend) – accepted and funded.

Nicholas Salim – CWU Office of Undergraduate Research Grant

Synthesis of 5,6-Dihydropyran-2-ones as Potential HIV-1 Protease Inhibitors – 01/31/06

Requested \$500 – funded. Award letter appended.

Kaori Noridomi – CWU Office of Undergraduate Research Grant

Organic Synthesis of a Precursor to a HIV-1 Protease Potential Inhibitor – 01/31/06

Requested \$500 – funded.

Nicholas Salim – CWU COTS Undergraduate Research Grant

Synthesis of 5,6-Dihydropyran-2-one Analogues as Potential HIV-1 Protease Inhibitors – 02/03/06

Requested \$500 – funded \$420.

Kaori Noridomi – CWU COTS Undergraduate Research Grant

Synthesis of a Precursor for 5,6-Dihydropyran-2-ones as Potential HIV-1 Protease Inhibitors – 03/17/06

Requested \$500 – funded.

David Nguyen – CWU COTS Undergraduate Research Grant

Synthesis of Novel 1,3-Azaborine Heterocycles as Potential HIV-1 Protease Inhibitors – 02/03/06

Requested \$500 – funded.

Tracy O’Connell – CWU COTS Undergraduate Research Grant

Organic Synthesis of a Precursor to a Potential HIV-1 Protease Inhibitor – 03/15/06

Requested \$500 – funded.

Heather N. Biles – CWU Office of Undergraduate Research Grant

Analyzing Force Field and Charge Conditions to Enhance Biological Activity

Predictions of Cathepsin D Inhibitors – 04/14/06

Requested \$500 – funded.

Amanda Blackmore – CWU Science Honors Research Program

Synthesis of Novel Cyclic Boronated Potential HIV-1 Protease Inhibitors– 01/17/07

Requested \$1500 (plus \$3000 summer stipend) – accepted and funded.

Jesse L. Nye – CWU Science Honors Research Program

Synthesis of 5,6-dihydropyran-2-ones as potential inhibitors of HIV-1 protease – 01/17/07

Requested \$1500 (plus \$3000 summer stipend) – accepted and funded.

Scott Palmer – CWU Science Honors Research Program

Synthesis of Four Novel 5,6-Dihydropyran-2-ones as Potential HIV-1 Protease Inhibitors – 01/17/07

Requested \$1500 (plus \$3000 summer stipend) – not accepted.

Amanda Blackmore – CWU Office of Undergraduate Research Grant

Synthesis of Novel Cyclic Boronated Potential HIV-1 Protease Inhibitors– 01/30/07

Requested \$500 – funded.

Scott Palmer – CWU Office of Undergraduate Research Grant

Synthesis of Four Novel 5,6-Dihydropyran-2-ones as Potential HIV-1 Protease Inhibitors – 01/31/07

Requested \$500 – funded.

Tracy K. O’Connell – CWU Office of Undergraduate Research Grant

Synthesis of a Novel Borinic Acid as Potential HIV-1 Protease Inhibitors – 01/31/07

Requested \$500 – funded.

Tajinder S. Heer – CWU Office of Undergraduate Research Grant

Synthesis of Novel Borinic Acid HIV-1 Protease Inhibitors– 01/31/07  
Requested \$500 – funded.

Jesse L. Nye – CWU Office of Undergraduate Research Grant

Synthesis of 5,6-dihydropyran-2-ones as potential inhibitors of HIV-1 protease –  
01/31/07  
Requested \$500 – funded.

Christopher Badi’ Abdul-Wahid – CWU Office of Undergraduate Research Grant

*In silico* study of *Plasmodium falciparum* proteases Plasmepsin II and IV: Prediction of  
biological activity of newly designed inhibitors – 01/31/07  
Requested \$500 – funded.

Amanda Blackmore – CWU COTS Undergraduate Research Grant

Synthesis of Novel Cyclic Boronated Potential HIV-1 Protease Inhibitors – 01/31/07  
Requested \$500 – not considered for funding because each faculty mentor may only  
sponsor a maximum of three student proposals per year.

Jesse L. Nye – CWU COTS Undergraduate Research Grant

Synthesis of 5,6-dihydropyran-2-ones as potential inhibitors of HIV-1 protease –  
02/01/07  
Requested \$500 – not considered for funding because each faculty mentor may only  
sponsor a maximum of three student proposals per year.

Tracy K. O’Connell – CWU COTS Undergraduate Research Grant

Synthesis of a Novel Borinic Acid as Potential HIV-1 Protease Inhibitor – 02/01/07  
Requested \$500 – not funded.

Christopher Badi’ Abdul-Wahid – CWU COTS Undergraduate Research Grant

*In silico* study of *Plasmodium falciparum* proteases Plasmepsin II and IV: Prediction of  
biological activity of newly designed inhibitors – 02/02/07  
Requested \$500 – funded.

Tajinder S. Heer – CWU COTS Undergraduate Research Grant

Synthesis of Novel Potential HIV-1 Protease Inhibitors– 02/02/07  
Requested \$500 – not funded. Decision letter appended.

Scott Palmer – CWU COTS Undergraduate Research Grant

Synthesis of Four Novel 5,6-Dihydropyran-2-ones as Potential HIV-1 Protease  
Inhibitors – 02/02/07  
Requested \$500 – not considered for funding because each faculty mentor may only  
sponsor a maximum of three student proposals per year.

Tracy K. O’Connell – CWU Office of Undergraduate Research Grant

Synthesis of a Novel Borinic Acid as a Potential HIV-1 Protease Inhibitor – 04/16/07  
Requested \$500 – funded.

Pei-Mien Chen – CWU Graduate Student Summer Research Grant

Synthesis of Cyclic Boronates as Potential HIV-1 Protease Inhibitors – 04/16/07  
Requested \$2,500 summer stipend – not funded.

Grant Barker – CWU Graduate Student Summer Research Grant

Computer modeling and neural networks used in the design and synthesis of novel  $\beta$ -  
secretase inhibitors for the therapeutic treatment of Alzheimer’s disease – 04/16/07  
Requested \$2,500 summer stipend – not funded.

Scott Palmer – CWU Office of Undergraduate Research Grant

Synthesis of Four Novel 5,6-Dihydropyran-2-ones as Potential HIV-1 Protease  
Inhibitors – 10/30/07  
Requested \$500 – not funded.

Jesse L. Nye – CWU Office of Undergraduate Research Grant

Synthesis of 5,6-dihydropyran-2-ones as potential inhibitors of HIV-1 protease – 10/31/07

Requested \$500 – funded.

Amanda Blackmore – CWU Office of Undergraduate Research Grant

Synthesis of Novel Cyclic Boronated Potential HIV-1 Protease Inhibitors – 10/31/07

Requested \$500 – funded.

Grant Barker – CWU Master’s Research or Creative Activity Fellowship

Computer modeling and neural networks used in the design and synthesis of novel  $\beta$ -secretase inhibitors for the therapeutic treatment of Alzheimer’s disease – 11/15/07

Requested \$700 – not funded.

Pei-Mien Chen – CWU Master’s Research or Creative Activity Fellowship

Synthesis of Cyclic Boronates as Potential HIV-1 Protease Inhibitors – 11/15/07

Requested \$700 – not funded.

Lee J. Ream – CWU Science Honors Research Program

Synthesis of Novel 1,3-Azaborine HIV-1 Protease Inhibitors– 01/18/08

Requested \$1000 (plus \$3000 summer stipend) – not funded.

Scott Palmer – CWU Office of Undergraduate Research Grant

Synthesis of Four Novel 5,6-Dihydropyran-2-ones as Potential HIV-1 Protease Inhibitors – 01/30/08

Requested \$500 – funded.

Lee J. Ream – CWU Office of Undergraduate Research Grant

Synthesis of (R,R)-1,2-dicyclohexyl ethane diol; an essential starting material for the synthesis of novel 1,3-azaborine HIV-1 protease inhibitors – 01/30/08

Requested \$500 – funded.

Pei-Mien Chen – CWU Master’s Research or Creative Activity Fellowship

Discovery of Novel Therapies for HIV/AIDS – 04/14/08

Requested \$700 – not funded.

Pei-Mien Chen – CWU Graduate Student Summer Research Fellowship

Discovery of Novel Therapies for HIV/AIDS – 04/14/08

Requested \$2,500 summer stipend – funded.

Grant Barker – CWU Master’s Research or Creative Activity Fellowship

Computational Chemistry used in the design and synthesis of novel  $\beta$ -secretase inhibitors for the therapeutic treatment of Alzheimer’s disease – 04/14/08

Requested \$700 – not funded.

Grant Barker – CWU Graduate Student Summer Research Fellowship

Computational Chemistry used in the design and synthesis of novel  $\beta$ -secretase inhibitors for the therapeutic treatment of Alzheimer’s disease – 04/14/08

Requested \$2,500 summer stipend – not funded.

Donald R. Clayton – CWU Office of Undergraduate Research Grant

Synthesis of a Novel Straight Chain Borinic Acid HIV-1 protease inhibitor – 10/31/08

Requested \$500 – funded.

Lee J. Ream – CWU Office of Undergraduate Research Grant

Synthesis of three novel cyclic 1,3-azaborine HIV-1 protease inhibitors – 10/31/08

Requested \$500 – not funded.

Jesse L. Nye – CWU Master’s Research or Creative Activity Fellowship

Synthesis of 5,6-Dihydropyran-2-ones as Potential Inhibitors of HIV-1 Protease – 11/14/08

Requested \$700 – not funded.

Pei-Mien Chen – CWU Master’s Research or Creative Activity Fellowship

Discovery of Novel Therapies for HIV/AIDS – 11/17/08

Requested \$700 – not funded.

Lee J. Ream – CWU COTS Undergraduate Research Grant

Synthesis of three novel cyclic 1,3-azaborine HIV-1 protease inhibitors – 02/06/09

Requested \$500 – funded.

Donald R. Clayton – CWU Science Honors Research Program

Synthesis of a Novel Borinic Acid as a Potential HIV-1 Protease Inhibitor – 03/06/09

Requested \$700 (plus \$3000 summer stipend) – accepted and funded.

Jesse L. Nye – CWU Master’s Research or Creative Activity Fellowship

Synthesis of Borinic Acids as Potential Novel Inhibitors of HIV-1 Protease – 04/15/09

Requested \$700 – pending.

Jesse L. Nye – CWU Graduate Student Summer Research Fellowship

Synthesis of Borinic Acids as Potential Novel Inhibitors of HIV-1 Protease – 04/15/09

Requested \$2,500 summer stipend – pending.

**Professional Affiliations:**

American Chemical Society, Member

Organic Chemistry Division, American Chemical Society, Member

American Association for the Advancement of Science, Member

Phi Lambda Upsilon Chemical Honor Society, Member

Omicron Delta Kappa National Honor Society, Member

**University Service:**

**1. Departmental:**

2008-2009	Biochemistry Tenure-track Faculty Search Committee, member.
2008-2009	Graduate Committee, member.
2008-2009	Undergraduate Committee, member.
2008-2009	Faculty Senate Representative, Spring 2009.
2008-2009	Departmental Website Committee, member.
2007-2008	Organic Chemistry Tenure-track Faculty Search Committee, member.
2007-2008	Computer Technician Search Committee, Co-Chair with Dr. JoAnn Peters (DeLuca).
2007-2008	Graduate Committee, member.
2007-2008	Undergraduate Committee, member.
2006-2007	Organic Chemistry Tenure-track Faculty 2 Search Committee, Chair.
2006-2007	Computer Technician Search Committee, Co-Chair with Dr. JoAnn Peters (DeLuca).
2006-2007	Organic Chemistry Non-tenure-track Faculty Search Committee, member
2006-2007	Graduate Committee, member.
2006-2007	Undergraduate Committee, member.
2006-2007	Pre-pharmacy Advisor.
2006-2007	Pre-pharmacy Club Advisor.
2005-2006	Physical/Analytical Chemistry Tenure-track Faculty Search Committee, member.
2005-2006	Organic Chemistry Non-tenure-track Faculty Search Committee, member.
2005-2006	Graduate Committee, member.
2005-2006	Undergraduate Committee, member.

2005-2006 Pre-pharmacy Advisor.  
 2005-2006 Pre-pharmacy Club Advisor.  
 2004-2005 Physical/Analytical Tenure-track Faculty Search Committee, member.  
 2004-2005 Graduate Committee, member.  
 2004-2005 Undergraduate Committee, member.  
 2004-2005 Pre-pharmacy Advisor.  
 2004-2005 Pre-pharmacy Club Advisor.  
 2003-2004 Graduate Committee, member.  
 2003-2004 Undergraduate Committee, member.  
 2003-2004 General Chemistry Lecturer Search Committee.  
 2003-2004 2004 ACS Puget Sound Section Undergraduate Research Symposium Organizing Committee, member.  
 2003-2004 Pre-pharmacy Club Advisor.

## 2. College of the Sciences:

2008-2009 Pre-medical Advisor.  
 2008-2009 Pre-medical Club Advisor.  
 2008-2009 Pre-medical Student Interviews Committee, Chair.  
 2008-2009 Dennis W. Farrell Pre-medical Scholarship Selection Committee, Chair.  
 2007-2008 COTS Instrumentation Grant Review Committee, Chair.  
 2007-2008 Science Honors Program Proposals Review Committee, member.  
 2007-2008 Pre-medical Advisor.  
 2007-2008 Pre-medical Club Advisor.  
 2007-2008 Pre-medical Student Interviews Committee, Chair.  
 2007-2008 Dennis W. Farrell Pre-medical Scholarship Selection Committee, Chair.  
 2006-2007 COTS Instrumentation Grant Review Committee, member.  
 2006-2007 Science Honors Program Proposals Review Committee, member.  
 2006-2007 Pre-medical Advisor.  
 2006-2007 Pre-medical Club Advisor.  
 2006-2007 Pre-medical Student Interviews Committee, Chair.  
 2006-2007 Dennis W. Farrell Pre-medical Scholarship Selection Committee, Chair.  
 2005-2006 COTS Summer Grant Committee, member.  
 2005-2006 Pre-medical Advisor.  
 2005-2006 Pre-medical Club Advisor.  
 2005-2006 Pre-medical Student Interviews Committee, Chair.  
 2005-2006 Dennis W. Farrell Pre-medical Scholarship Selection Committee, Chair.  
 2004-2005 Pre-medical Advisor.  
 2004-2005 Pre-medical Club Advisor.  
 2004-2005 Pre-medical Student Interviews Committee, Chair.  
 2004-2005 Dennis W. Farrell Pre-medical Scholarship Selection Committee, Chair.  
 2003-2004 Pre-medicine Student Interviews Committee, member.  
 2003-2004 Dennis W. Farrell Pre-Medical Scholarship Selection Committee, member.

**3. University:**

2008-2009	Health Career Education Resources Ad hoc Task Force, member.
2007-2008	Health Career Education Resources Ad hoc Task Force, member.
2006-2007	Health Career Education Resources Ad hoc Task Force, member.
2005-2006	Health Career Education Resources Ad hoc Task Force, member.
2004-2005	Health Career Education Resources Ad hoc Task Force, member.
2003-2004	Health Career Education Resources Ad hoc Task Force, member.

**Yingbin Ge, Ph. D.**  
**Assistant Professor of**  
**Chemistry**

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Chemistry Department  
Central Washington University  
400 East University Way  
Ellensburg WA 98926

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Office Fax: 509-963-1050  
Email: [yingbin@cwu.edu](mailto:yingbin@cwu.edu)  
Homepage: <http://www.cwu.edu/~yingbin/>  
Chem. Dept.: <http://www.cwu.edu/~chem/>

**Education**

- 2004 - **Ph. D.** Physical Chemistry, University of Hawaii; Advisor: Professor John D. Head
- 2005 - **M. S.** Information and Computer Sciences, University of Hawaii
- 1995 - **B. S.** Polymer Chemistry, University of Science and Technology of China

**Professional Experience**

- Sept. 2008 - Present, **Assistant Professor**, Department of Chemistry, Central Washington University
- Jul. 2005 - Jul. 2008, **Postdoc Research Associate**, Department of Chemistry, Iowa State University; Advisor: Professor Mark S. Gordon
- Jan. 2005 - Jun. 2005, **Visiting Assistant Professor**, Department of Chemistry, University of Hawaii

**Professional Affiliations and Service**

- 2007 - present: Sigma Xi, the Scientific Research Society
- 2005 - present: American Chemical Society

**Awards**

- Rechnitz Dissertation Prize from the University of Hawaii (2005)
- Teaching Assistant Award from the University of Hawaii (2003)
- Teaching Assistant Award from the University of Hawaii (2001)

## Grants

- Start-up fund from the Central Washington University (2008)

## Courses Taught at Central Washington University

- Chem 383 (Physical Chemistry III: Statistical Thermodynamics and Kinetics) in spring, 2009
- Chem 383L (Physical Chemistry Lab II) in spring, 2009
- Chem 382 (Physical Chemistry II: Quantum Chemistry) in winter, 2009
- Chem 382L (Physical Chemistry Lab I) in winter, 2009
- Chem 381 (Physical Chemistry I: Thermodynamics) in fall, 2008
- Chem 181 (General Chemistry I) in fall, 2008
- Chem 181L (General Chemistry Lab I) in fall, 2008 and winter, 2009
- Chem 152 (Survey of Organic Chemistry and Biochemistry) at University of Hawaii in spring, 2005
- Chem 152L (Survey of Organic Chemistry and Biochemistry Lab) at University of Hawaii in spring, 2005

## Publications, Peer-Reviewed:

12. Y. Ge, M. S. Gordon, P. Piecuch, M. Wloch, and J. R. Gour, [\*Breaking bonds of open-shell species with the restricted open-shell size extensive left eigenstate completely renormalized coupled-cluster method\*](#), *Journal of Physical Chemistry A*, **112**, 11873-11884, 2008.
11. Y. Shiraishi, D. Robinson, Y. Ge, J. D. Head, [\*Low Energy Structures of Ligand Passivated Si Nanoclusters: Theoretical Investigation of  \$Si\_2L\_4\$  and  \$Si\_{10}L\_{16}\$  \( \$L=H, CH\_3, OH\$  and  \$F\$ \)\*](#), *Journal of Physical Chemistry C*, **112**, 1819-1824, 2008.
10. Y. Ge, M. S. Gordon, and P. Piecuch, [\*Breaking Bonds with the Left Eigenstate Completely Renormalized Coupled-Cluster Method\*](#), *Journal of Chemical Physics*, **127**, 174106, 2007.
9. Y. Ge, M. S. Gordon, F. Battaglia, and R. O. Fox, [\*Theoretical Study of the Pyrolysis of Methyltrichlorosilane in the Gas Phase. 2. Reaction Paths and Transition States\*](#), *Journal of Physical Chemistry A*, **111**, 1475-1486, 2007.
8. Y. Ge, M. S. Gordon, F. Battaglia, and R. O. Fox, [\*Theoretical Study of the Pyrolysis of Methyltrichlorosilane in the Gas Phase. 1. Thermodynamics\*](#) *Journal of Physical Chemistry A*, **111**, 1462-1474, 2007.

7. Y. Ge, K. Olsen, R. I. Kaiser, and J. D. Head, [The Potential Energy Surface of the H<sub>2</sub>O<sub>2</sub> System \(word file\)](#), *AIP Conference Proceedings Volume 855, ASTROCHEMISTRY: From Laboratory Studies to Astronomical Observations*, **4A**, 253-259, 2006.
6. J. D. Head and Y. Ge, [Theoretical Identification of the Lowest Energy Si<sub>x</sub>L<sub>y</sub> Clusters Using Genetic Algorithms](#), *Lecture Series on Computer and Computational Sciences*, **4A**, 1014-1017, 2005.
5. Y. Ge and J. D. Head, [Ligand Effects on Si<sub>x</sub>L<sub>y</sub> Cluster Structures with L = H and F](#), *Molecular Physics*, **103**, 1035-1045, 2005.
4. Y. Ge and J. D. Head, [Fast Global Optimization of Si<sub>x</sub>H<sub>y</sub>: New mutation operators in the cluster genetic algorithm](#), *Chemical Physics Letters*, **398**, 107-112, 2004.
3. Y. Ge and J. D. Head, [Global Optimization of H-Passivated Si Clusters at the Ab Initio Level via the GAM1 Semiempirical Method](#), *Journal of Physical Chemistry B*, **108**, 6025-6034, 2004.
2. Y. Ge and J. D. Head, [Global Optimization of Si<sub>x</sub>H<sub>y</sub> Clusters at the Ab Initio Level via an Iteratively Parametrized Semiempirical Method](#), *International Journal of Quantum Chemistry*, **95**, 617-626, 2003.
1. Y. Ge and J. D. Head, [Global Optimization of H-Passivated Si Clusters with a Genetic Algorithm](#), *Journal of Physical Chemistry B*, **106**, 6997-7004, 2002.

### **Publications, Non-Peer-Reviewed:**

2. Y. Ge, Ph. D. Dissertation, [Global Optimization of Passivated Si Clusters at the Ab Initio Level Via Semiempirical Methods, \(two-sided\)](#)
1. J. D. Head and Y. Ge, *Global Optimization of Si<sub>x</sub>H<sub>y</sub> and Si<sub>x</sub>F<sub>y</sub> Clusters at the Ab Initio Level*, [Maui High Performance Computing Center Application Briefs](#), page 6-7, 2004.

### **Talks (The presenter's name is underlined.):**

- Y. Ge, M. S. Gordon, P. Piecuch, M. Wloch, and J. R. Gour, *Breaking bonds of open-shell species with the left-eigenstate renormalized coupled-cluster method*, 235th ACS National Meeting, New Orleans, LA, USA (2008)
- F. Battaglia, Z. Gao, R. O. Fox, Y. Ge and M. S. Gordon, *Detailed Reaction Kinetics for CFD Modeling of Nuclear Fuel Pellet Coating for High-Temperature Gas-Cooled Reactors*, American Nuclear Society 2007 Winter Meeting, Washington D. C., USA (2007)

- Z. Gao, F. Battaglia, R. O. Fox, Y. Ge, M. Gordon and S. Pope, *Implementation of detailed chemistry of methyltrichlorosilane decomposition into ISAT and parametric study*, AIChE Annual Meeting, Salt Lake City, Utah, USA (2007)
- Y. Ge, *Chemistry with Computers*, Central Washington University, Ellensburg, Washington, USA (2007)
- F. Battaglia, R. O. Fox, M. S. Gordon, and Y. Ge, *Coupling Molecular and Continuum Modeling for Detailed Reaction Kinetics of TRISO Fuel Coating*, SIAM Conference on Computational Science & Engineering, Costa Mesa, California, USA (2007)
- Y. Ge, K. Olsen, R. I. Kaiser, and J. D. Head, *The Potential Energy Surface of the H<sub>2</sub>O<sub>2</sub> System*, International Chemical Congress of Pacific Basin Societies, Honolulu, Hawaii, USA (2005)
- J. D. Head and Y. Ge, *Theoretical Identification of the Lowest Energy Si<sub>x</sub>L<sub>y</sub> clusters Using Genetic Algorithms*, International Conference of Computational Methods in Sciences and Engineering, Loutraki, Korinthos, Greece (2005)

### **Posters (The presenter's name is underlined.):**

- Y. Ge, M. S. Gordon, R. O. Fox, and F. Battaglia, *Theoretical Study of the Pyrolysis of CH<sub>3</sub>SiCl<sub>3</sub> in the Gas Phase: Rate Constant Calculations*, Mark Gordon Conference, Maui, Hawaii, USA (2007)
- J. D. Head and Y. Ge, *Theoretical investigation of the low energy structures of SixLy clusters*, 232nd ACS National Meeting, San Francisco, CA, USA (2006)
- Y. Ge, M. S. Gordon, R. O. Fox, and F. Battaglia, *Theoretical Study of the Pyrolysis of CH<sub>3</sub>SiCl<sub>3</sub> in the Gas Phase*, International Chemical Congress of Pacific Basin Societies, Honolulu, Hawaii, USA (2005)
- Y. Ge and J. D. Head, *Ligand Effects on SixLy Cluster Structures with L = H and F*, International Chemical Congress of Pacific Basin Societies, Honolulu, Hawaii, USA (2005)
- Y. Ge and J. D. Head, *Ligand Effects on SixLy Cluster Structures with L = H and F*, Molecular Quantum Mechanics Conference, Cambridge University, Cambridge, England (2004)
- K. L. Wong, Y. Ge, and J. D. Head, *Global Optimization of SixHy Clusters at the Ab Initio Level via an Iteratively Parametrized Semiempirical Method*, the 3rd annual Computation Chemistry Grid Conference, University of Kentucky, Lexington, Kentucky, USA (2003)
- Y. Ge and J. D. Head, *Global Optimization of SixHy Clusters at the Ab Initio Level via an Iteratively Parametrized Semiempirical Method*, the 43rd Sanibel Symposium, St. Augustine, Florida, USA (2003)
- Y. Ge and J. D. Head, *Theoretical Investigation for Si<sub>20</sub> and Its Derivatives*, International Chemical Congress of Pacific Basin Societies, Honolulu, Hawaii, USA (2000)

# Anne M. Johansen

Associate Professor

Chemistry Department, CWU  
Ellensburg, WA 98926

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e-mail: johanse@cwu.edu

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## EDUCATION

- Ph.D.**, Environmental Engineering Science, Atmospheric Chemistry, Geology Minor June 1999  
California Institute of Technology, Pasadena, California  
- Thesis title: **Chemistry of Marine Aerosol**  
- Thesis advisor: Dr. Michael R. Hoffmann
- M.S.**, Material Science and Engineering Oct. 1993  
Oregon Graduate Institute, Portland, Oregon  
- Non-Thesis master research project: **Rapid Phase Identification of Mixed Crystalline Solids**  
- Research advisor: Dr. David Downham
- M.S.**, Inorganic Chemistry Jan. 1991  
University of Oslo, Oslo, Norway  
- Thesis title: **Corrosion and Passive Behavior of Beryllium in Aqueous Solutions**  
- Thesis advisor: Dr. Tor Hurlen
- B.S.**, Chemistry May 1989  
University of Oslo, Oslo, Norway

## PROFESSIONAL EXPERIENCE

- Visiting Scientist, Analytical Chemistry** Aug. 2008-present  
Institute for Water Chemistry, Department of Analytical Chemistry, Technical University Munich, DE
- Associate Professor, Analytical/Environmental Chemistry** July 2008-present  
Department of Chemistry, Central Washington University
- Assistant Professor, Analytical/Environmental Chemistry** Sept. 2002-June 2008  
Department of Chemistry, Central Washington University
- Adjunct Professor, part-time, Analytical/Environmental Chemistry** Jan. 2000-June 2002  
Department of Chemistry, Central Washington University
- Graduate Research Assistant** Sept. 1993-April 1999  
Environmental Engineering Science Department, California Institute of Technology
- Graduate Teaching Assistant** Sept. 1997-April 1998  
Environmental Engineering Science Department, California Institute of Technology
- Graduate Research Assistant** Jan. 1992-Sept. 1993  
Material Science and Engineering Department, Oregon Graduate Institute
- Undergraduate Teaching Assistant** Aug. 1989-Dec. 1991  
Department of Pharmacy and Department of Chemistry, University of Oslo, NO
- Graduate Research Assistant** Jan. 1989-Jan. 1991  
Chemistry Department, Division of Inorganic Chemistry, University of Oslo, NO

## ACADEMIC AWARDS AND FELLOWSHIPS

- 2007 Editors' Citation for Excellence in Refereeing for JGR-Atmospheres** May 2008  
American Geophysical Union, Joint Assembly
- Certificate of Merit for Material Content and Presentation** March 2007  
American Chemical Society National Meeting, Chicago, IL
- Distinguished Thesis Award**, by graduate student Jennifer M. Key June 2005  
Central Washington University
- Mentor Award** May 2004  
Center for Excellence in Leadership, Central Washington University
- NSF-ADVANCE Fellows Award** May 2002  
National Science Foundation
- Graduate Research and Tuition Fellowships** Sept. 1993-June 1999  
Environmental Engineering Science Department, California Institute of Technology

## **COURSES TAUGHT**

### **Undergraduate, lower division**

- University 101
- General Chemistry for science majors, lectures and laboratories
- General Chemistry for non-science majors, lectures and laboratories

### **Undergraduate, upper division**

- Quantitative Analysis lectures and labs
- Instrumental Analysis lectures and labs
- Environmental Chemistry lectures and labs
- Colloquium

### **Graduate**

- Current Topics in Chemistry
- Introduction to Research
- Atmospheric Chemistry
- Aquatic Chemistry

## **CURRENT EXTERNALLY FUNDED PROJECTS**

### **Department of Education - Fund for the Improvement of Postsecondary Education (FIPSE)**

- "Research and Education of Wine Faults", Congressionally directed grant, **Team Member**, PI: Amy Mumma, co-PI: Kevin Nemeth, CWU Continuing Education Department, \$191,593, 2008-2009

### **National Science Foundation**

- "RUI: Do Dimethyl Sulfide (DMS) and Isoprene Control Iron Bioavailability in Marine Aerosols?", **PI**, \$135,500, 2009-2011

### **National Science Foundation**

- "Yakima River Water Activities to Enhance Research in Schools (WATERS)", **Mentor**, PI: Carey Gazis, \$2,800,000, 2007-2012

### **National Park Service**

- "Acid rain and snow precipitation study at Mt. Rainier", **PI**, \$50,000, 2002-2007, contract renewed for 2007-2012
- "Acidification of high elevation lakes at Mt. Rainier and North Cascades National Park", **PI**, \$12,250, 2007-2012, contract renewed for 2007-2012

### **Pacific Northwest National Laboratories**

- PNNL User Facility Proposal: "Open Ocean Ship-Board Study of Atmospheric Aerosols at the Equatorial Pacific: Characterizing Iron Phases with SEM/EDX and TEM", **PI**, co-PIs: Jim Murray, Lindsey Shank, A. Laskin, Y. Desyaterik, V. Shuthanandan, C. Wang, Z. Zhu, 2006-2009
- PNNL User Facility Proposal: "Surface and Bulk Characterization of Ambient Ultrafine Particles", **co-PI**, PI: Eric Bullock, other co-PIs: Carin Thomas, V. Shuthanandan, et al., 2006-2009

## **OTHER CURRENT PROJECTS (PENDING FUNDING AS INDICATED)**

### **EPA Accredited CWU Chemical Analysis Laboratory**

EPA accreditation for 10 chemical components since Spring 2006, with special focus on precipitation, water and wine analyses. Serving: NPS and additional grants within Geology and Geography. Students receive training essential for regulatory laboratory work.

### **Climate Commitment Atmospheric Chemistry**

Provide expertise in atmospheric chemistry to assist the University in its newly established goal to become carbon neutral.

## **PAST EXTERNAL FUNDING**

### **National Institutes of Health**

- "Ultrafine Particles and Mitochondrial Dysfunction", R15, **PI**, co-PIs: Eric Bullock and Carin Thomas, \$203,000, 2005-2008

### **National Science Foundation**

- "Iron and sulfur chemistries in the marine atmosphere", **PI**, \$370,000, plus \$20,000 in institutional match, 2002-2007, NSF-Advance Fellowship
- REU Supplement for the NSF grant above, **PI**, \$5,000, 2006-2007

### **National Park Service**

- "Acid rain and snow precipitation study at Mt. Rainier", **PI**, \$42,500, 2002-2007
- "Acidification of high elevation lakes at Mt. Rainier and North Cascades National Park", **PI**, \$4,500, 2004-2007

## **INTERNAL GRANTS**

### **Faculty Grants/Funding**

- Essential Equipment Grant: New Ion Chromatograph: Water and Wine Testing, June 2008, \$81,816, **PI**
- Essential Equipment Grant: Laser Particle-Size Analyzer for Environmental and Chemical Applications, June 2008, \$58,410, **co-PI**
- Sabbatical Leave Funding, Sept. 2008- June 2009, **PI**
- COTS-SEED Faculty Summer Development Grant to write and submit NSF grant, Summer 2007, \$3,000, **PI**
- Len Thayer Grant, Funds for EPA Laboratory Accreditation, 2007, \$650, **PI**
- Essential Equipment Grant: Surface Area Analyzer, April 2004, \$10,000, **PI**
- Spheres of Distinction: Energy Studies, Environmental Sciences Major, 2007, **co-PI**

### **Student Grants**

- Science Honors Student, Annika Nieber, 2008-present
- Students in my group have received approx. 15 research, thesis and travel grants between 2002 and present amounting to approx. \$7,000.

## **PEER REVIEWED PUBLICATIONS (\*CWU STUDENT CO-AUTHORS)**

- "Dissolution of aerosol-derived iron in seawater: Leach solution chemistry, aerosol type, and colloidal iron fraction", A. M. Aguilar-Islas, J. Wu, R. Rember, A. M. Johansen, and L. M. Shank\*, *Marine Chemistry*, doi:10.1016/j.marchem.2009.01.011, **2009**
- "Atmospheric Iron Deposition: Global Distribution, Variability, and Human Perturbations", N. M. Mahowald, S. Engelstaedter, C. Luo, A. Sealy, P. Artaxo, C. Benitez-Nelson, S. Bonnet, Y. Chen, P. Y. Chuang, D. D. Cohen, F. Dulac, B. Herut, A. M. Johansen, N. Kubilay, R. Losno, W. Maenhaut, A. Paytan, J. M. Prospero, L. M. Shank\*, and R. L. Siefert, *Annual Review of Marine Science*, 1:245-79, **2009**
- "Photochemistry of iron in simulated crustal aerosols with dimethyl sulfide oxidation products", J. M. Key\*, N. Paulk\*, and A. M. Johansen, *Environmental Science & Technology*, 42, 1, **2008**
- "Photoreductive dissolution of ferrihydrite by methanesulfinic acid; evidence of a direct link between dimethylsulfide and iron-bioavailability", A. M. Johansen and J. M. Key\*, *Geophysical Research Letters*, 33, doi:10.1029/2006GL026010, **2006**
- "Estimation of iron solubility from observations and a global aerosol model", C. Luo, N. Mahowald, N. Meskhidze, Y. Chen, R. L. Siefert, A. R. Baker, A. M. Johansen, *Journal of Geophysical Research*, 110, D23307, doi:10.1029/2005JD006059, **2005**
- "Chemical characterization of ambient aerosol collected during the northeast monsoon season over the Arabian Sea: Anions and cations", A. M. Johansen and M. R. Hoffmann, *Journal of Geophysical Research*, 109, D05305, **2004**
- "Chemical characterization of ambient aerosol collected during the northeast monsoon season over the Arabian Sea: Labile-Fe(II) and other trace metals", A. M. Johansen and M. R. Hoffmann, *Journal of Geophysical Research*, 108, 4408, **2003**
- "Chemical composition of aerosols collected over the tropical North Atlantic Ocean", A. M. Johansen, R.L. Siefert, M.R. Hoffmann, *Journal of Geophysical Research*, 105, 15277-15312, **2000**
- "A revised nitrogen budget for the Arabian Sea", H. W. Bange, T. Rixen, A.M. Johansen, et al., *Global Biogeochemical Cy*, 14, 1283-1297, **2000**
- "Chemical characterization of ambient aerosol collected during the southwest-monsoon and inter-monsoon periods over the Arabian Sea: Anions and cations", A. M. Johansen, R. L. Siefert, M. R. Hoffmann, *Journal of Geophysical Research*, 104, 26325-26347, **1999**
- "Chemical characterization of ambient aerosol collected during the southwest-monsoon and inter-monsoon periods over the Arabian Sea: Labile-Fe(II) and other trace metals", R. L. Siefert, A. M. Johansen, M. R. Hoffmann, *Journal of Geophysical Research*, 104, 3511-3526, **1999**

- “An extensive bloom of the N<sub>2</sub>-fixing cyanobacterium, *Trichodesmium erythraeum*, in the central Arabian Sea During the Spring Intermonsoon, D. G. Capone, A. Subramaniam, J. P. Montoya, M. Voss, C. Humborg, A. M. Johansen, R. L. Siefert, E. J. Carpenter, *Mar Ecol Progr Ser*, 172, 281-292, **1998**
- “Measurements of trace metal (Fe, Cu, Mn, Cr) oxidation states in fog and stratus clouds”, R. L. Siefert, A. M. Johansen, M. R. Hoffmann, S. O. Pehkonen, *J. Air & Waste Manage. Assoc.*, 48, 128-143, **1998**
- “A study of the passive behaviour of beryllium in aqueous solutions”, E. Gulbrandsen and A. M. J. Johansen, *Corrosion Science*, 36, 9, 1523-1536, **1994**
- “Rapid phase identification of mixed crystalline solids”, J. Stanley, C. D. Palmer, D. Downham, A. Johansen, *Proceedings of TMS Annual Meeting in Denver*, Colorado, paper and oral presentation, Feb. 21-25, **1993**

### **SELECTED CONFERENCE PRESENTATIONS (SOURCE PRESENTATIONS IN SEPARATE SECTION)**

- “Evidence of DMS and other biogenic gases affecting iron bioavailability in remote marine aerosols”, Anne M. Johansen and Lindsey M. Shank, platform presentation, AGU-Fall, San Francisco, CA, December **2008**
- “Atmospheric trace metal and labile iron deposition fluxes to the equatorial Pacific during EUCFe2006”, Lindsey Shank and Anne M. Johansen, poster presentation, AGU-OS, Orlando, FL, March **2008**
- “Evidence of DMS and other biogenic gases affecting iron bioavailability in remote marine aerosols”, Anne M. Johansen, Lindsey M. Shank, Mari N. Sorey, Matthew J. Lenington, Zhen Zhang, Brittany Best, poster presentation, AGU-OS, Orlando, FL, March **2008**
- “A Collaborative Model for Bringing Undergraduate Research to Community College”, Kalyn S. Owens, Anne M. Johansen and Ann Murkowski, oral presentation, Washington College Chemistry Teachers Association, Sleeping Lady Conference Resort, Leavenworth, WA, Oct. **2007**
- “Does Phytoplankton DMS Affect Iron Bioavailability in Marine Atmospheric Aerosols?”, Lindsey Shank and Anne M. Johansen, poster presentation, AAAR, Reno, NV, Sept. **2007**
- “Correlation of atmospheric ultrafine particle ferrous iron and mitochondrial toxicity”, Anne M. Johansen, Stephanie L. Bryner, Eric L. Bullock, Justin M. Johnston, Carin Thomas, and Josie K. Wells, platform presentation, AAAR, Reno, NV, Sept. **2007**
- “Correlation of Atmospheric Ultrafine Particle Iron and Mitochondrial Toxicity”, Stephanie L. Bryner, Eric L. Bullock, Anne M. Johansen, Justin M. Johnston, Carin Thomas, and Josie K. Wells, poster presentation, Council for Undergraduate Research, Posters on the Hill (POH), DC, April **2007**
- “Correlation of Atmospheric Ultrafine Particle Iron and Mitochondrial Toxicity”, Carin Thomas, Stephanie L. Bryner, Eric L. Bullock, Anne M. Johansen, Justin M. Johnston, and Josie K. Wells, platform presentation, ACS Chicago, IL, March **2007**
- “Photochemical Reduction of Iron(oxy)hydroxides in the presence of Dimethyl Sulfide Derived Electron Donors”, Brittany Affholter, Annika Nieber, Nicole Paulk, Jennifer M Key, and Anne M. Johansen, poster presentation, ACS Chicago, IL, March **2007**, and ACS-Puget Sound Conference for Undergraduate Research, May **2007**
- “Iron photochemical dissolution in simulated marine aerosols affected by dimethylsulfide derived methanesulfinic acid”, Niki Paulk, Jennifer M. Key and Anne M. Johansen, oral presentation, AGU-Ocean Sciences Meeting, Honolulu, HI, Feb. **2006**
- “Siderophore producing microorganisms in the marine atmosphere”, Lindsey Shank, Matt Lenington, Curt Moon, Anne M. Johansen, Holly Pinkart, poster presentation, AGU-Ocean Sciences Meeting, Honolulu, HI, Feb. **2006**
- “Effect of DMSO in Iron Speciation in Photochemical Simulation Experiments”, J. M. Key and A. M. Johansen, SOLAS Conference, Halifax, Canada, poster presentation, October **2004**
- “Does Dimethyl Sulfoxide (DMSO) enhance the reductive dissolution of Iron in Marine Aerosols?”, J. M. Key and A. M. Johansen, AGU Ocean Sciences Meeting, Portland, California, oral presentation, January **2004**
- “The Role of Dimethyl Sulfoxide (DMSO) in the Reductive Dissolution of Iron in Marine Aerosols”, J. M. Key and A. M. Johansen, AGU Fall Meeting, San Francisco, California, oral presentation, December **2003**
- “Variability in the Chemical Composition of Ambient Aerosol Over the Arabian Sea Imparted by the Seasonal Reversals of the Monsoon”, A. M. Johansen, R. L. Siefert, M. R. Hoffmann, AGU Ocean Sciences Meeting, San Diego, California, oral presentation, February **1998**

- “Chemical Characterization of Ambient Aerosol over the Northern Indian Ocean during Different Seasons of the Monsoon: Fe(II) and Other Trace Metals”, A. M. Johansen, R. L. Siefert, M. R. Hoffmann, AAAR Annual Conference, Denver, Colorado, poster presentation, October **1997**
- “Chemical Characterization of Aerosol Over the Arabian Sea - Occurrence of Labile Fe(II)”, M. R. Hoffmann, A. M. Johansen, R. S. Siefert, ACS Annual Conference, San Francisco, California, oral presentation, April **1997**
- “The Effect of the Monsoon on Trace Elements Over the Arabian Sea”, AGU Fall Meeting, San Francisco, California, oral presentation, December **1996**

## **CWU SYMPOSIUM ON UNIVERSITY RESEARCH AND CREATIVE EXPRESSION (SOURCE) PRESENTATIONS BY STUDENTS**

- Jacob Johnson, 2008, 2009
- Annika Nieber, 2007, 2009
- Lindsey Shank, 2007, 2006
- Niki Paulk, 2006 (Award for Outstanding Oral Presentation), 2005
- Stephanie Bryner, 2007, 2006 (Award for Outstanding Poster Presentation)
- Jennifer Key, 2005, 2004
- Dan Baker, 2004

## **INVITED SEMINARS/TALKS/WORKSHOPS**

- “Anthropogenic vs. Biogenic Control of Iron Speciation in Marine Aerosols over the Equatorial Pacific Ocean”, Institute for Marine Sciences – GEOMAR, University in Kiel, Kiel, Germany, May **2009**
- “Iron Solubility in Marine Aerosols and Surface Ocean; Analytical Issues, Current State and Outlook”, expert scientist in international workshop, East Anglia University, Norwich, UK, February **2009**
- “Iron in Atmospheric Aerosols: Implications on global climate and human health”, Oregon Health and Sciences University, OGI, Portland, OR, February **2008**
- “Iron in Atmospheric Aerosols: Implications on global climate and human health”, Washington State University, Environmental and Civil Engineering, Pullman, WA, February **2008**
- “Iron in Atmospheric Aerosols: Implications on global climate and human health”, Gonzaga University, Spokane, WA, February **2008**
- “Impacts of bioavailable aerosol iron on global climate and public health”, Ludwig Maximilians University, Munich, Germany, November **2007**
- “Atmospheric aerosols during EUCFe 2006: A source of nutrients to the equatorial Pacific Ocean?”, Lindsey M. Shank and Anne M. Johansen, Equatorial Pacific Ocean – Iron Cruise Workshop, School of Oceanography, UW, Seattle, WA, September **2007**
- “Is Iron Speciation in Atmospheric Dust Controlled by Phytoplankton DMS Emissions?”, Dr. Hoffmann 60<sup>th</sup> Birthday Symposium, Harvard University, Cambridge, MA, Sept. **2006**
- “Iron Aerosols in Global Climate and Human Health”, Keynote Speaker, 2<sup>nd</sup> Forum for Aerosol Science and Technology, NCAR, Boulder, CO, June **2006**
- “Trace Metals in the Atmosphere; Global Climate and Human Health”, Chemistry Department, Willamette University, Salem, OR, Feb. **2006**
- “Iron Aerosols in Global Climate and Human Health”, University of Alaska, Fairbanks, AK, March **2006**
- “Dust and Global Climate”, Chemistry Department, Eastern Washington University, Cheney, WA, Feb. **2005**
- “Is Iron Speciation in Windblown Dust Affected by Marine Biogeochemical Feedback?”, Chemical Oceanography, University of Washington, Seattle, WA, February 4<sup>th</sup>, **2005**
- “Iron Photoreduction by MSIA”, Forum for Aerosol Science and Technology, University of California, Santa Cruz, CA, June **2004**
- “Globalization and Global Climate”, CWU, Ellensburg, WA, February 9<sup>th</sup>, **2004**
- “Dust and Global Climate”, CWU Natural Science Seminar, November 7<sup>th</sup>, **2003**
- “Atmospheric Iron – Impact on Global Climate”, Boise State University, Boise, ID, recruiting graduate students, February 28<sup>th</sup>, **2003**
- “Iron Speciation in the Marine Atmosphere”, Institute for Marine Science at the University in Kiel, Germany, invited presentation, August 16<sup>th</sup>, **2002**
- “Air Pollution in China”, NSF REU China Summer Environmental Science 2 hour lecture, CWU, Ellensburg, WA, June 9<sup>th</sup>, **2002**
- “Implications of Atmospheric Iron on Global Climate”, CWU Geological Sciences Seminar, CWU, Ellensburg, WA, April 12<sup>th</sup>, **2002**
- “Iron in the Marine Atmosphere”, Chemistry Department, CWU, Ellensburg, WA, Jan. **2002**
- “Chemistry of Marine Aerosol”, PNNL, Richland, WA, Nov. **2001**

## **PROFESSIONAL AFFILIATIONS**

- American Geophysical Union, 1993-present
- American Association for Aerosol Research, 1994-present
- American Chemical Society, 2002-present

## **GRADUATE RESEARCH ADVISING**

### **Committee Chair**

- Jacob Johnson, M.S. Thesis, "Trace Metals, Anions and Cations in Atmospheric Aerosols over the South Atlantic Ocean", 2007-present
- Zhen Zhang, M.S. Thesis, "Transformation and Modeling of iron(oxy)hydroxides in marine atmospheric aerosols particles", 2006-August 2008
- Lindsey Shank, M.S. Thesis, "Collection and analysis of iron and sulfur species in marine aerosols", 2005-May 2008
- Jennifer Key, M.S. Thesis, "Photochemistry of atmospheric iron in marine aerosols", 2002-2005

### **Committee Member**

- Brittany Best, Chemistry, 2008-present
- Caitlyn Cornell, Chemistry, 2007-2008
- Justin Johnston, Chemistry, 2006-2008
- Sarah Taylor, Geology, 2006-2007
- Curt Moon, Biology, 2005-present
- Jeff King, Biology, 2005-present
- Vicki Rodriguez, Geology, 2002-2005
- Mizti Mackey, Chemistry, 2001-2003

## **UNDERGRADUATE RESEARCH ADVISING**

- Tyler Schaffeld, Spring 2009
- Sara Rybka, Chemistry, Fall 2007-present
- Celia Braun, Chemistry, Summer 2007-present
- Leah Leonard, Chemistry, Summer 2007-June 2008
- Brittany Best, Chemistry, Winter 2007-June 2008
- Annika Nieber, Chemistry, Spring 2006-present
- Brittany Affholter, Chemistry, Spring 2006-June 2007
- Justin Johnston, Chemistry, Fall 2005-Spring 2006
- Ian Kittelson, Biology, Summer 2005-Spring 2006
- Niki Paulk, Biology, Winter 2004-Spring 2006,
- Megan Jones, Chemistry, 2004-2005
- Jeff Martin, Biology, 2003-2004
- Jared Erickson, Biology, summer 2004
- Lacy Ledbeter, Chemistry/Geology, 2003-2005
- Dan Baker, Geology, 2003-2004
- Matt Lenington, Chemistry, 2001-2005

## **SERVICE**

### **Chemistry Department Committees**

- Biochemistry TT Faculty Search Committee Member, Summer 2007-Fall 2007
- Organic I TT Faculty Search Committee Member, Fall 2006-Winter 2007
- Personnel Committee Member, Fall 2006-Spring 2007
- Graduate Program Director and Graduate Committee Chair, Fall 2005-Spring 2008
- Physical/Analytical TT Faculty Search Committee Member, Fall 2004 and Fall 2005
- Non-Tenure Track Faculty Search Committee Chair, Summer 2006
- Undergraduate Committee Member, Fall 2004-present
- Safety Committee Member, Chemistry Department, Fall 2004-present

### **College Committees and Task Forces**

- Search for COTS Dean, Committee Member, Fall 2007-Spring 2008
- Search for COTS Associate Dean for Undergraduate Research and Resource Development, Committee Chair, Fall 2006-2007
- Committee for Environmental Research and Education (ERE), Member, Fall 2003-present
- Search for ERE Faculty, Committee Member, Fall 2007-Spring 2008
- Search for COTS fiscal tech, Committee Member, Fall 2007-Winter 2008
- Engineering Techs I and II Advisory Committee Member, COTS, Fall 2005-present
- Engineering Tech. Search Committee Member, Chemistry Department, Fall 2004

### **University Committees, Councils and Task Forces**

- Equal Opportunities Committee, Vice Chair then Member, Fall 2005-present
- Task Force for Economic Development and Community Engagement, Member, Fall 2005
- Task Force for the new CWU Teacher-Scholar Center, Member, Winter 2007-present
- Climate Commitment Task Force, Member, Spring 2007-present
- Faculty Fellow for Academic Service Learning, Fall 2006-2007
- Diversity Council, Member, Fall 2005-Spring 2007
- Diversity Council Commission on Employment, Member, Fall 2006-Spring 2007
- Ad-Hoc Committee to Diversity Council to Assess and Evaluate CWU Diversity Goals and Initiatives, Member, Winter 2005

### **Professional Service**

- NSF Panelist for Proposal Review, Major Research Instrumentation – Mass Spectrometry and Chromatography, May 1-2, 2008, Washington DC
- NIH Panelist for Proposal Review, Gene and Drug Delivery Study Section, Feb. 6-7, 2008, Santa Monica, CA
- PNNL User Advisory Committee Member, Jan. 2007-present
- Proposal Reviewer, PNNL, May 2006-present
- Proposal Reviewer, NSF Atmospheric Sciences Division, Summer 2002-present
- Proposal Reviewer, Israel Science Foundation, Spring 2007-present
- Manuscript Reviewer, Journal of Physical Chemistry, Nov. 2008-present
- Manuscript Reviewer, Deep-Sea Research, Jan. 2006-present
- Manuscript Reviewer, Chemosphere, Dec. 2004-present
- Manuscript Reviewer, Marine Chemistry, Spring 2004-present
- Manuscript Reviewer, Environmental Science and Technology, Summer 2002-present
- Manuscript Reviewer, American Geophysical Union, Summer 2002-present

### **Outreach**

- Panel on Alternative Ways to Mitigate CO2 Emissions, Panelist, Climate Commitment Council Event, CWU, 2008
- Panel on Women in Science, Panelist, CWU, April 2008
- Expanding Your Horizons (EYH), Session Leader, CSI-Ellensburg, Winters 2006 and 2007
- CWU Biodiesel Forum, Presentation to Community, Winter 2006
- No Fossil Fuel Day, Civic Engagement Event, Invited presentation about Global Climate and Fossil Fuel, Spring 2006
- Wine Initiative Congressional Press Conference with Senator Doc Hastings, Contributor, Summer 2006
- Collaborations with North Seattle Community College, engaging NSCC students with our NIH collection of particles in Seattle, Spring 2006-present
- CWU Chemical Analysis Laboratory, EPA accredited lab with the goal of serving the need of the community (Faculty Fellow Project)

### **LANGUAGES (FLUENT; WRITTEN AND ORAL)**

- English (living in the USA since 1991)
- German (mother tongue)
- Spanish (lived in Venezuela for 18 years, 0-18 years of age)
- Norwegian (lived in Norway for 5.5 years)

### **REFERENCES**

- Dr. Michael Hoffmann, James Irvine Professor of Environmental Chemistry, Dean of Graduate Studies, Caltech, Pasadena, CA 91125, T: 1-626-395-4391, mrh@caltech.edu
- Dr. Janet Hering, Director, Eawag, Swiss Federal Institute of Aquatic Science & Technology, CH-8600 Dübendorf, T: +41 (0)44 823 5001, janet.hering@eawag.ch
- Dr. Hermann Bange, Leibniz-Institut für Marine Science (IFM-GEOMAR), Marine Biogeochemistry-Chemical Oceanography, Düsternbrooker Weg 20, D-24105 Kiel, T: +49 (0)431 6004204, hbange@ifm-geomar.de
- Dr. Natalie Mahowald, Earth and Atmospheric Science, Cornell University, Ithaca, NY 14850, T: 1-607-255-5166, nmm63@cornell.edu
- Dr. JoAnn Peters, Chair of Chemistry Department, CWU, 400 E. University Way, Ellensburg, WA 98926, T: 1-509-963-2022, petersj@cwu.edu
- Dr. Carey Gazis, Associate Professor of Geology, Central Washington University, Ellensburg, WA 98926, T: 1-509-963-2820, cgazis@cwu.edu

## Todd T. Kroll

*Curriculum Vitae – Dec. 2009*

### **Current Position and Address**

Assistant Professor  
Department of Chemistry  
400 E. University Way  
Central Washington University  
Ellensburg, WA 98926-7539

### **Education and Training**

Oct. 2002 to Aug. 2009 - postdoctoral training, Salk Institute for Biological Studies

**Research advisor:** Dennis D.M. O'Leary, Ph.D.

Aug. 2002 - Ph.D., Biochemistry, University of Notre Dame

**Thesis advisor:** Paul W. Huber, Ph.D.

**Dissertation:** Characterization of the ribonucleoprotein complex that forms on the localization element of *Xenopus* Vg1 mRNA.

The Vg1 mRNA is localized at a discrete region in *Xenopus* oocytes. Several proteins are known to bind this RNA, including Prrp (proline-rich RNA-binding protein). To gain insight into the role of this protein, a yeast two-hybrid screen was performed, resulting in the identification of several Prrp-binding proteins. Co-immunoprecipitation assays were used to confirm the *in vivo* interactions of these proteins to Prrp. Both Prrp and its binding partners were further characterized using laser-scanning confocal microscopy to investigate their distributions in developing oocytes.

Spring 1997, volunteer research assistant with Nancy Bowers, Ph.D. at Portland State University

June 1995 - B.S., Chemistry and Biology, Eastern Washington University

**Majors:** Biology and Chemistry, with emphasis in Biotechnology

## **Teaching Experience**

- 2009-present Teaching upper division biochemistry lecture and lab courses and lower division general chemistry and biochemistry lecture and lab courses. Developing and teaching specialty upper division course on RNA biochemistry (winter 2010).
- 2004-2009 Supervised and advised two Ph.D. graduate students from UC-San Diego. I also designed projects for and supervised multiple visiting summer interns.
- 2000-2002 Supervised and advised several undergraduates and multiple junior graduate students conducting research in the laboratory of Paul Huber, Ph.D. at the University of Notre Dame.
- 1998-1999 Helped to design experiments for a graduate-level biochemistry laboratory course and supervised/assisted the students taking this course. TA for general chemistry laboratory courses. University of Notre Dame.
- 1994-1995 Tutored nursing students in general, organic and biochemistry. Eastern Washington University.
- 1993-1995 TA for undergraduate general and organic chemistry courses. Eastern Washington University.

## **Fellowships, Honors and Professional Organizations**

- Neuroplasticity of Aging Training Grant Fellowship, UCSD/NIH (2003-6)
- McCanna Fellowship, University of Notre Dame (2001-2002)
- Schmitt Fellowship, University of Notre Dame (1997-2001)
- Graduated cum laude (EWU, 1995)
- Member of Society for Neuroscience (2005-present)

## References

Dr. Dennis D.M. O’Leary  
Salk Institute for Biological Studies  
Molecular Neurobiology Laboratory  
10010 N. Torrey Pines Rd.  
La Jolla, CA 92037  
Phone: (858) 453-4100 ext. 1415, Email: [doleary@salk.edu](mailto:doleary@salk.edu)

Dr. Paul W. Huber (Ph.D. advisor)  
University of Notre Dame  
Department of Chemistry and Biochemistry  
251 Nieuwland Science Hall  
Notre Dame, IN 46556  
phone: (219) 631-6042, E-mail: [huber.1@nd.edu](mailto:huber.1@nd.edu)

Dr. Holly V. Goodson (Ph.D. committee member)  
University of Notre Dame  
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Notre Dame, IN 46556  
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Dr. Charles Stevens  
Salk Institute for Biological Studies  
Molecular Neurobiology Laboratory  
10010 N. Torrey Pines Rd.  
La Jolla, CA 92037  
phone: (858) 453-4100 ext. 1155, E-mail: [cfs@salk.edu](mailto:cfs@salk.edu)

## **Publications**

Chou, S.J., Perez-Garcia, C.G., Kroll, T.T. and D.D.M. O'Leary. (2009) Lhx2 specifies regional fate in Emx1 lineage of telencephalic progenitors generating cerebral cortex. *Nat. Neurosci.* 12(11):1381-9.

Kroll, T.T., L.B. Swenson, E.I. Hartland, D.D. Snedden, H.V. Goodson, and P.W. Huber. (2009) Interactions of 40LoVe within the ribonucleoprotein complex that forms the localization element of *Xenopus* Vg1 mRNA. *Mech Dev.* 126(7):523-38.

O'Leary D.D.M. and T.T.Kroll. (2009) Neural Patterning: Arealization of the Cortex. In: Squire LR (ed.) *Encyclopedia of Neuroscience*, volume 6, pp. 189-197. Oxford: Academic Press.

Leingartner, A<sup>1</sup>., S. Thuret<sup>1</sup>, T.T. Kroll, S-J. Chou, J.L. Leasure, F.H. Gage and D.D.M. O'Leary. (2007) Cortical area size dictates performance at modality-specific behaviors. *PNAS* 104(10): 4153-8.

Kroll, T.T. and D.D.M. O'Leary. (2005) Ventralized dorsal telencephalic progenitors in Pax6 mutant mice generate GABA interneurons of a lateral ganglionic eminence fate. *PNAS* 102(20): 7374-9.

Kroll, T.T.<sup>1</sup>, W. Zhao<sup>1</sup>, C. Jiang and P.W. Huber. (2002) A homolog of FBP2/KSRP binds to localized mRNAs in *Xenopus* oocytes. *Development* 129: 5609-19.

Zhao, W., C. Jiang, T.T. Kroll, and P.W. Huber (2001) A proline-rich protein binds to the localization element of *Xenopus* Vg1 mRNA and to ligands involved in actin polymerization. *EMBO J.* 20(9): 2315-25.

Bowers, N., T.T. Kroll, and J.R. Pratt (1998) Diversity and geographic distribution of riboprints from three cosmopolitan species of *Colpoda* Muller (Ciliophora: Colpodea). *Europ. J. Protistol.* 34: 341-7.

<sup>1</sup>denotes co-first authors

**Select Presentations**

- 2005 “Ventral respecification of dorsal telencephalon in Pax6<sup>sey/sey</sup> mice.” Oral Presentation - Developmental Neurobiology Symposium for UCSD and Salk Institute.
- 2004 “Ventralization of dorsal telencephalic progenitors in Pax6<sup>sey/sey</sup> mice results in ectopic production and migration of GABAergic interneurons” Poster presentation, Society for Neuroscience annual meeting - San Diego, CA.
- 2002 “A proline-rich protein may mediate an RNA-microfilament interaction” Oral presentation, Chicago Cytoskeleton Meeting - Northwestern Medical School.
- 2001 “KSRP/FBP2 Binds to the Localization Element of *Xenopus* Vg1 mRNA and to Prrp,” Poster presentation, ASCB annual meeting - Washington, D.C.



- 9/06 – 9/07 Program Director, CWU at Green River Community College, Central Washington University  
 Director is responsible for coordinating the Elementary Education Major and Science Education Minor program of study for student cohorts of ~30. Oversees application process including interview and cohort selection; sets class schedule; recruits adjunct faculty; advises students; and communicates with contributing departments.
- 9/05 – 12/07 Chair, Department of Chemistry, Central Washington University  
 Chair is responsible for providing a positive learning environment in the chemical sciences for ~80 majors and minors. The department consists of twelve faculty and seven staff. The chair is responsible for budgets totaling over \$1M. Duties include scheduling, supervision of staff, reappointment/tenure/post-tenure/promotion review of faculty, writing reports, budgeting, hiring staff and student workers (30 TAs/stockroom assistants/office assistants).
- 9/05 – 12/07 Program Director, Science Education, Central Washington University
- 6/01 - 9/04 Chair, Department of Chemistry, Central Washington University
- 9/98 - 9/04 Program Director, Science Education, Central Washington University

### RECENT TRAININGS, INSTITUTES, and WORKSHOPS

- 9/08 QuIRK/PKAL Workshop, Quantifying Quantitative Reasoning in Undergraduate Education: Alternative Strategies for the Assessment of Quantitative Reasoning
- 8/08 LENS Math Science Partnership Institute, Yakima Public Schools
- 6/08 Harvard Institute of Higher Education, Management Development Program
- 8/07 LENS Math Science Partnership Institute, Yakima Public Schools

### OTHER WORK EXPERIENCE

- 8/87 - 10/88 Research Assistant; Hazleton Laboratories America, Inc.

### AWARDS

- Washington Higher Education Science Teacher of the Year, 2009  
 CWU Distinguished Professor: Service, 2008  
 Center for Teaching and Learning Apple Award for Outstanding Teacher Educator, 2002, 2003

### PROFESSIONAL ORGANIZATIONS AND HONORARY SOCIETIES

- |  |   |
|--|---|
| American Chemical Society                | Association for Science Teacher Education         |
| Washington Science Teachers Association  | Phi Eta Sigma                                     |
| National Science Teachers Association    | Phi Kappa Phi                                     |
| Washington College Chemistry Association | Environmental Education Association of Washington |
| Kittitas Environmental Education Network |   |

### BOARD MEMBERSHIPS

- Washington Science Teachers Association Board of Directors, member, 4/09 - present  
 CWU Culture and Environment Museum Advisory Council, 3/09 – present  
 CWU Professional Educators Advisory Board, 9/08 - present  
 Environmental Education Association of Washington Board of Directors, member, 8/06 – 12/08  
 Phi Kappa Phi Executive Board, treasurer, 6/99 – present

### JOURNAL, BOOK, and CONFERENCE PUBLICATIONS (\*Denotes student co-author)

- Cox, J., Kurtz, M., Sterner, D., Otto, P., Ryken, A., & Tudor, M. Bridging K-12/13-20 Science Education in Washington: A Model for Field Investigation in the Science Classroom. *Phi Delta Kappan*, in preparation.
- Quitadamo, I. J., Cornell, C.\*, Holstad, J.\*, Brown, L.\*, Hunter, B.\* & Kurtz, M. J. Critical Thinking Grudge Match: Biology vs. Chemistry. *Journal of College Science Teaching*, in preparation.
- Quitadamo, I. J., Faiola, C.\*, Johnson, J., & Kurtz, M. J. (2008) Community-based Inquiry Improves Critical Thinking in General Education Biology. *Cell Biology Education-Life Science Education*, 7, 327-337.
- Quitadamo, I., Kurtz, M., Sorey, T., Pratt-Sitaula, B., & Palmquist, B. (2006). "Using e-Portfolio to Assess Pre-Service Teacher Performance," *Journal of Washington Science Teachers Association*, 46(4), 20-27.
- Kurtz, M. J., Oursland, M. & Quitadamo, I. J. (2006). Cougars across the curriculum: Using just-in-time technology to support integrated student research, preservice teacher development, and enhanced K-12 learning. *Leadership Information*, 5(4), 31-39.
- Kurtz, M. J. (2006). Environment-based Integrated Learning: Building a Sustainable Future. *Proceedings of 4<sup>th</sup>*

*International Conference on Science, Mathematics, and Technology Education*, 359-369.

- Kurtz, M. J., Oursland, M., & Quitadamo, I. J. (2005). Just-in-Time Technology that Supports Cougar Research Across the Curriculum. *Society for Information Technology & Teacher Education 16<sup>th</sup> International Conference Proceedings*, 2701-2708.
- Kurtz, M. J., Oursland, M., Miller, J. & Quitadamo, I. (2005). Project CAT, *PT<sup>3</sup> Monograph*, 17-27.
- Kurtz, M. J. & Holden, B. E.\* (2001). Analysis of a Distance Education Program in Organic Chemistry. *J. Chem. Ed.*, 78:8, 1122-1125.
- Baxter, L. M. & Kurtz, M. J. (2001). When a Hypothesis is Not an Educated Guess. *Science and Children*, 38:7, 18-20.
- Kurtz, M. J. & Birk, J. P. (1999). The Effect of Experience on the Retention and Elimination of Misconceptions on Molecular Structure and Bonding. *J. Chem. Ed.*, 76:1, 124-128.
- Birk, J. P. & Kurtz, M. J. (1996). Using Cooperative Learning Techniques To Train New Teaching Assistants. *J. Chem. Ed.*, 73, 615.
- Birk, J. P. & Kurtz, M. J. (1994). Laboratory Equipment and Techniques. *The Burgess Collection of General Chemistry Exercises*, Burgess Publishing, Minneapolis, 18 pages
- Birk, J. P. & Kurtz, M. J. (1994). Semimicro Techniques. *The Burgess Collection of General Chemistry Exercises*, Burgess Publishing, Minneapolis, 3 pages
- Birk, J. P. & Kurtz, M. J. (1994). Safety and Laboratory Procedures. *The Burgess Collection of General Chemistry Exercises*, Burgess Publishing, Minneapolis, 7 pages
- Birk, J. P. & Kurtz, M. J. (1994). *Investigations in Chemistry*, Houghton Mifflin Company, Boston, 514 pages
- Birk, J. P. & Kurtz, M. J. (1994). *Instructor's Resource Manual to Accompany Investigations in Chemistry*, Houghton Mifflin Company, Boston, 268 pages
- Birk, J. P., Ronan, M., Bennett, I., & Kinney, C. (1991). Reactivity of Nickel. *J. Chem. Ed.*, 68, 48
- Tonkyn, R., Ronan, M., & Weisshaar, J. C. (1988). Multi-Collision Chemistry of Gas Phase Transition Metal Ions With Small Alkanes: Rate Constants and Product Branching at 0.75 torr He. *J. Phys. Chem.*, 92, p. 92

#### **OTHER PUBLICATIONS**

- Kurtz, M., Strohm, K.\*, and CWU SCED 301 students\*. (2006). Helen McCabe State Park Interpretive Trail. Kittitas Environmental Education Network, Ellensburg, WA
- Kurtz, M. J. & Birk, J. P. (1994). *Guide for Teaching Assistants in Chemistry*, 6th edition, Arizona State University, Tempe, AZ
- Ronan, M. & Essenmacher, G. (1986). Copper Reactions. University of Wisconsin-Madison, General Chemistry Division

#### **ORAL PRESENTATIONS** (\*Denotes student co-author, \*\*denotes student presenter)

- Cornell, C\*\*, Quitadamo, I., and Kurtz, M. "Effects of Community-based Inquiry on Critical Thinking in Non-Majors Chemistry," Symposium on University Research and Creative Expression, Central Washington University, Ellensburg, WA, May 15, 2008.
- Cornell, C\*\* and Kurtz, M. "Effects of Community-based Inquiry on Critical Thinking in General Education Chemistry, National Science Teachers Association, Boston, MA, Mar. 28, 2008.
- Kurtz, M. J. "A Community-based Inquiry Model to Enhance Watershed Research in the Schools." 17<sup>th</sup> Annual Conference of the Environmental Education Association of Washington, SeaTac, WA, Nov. 10, 2007.
- Cornell, C.\* and Kurtz, M. "Critical Thinking in Introductory Chemistry." Washington College Teachers Association, Leavenworth, WA, Oct. 19, 2007.
- Fiola, C\*\*, Quitadamo, I., Johnston, J., & Kurtz, M. "Community-Based Inquiry to Improve Critical Thinking and Content Knowledge." Symposium on University Research and Creative Expression, Central Washington University, Ellensburg, WA, May 17, 2007.
- Kurtz, M. J., Sorey, T, Quitadamo, I. J., Palmquist, B., & Pratt-Sitaula, B. "Developing electronic Portfolios to Assess Student Performance Relative to National and State Science Education Standards: A Collaborative Process." 2007 Association for Science Teacher Education International Conference, Clearwater Beach, FL, Jan. 4, 2007.
- Kurtz, M. J. "Using the Environment to Integrate the Sciences: An inquiry course for elementary teachers." Teachers of Teachers of Science, Pullman, WA, Jun. 10, 2006.
- Kurtz, M. J. "Misconceptions in Science: Where Do They Come From and What Can We Do?" invited seminar, Southern Oregon University, Ashland, OR, May 5, 2006.

- Baxter, L. & Kurtz, M. J. "Helping Students Make *Contact* with the Nature of Science." Washington Science Teachers Association, Wenatchee, WA, October 15, 2005.
- Kurtz, M. J. "Environment-based Integrated Learning: Building a Sustainable Future." 4<sup>th</sup> International Conference on Science, Mathematics, and Technology Education, Victoria, BC, August 25, 2005.
- Kurtz, M. J. "Expanding Your Horizons at CWU: A Report to the American Association for University Women." Regional Meeting of the American Association for University Women, Ellensburg, WA, August 20, 2005.
- Kurtz, M. J. & Quitadamo, I. J. "Project CAT: Authentic Research in the Classroom." Teachers of Teachers of Science, Pullman, WA, May 20, 2005.
- Kurtz, M. J., Oursland, M., & Quitadamo, I. J. "Just-in-Time Technology that Supports Cougar Research Across the Curriculum." Society for Information Technology & Teacher Education 16<sup>th</sup> International Conference, Phoenix, AZ, March 1, 2005.
- Kurtz, M. J. "Cougars, Integration, Technology and Internships: Project-based Preparation of Science and Math Teachers." National Science Teachers Association Conference, Seattle, WA, Nov. 19, 2004.
- Quitadamo, I. J. & Kurtz, M. J. "A Quantitative Assessment Model for Measurement of Undergraduate Critical Thinking." Pacific Northwest Higher Education Conference, Vancouver, WA, May 7, 2004.
- Kurtz, M. J. "Misconceptions in Science: Where Do They Come From and What Can We Do?" invited seminar, Eastern Washington University, Cheney, WA, Apr. 29, 2004.
- Kurtz, M. J. & Tudor, M. "Integrated Environmental Education Benchmarks;" Environmental Education Association of Washington, Ellensburg, WA, Mar. 19, 2004.
- Oursland, M. & Kurtz, M. J. "Integrating High School Science and Mathematics Using GIS Modeling." Microcomputers in Education Conference, Tempe, AZ, Mar. 16, 2004. Presented by co-author.
- Kurtz, M. J. & Oursland, M. "Using a Computer Model to Assess the Relationship Between Teaching Behavior and student Engagement." Microcomputers in Education Conference, Tempe, AZ, Mar. 15, 2004.
- Kurtz, M. J. "Our Emerging role in Teacher Training: A Chemist's Perspective." Washington College Chemistry Teachers Association, Leavenworth, WA, Oct. 17, 2002.
- Baxter, L. B. & Kurtz, M. J. "Questioning: The Heart of Inquiry." Washington Science Teachers Association, Yakima, WA, Nov. 3, 2001.
- Kurtz, M. J. "Assessment Potpourri." Washington College Chemistry Teachers Association, Leavenworth, WA, Oct. 12, 2001.
- Baxter, L. B. & Kurtz, M. J. "Questioning: The Heart of Inquiry." Washington Science Teachers Association, Vancouver, WA, Oct. 14, 2000.
- Kurtz, M. J., McClung, M.,\* Thiel, T.\*, & Dunn, S. M.\* "Using Computer Interfaces in the General Chemistry Classroom: Do They Really Have a Positive Impact on Student Learning?" 16th Biennial Conference on Chemical Education, Ann Arbor, MI, Aug. 2, 2000.
- Holden, B. E.\*\* & Kurtz, M. J. "An Assessment of the Effectiveness of Distance Education in Teaching Organic Chemistry." 16th Biennial Conference on Chemical Education, Ann Arbor, MI, Aug. 2, 2000.
- Kurtz, M. J. "The Efficiency and Effectiveness of Learning When Using Computers to Acquire and Analyze Data in General Chemistry Labs." Washington College Chemistry Teachers Association Meeting, Leavenworth, WA, Apr. 21, 2000.
- Kurtz, M. J. "Lunar Misconceptions Held By Pre-service Teachers: Where Do They Come From and What Should We Do About It?" Washington Science Teachers Association Meeting, Spokane, WA, Oct. 30, 1999.
- Kurtz, M. J. "Misconceptions in Science: Where Do They Come From and What Can We Do About It?" Natural Science Seminar, Central Washington University, Nov. 20, 1998.
- Gerdes, DeLuca, Dibari, Logan, & Kurtz, M. J. "A Collaborative Model for Distance Organic Chemistry Curriculum: MCUs, T1 Lines, Couriers, Adjuncts, and Administrators" 53rd Northwest Regional Meeting of the American Chemical Society, Richland, WA, June 18-20, 1998. Presentation given by co-authors.
- Kurtz, M. J. "Using the Learning Cycle in the College Chemistry Laboratory." Washington College Chemistry Teachers Association Meeting, Leavenworth, WA, Apr. 16-18, 1998.
- Kurtz, M. J. "Assessing Departmental Goals and Student Outcomes for Chemistry 105." A Celebration of Learning; Fall 1997 Faculty Meeting, Central Washington University, Ellensburg, WA, Sept. 18, 1997.
- Kurtz, M. J. "Assessing Departmental Goals and Student Outcomes for Chemistry 105." Faculty Development Seminar, Central Washington University, Ellensburg, WA, May 15, 1997.
- Kurtz, M. J. & Birk, J. P. "Misconceptions in Chemistry: A Persistent Problem." 211th American Chemical Society National Meeting, New Orleans, LA, Mar. 24-28, 1996.

Kurtz, M. J. & Birk, J. P. "Using Multiple Analogies to Teach College Chemistry: A Multiple Analogy Approach." American Chemical Society Spring Meeting, Anaheim, CA, Apr. 2-6, 1995.

**POSTER PRESENTATIONS** (\*Denotes student co-author, \*\*denotes student presenter)

- Brady S.\*\*, Kurtz, M., Carolan, L., Hilferty, C.\*\*, Ketsdever, A.\*\*, and Wickwire, E. "Yakima WATERS Project: Watershed Activities To Enhance Research in Schools," NSF Graduate Teaching Fellows in K-12 Education (GK-12) Annual Meeting, Washington, D.C., March 28, 2009.
- Bohrson, W., Braunstein, M., Ely, L. Piacsek, A., Nye, J.\*, Kurtz, M. and Moses, M.\* "CWU Science Talent Expansion Program: Recruiting and Retaining the Next Generation of STEM Professionals," NSF STEP Grantee Meeting, Washington, D.C., March 13, 2009.
- Cornell, C. \*\*, Affholter, T., and Kurtz, M. "WATERS in Lincoln Elementary Fifth Grade," Symposium on University Research and Creative Expression, Central Washington University, Ellensburg, WA, May 15, 2008.
- Cornell, C.\*\*, Kurtz, M. J., Quitadamo, I. J., Holstad, J.\*, Brown, L.\*, & Hunter, B.\* "Critical Thinking Grudge Match: Biology vs. Chemistry, Academic and personal factors that affect thinking skills in non-majors science." Symposium on University Research and Creative Expression, Central Washington University; Ellensburg, WA; May 17, 2007
- Huddleston, K.\*\* & Kurtz, M. J. "STEP (Science Talent Expansion Program): The data and response behind the three-year pilot program." Symposium on University Research and Creative Expression, Central Washington University; Ellensburg, WA; May 18, 2006.
- Berkeley, A.\*\*, Kurtz, M. J. "Analysis of STEP: The Freshman Science Seminar Series." Symposium on University Research and Creative Expression, Central Washington University; Ellensburg, WA; May 19, 2005.
- DePape, J., Ault, P., Mathias, K., Oursland, M., Quitadamo, I., Wagner, S., Sledge, A., Kurtz, M., Englund, T., & Briggs, K. "Teacher Interns Learn New Technological Skills Through Heart, Frog, Cougar, and Robotic Research." Society for Information Technology & Teacher Education 16<sup>th</sup> International Conference, Phoenix, AZ; March 1, 2005.
- Brewer, M.\*\*, Flaugh, D.\*\*, Quitadamo, I., & Kurtz, M. J. "A Quantitative Model for Assessment of Undergraduate Critical Thinking." Symposium on Undergraduate Research and Creative Expression, Central Washington University; Ellensburg, WA; May 20, 2004.
- Earlywine, J. C.\*\* & Kurtz, M. J. "Design and Implementation of a Pedagogical Research Project to Assess the Effectiveness of a Specially Designed Ramp in Explaining Electron Configuration to Introductory Chemistry Students." Symposium on Undergraduate Research and Creative Expression, Central Washington University; Ellensburg, WA; May 17, 2001.
- Earlywine, J. C.\*\* & Kurtz, M. J. "Design and Implementation of a Pedagogical Research Project to Assess the Effectiveness of a Specially Designed Ramp in Explaining Electron Configuration to Introductory Chemistry Students." 221st ACS National Meeting; San Diego, CA; Apr. 1-5, 2001.
- McClung, M. G.\*\*, Thiel, T. \*, & Kurtz, M. J. "An Analysis of Computer Use and Related Student Attitudes in General Chemistry Laboratories." Symposium on Undergraduate Research and Creative Expression, Central Washington University; Ellensburg, WA; May 19, 2000.
- McClung, M. G.\*\*, Thiel, T. \*, & Kurtz, M. J. "An Analysis of Computer Use and Related Student Attitudes in General Chemistry Laboratories." 14th National Conference on Undergraduate Research; Missoula, MT; Apr. 27-29, 2000.
- Holden, B.\*\* & Kurtz, M. J. "Analysis of a Distance Education Program in Organic Chemistry." Symposium on Undergraduate Research and Creative Expression, Central Washington University; Ellensburg, WA; May 16, 1998.

**GRANTS and CONTRACTS AWARDED**

- "Personalizing Student Learning of Math and Science to Increase Achievement," Higher Education Coordinating Board Educators for the 21<sup>st</sup> Century, co-Director (Academic PI), \$1.2M, 2009 (pending)
- "Math 360: Building Academic Language and Content Skills in Mathematics," Higher Education Coordinating Board Educators for the 21<sup>st</sup> Century, Senior Personnel, \$1.2M, 2009 (pending)
- "STEM Journeys," NSF: Informal Science Education, PI w/ co-PIs Jackson and Peterson, \$2.99M, 2008 (pending)
- "Family Science and Math Standards Showcase Events," CWU Foundation, PI, \$500, 2009.
- "Recruiting and Retaining the Next Generation of STEM Professionals Central Washington University," CWU NSF: STEP grant evaluation contract, 2007.
- "Through the Lens: Building Success in Science – Ensuring Success in Math and Literacy," OSPI Math Science

Partnership, Yakima School District, Senior Personnel, \$743K, 2007.

“General Science Education Program,” State Board for Community and Technical College, University Contract with Edmonds Community College Proposal, \$88,500, 2007.

“Science Education Curriculum Expansion,” CWU CESME Faculty Grant Program, PI, \$1,600, 2007.

“Purchase of Large Format Printer,” CWU COTS Equipment Grant, PI, \$5,616, 2007.

“Yakima Watershed Activities To Enhance Research,” NSF: GK-12, co-PI w/Gazis, Quitadamo, Wagner, and Pratt-Sitaula, \$2.8M, funded for 5 yrs., 2007.

“Center for Excellence in Science and Mathematics Education,” CWU Spheres of Distinction, PI, \$61K, 2006.

“Organic Chemistry,” Higher Education Coordinating Board High Demand Programs, PI, \$189K, 2006; funding converted to annual base budget, 2007.

“Tools for Lifelong Learning,” CWU SOAR Grant, co-PI w/ Quitadamo, \$8,500, 2005.

“MSP Watershed Investigation Project,” OSPI, Math/Science Partnership Program, Senior Personnel, \$721K, funded for 3 yrs., 2004.

“Lincoln School Partnership,” CWU Foundation Leonard Thayer Small Grant, PI, \$590, 2004.

“Middle Level Math/Science Endorsement,” Higher Education Coordinating Board High Demand Programs, PI, \$380K; funding converted to annual base budget, 2003.

“Faculty Workshop on Critical Thinking and Peer Led Team Learning,” CWU Faculty Senate Development and Appropriations Committee, PI, \$4,952, 2003.

“Lincoln School Partnership,” CWU Foundation Leonard Thayer Small Grants Program, PI, \$500, 2003.

“In Answer to A National Challenge: A Pilot Program to Increase Participation in Science, Technology and Mathematics (STEM) Fields,” National Science Foundation, STEP, co-PI w/Bohrson, Braunstein, Ely, Gazis, Gellenbeck, and Piacsek, \$250K, funded for 3 yrs., 2002.

“Expanding Your Horizons,” CWU Foundation Leonard Thayer Small Grants Program, PI, \$300, 2002.

“Expanding Your Horizons,” CWU Foundation Leonard Thayer Small Grants Program, PI, \$500, 2001.

“Summer Science Institutes,” RGK Foundation, PI, \$6,000, 2001.

“Summer Science Institutes,” GTE Focus Grant, co-PI w/Baxter, \$30K, funded for 2 yrs., 2000.

“Summer Science Institutes,” Northwest Learning and Achievement Group, co-PI w/Baxter, \$70K, funded for 2 yrs., 2000.

“Expanding Your Horizons,” CWU Foundation Leonard Thayer Small Grants Program, PI, \$700, 1999.

“Multicultural Experiences in Mathematics and Sciences,” CWU Foundation Leonard Thayer Small Grants Program, PI, \$4,500, 1998.

“Development of General Chemistry Laboratory Experiments Using a Computer-Based Design,” CWU Summer Research Grant, PI, \$3,500, 1998.

“Preservice Training for Teachers in Molecular Biology,” NSF – ILI/IP, PI, \$33,614, funded for 2 yrs., 1997.

“Delivering Essential Academic Learnings in Science to All Rural Students - A collaborative Project Between Central Washington University and Kittitas County Schools,” Eisenhower Program, co-PI w/Baxter, \$36K, 1995.

## **COURSES TAUGHT**

Chemistry:           CHEM 101 – Contemporary Chemistry with Laboratory  
                           CHEM 105 – Processes in Physical Science: Chemistry (for Elementary Education Majors)  
                           CHEM 111 – Introduction to Chemistry with Laboratory  
                           CHEM 181L – General Chemistry Laboratory  
                           CHEM 182L – General Chemistry Laboratory  
                           CHEM 492 – Laboratory Experience in Teaching Chemistry  
                           CHEM 495 – Undergraduate Research  
                           CHEM 542 – Teaching Chemistry at the Community College  
                           CHEM 595 – Graduate Research

Science Education:   SCED 301 – Interdisciplinary Science Inquiry  
                           SCED 322 – Science Education in the Elementary Schools  
                           SCED 354 – Science, Society, and the Teaching Community  
                           SCED 420 – Inquiry Activities for Elementary Science  
                           SCED 422 – Advanced Strategies for Teaching Elementary Science  
                           SCED 442 – Development of Special Materials

SCED 495 – Undergraduate Research  
SCED 501 – Interdisciplinary Science Inquiry for Teachers  
SCED 541 – Chemistry Concepts for Teachers  
SCED 598 – Misconceptions in Science

General: UNIV 101 – General Education Colloquium

Education: EDEL 598 – Middle School Educational Strategies, team taught

## **REPRESENTATIVE SERVICE**

### **Professional Service**

Environment and Sustainability Education Specialty Endorsement Standards Writing Team, 9/08 – present  
Kittitas Environmental Education Network Education Committee, 3/04 – 6/08.  
Pacific Education Institute, 7/02 – present, work with non-formal educators, agency educators and public school teachers to develop and implement integrated environmental education curricula.  
WEST-E Chemistry Test Item Validation Team, 11/07, only higher education representative on team to validate items for state exit exam for pre-service chemistry teachers.  
NAAEE Environmental Education Standards Writing Committee, 5/04 – 10/07; work group to write national NCATE standards for training environmental education teachers.  
American Association for University Women Steering Committee on Women in STEM, 8/05 – 12-06  
Panel Member, Summit on Women in STEM, American Association of University Women, Redmond, WA, 10/06  
Session Moderator, Washington College Chemistry Teachers Association, 10/01, 10/02, 10/04; session title: “Review and Discussion of Current Articles from the Science Ed/Chem Ed Literature.”  
Panel Member, Rocky Mountain Chemistry Chairs Conference, 4/04; session title: “Student Evaluation of Instruction.”  
Standard Setting Team for PRAXIS II, 3/04, set statewide cutoff scores for the chemistry teaching content exit exam.  
Secondary Math and Science Articulation Committee, 6/02; statewide committee to develop articulation agreements between community colleges and four-year schools for secondary science and math majors.  
Associate of Science Degree Advisory Committee, 4/99; developed a proposal for a statewide transferable AS degree.  
7th Annual Washington College Chemistry Teachers Association Conference Organizer, 9/98-4/99; organized entire conference including conference program, vendor show, accommodations.

### **Community Service**

Yakima River Canyon Scenic Byway Committee, Kittitas Environmental Education Network, 3/09 – present  
Nature of Night Organizer; 11/08; day long community event to explore night time science.  
Expanding Your Horizons Conference Organizer, 9/99 – present; a day long conference presented by women scientists for middle school girls.  
Professional Development Workshop Organizer, 6/96 – present, organized many professional development workshops for P-12 teacher and pre-service teachers including Project WET, Project Wild, Project Learning Tree, *NatureMapping*, Fuel Cell, Renewable Energy.  
GEAR UP Science and Leadership Camp, Science Coordinator, 6/03 – 7/07; coordinate 3 day camp for 6<sup>th</sup> and 7<sup>th</sup> graders each summer, science sessions taught by CWU pre-service teachers.  
Lincoln School Science Partnership, 1/00 – 3/07, 1/09 - present; 3<sup>rd</sup> grade students taught science by CWU pre-service teachers twice a week for one quarter each year.  
Science, Mathematics, and Technology Education Statewide Summit, Gonzaga University, participant, 10/05.  
Washington Department of Fish and Wildlife Citizen Science Statewide Summit, participant, 9/05.  
Multicultural Experiences in Math and Science Host, 10/98 – 5/05; annual three day event for middle school students to experience science and math, targeted to ethnic minorities.  
Flinn Scientific Summer Science Teacher Workshop, Co-host/Director, 8/01  
Youth Summer Science Institute, Co-Organizer/Co-Instructor, 7/00, 7/01; a week long residential science camp for 9<sup>th</sup> graders.  
Way Cool Science Discovery Camp, Co-Organizer/Co-Instructor, 6/00, 6/01; a week long science camp for 6<sup>th</sup> graders, sessions taught by CWU pre-service teachers.  
Event Supervisor, Science Olympiad, Columbia Basin Community College, 11/96.

### **University Service**

Professional Education Program Committee on Classroom Management, 2/09 – pres.  
Center for Teaching and Learning Advisory Board, 3/99 – 5/04, 9/05 – 12/07, 9/08 – pres.; chair 9/00 – 5/01  
Academic Department Chairs Organization, 9/01 – 9/04, 9/05 – 12/07, 9/08 – pres.; chair-elect, 9/06 – 8/07; chair, 9/07 – 12/07  
Student Chapter of the National Science Teachers Association Faculty Advisor, 9/02 – 5/04, 9/05 – 6/06, 9/08 - pres.  
Environmental Research and Education Committee, 1/06 – 12/07  
Assistant Vice President for Faculty Relations Search Committee, 8/07 – 12/07  
Pre-Pharmacy Club Advisor, 1/07 – 12/07  
Engineering Technician Steering Committee, chair, 9/05 – 12/07  
Science Occupants Committee, 9/01 – 12/07  
Associate Vice President for Undergraduate Studies Search Committee, 10/06 – 3/07  
NCATE Task Force, 9/00 – 5/01, 3/06 – 5/07  
NCATE Standard 6 Committee, co-chair, 4/06 – 9/06  
Student Teaching Intern Supervisor, 9/02 – 5/04, mentored 5 year-long interns  
Faculty Senate Representative, 9/99 – 5/04  
Dean Search Committees, College of Education and Professional Studies: 9/99 – 5/00, College of the Sciences: 9/03 – 5/04  
Student Affiliates of the American Chemical Society Chapter Advisor, 9/97 – 5/02  
Faculty Search Committees, numerous  
Faculty Professional Development Workshop Presenter; topics: peer evaluation of instruction, critical thinking  
Department Committees, numerous including Undergraduate, 9/96 – 5/01; Graduate, 9/95 – 5/02; Personnel, 9/01 – 9/02, 9/04 – 9/05, TA Assignment and Orientation, 9/95 – 5/04, 9/05 – 12/07

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**E-mail:** jdeluca@cwu.edu

**Birthdate:** March 14, 1958

**Education:**

B.S., 1980, Chemistry, Antioch College-Yellow Springs, Ohio  
Ph.D., 1986, Organic Chemistry, Harvard University, advisor: W. v. E. Doering

**Professional Employment:**

June 2001-present, Full Professor and Chair (Dec. 2008 - present), Department of Chemistry, Central Washington University  
Sept. 1996-June 2001, Associate Professor and Chair (August 1998 - June 2001), Department of Chemistry, Central Washington University  
Aug. 1987-May 1996, Assistant Professor (1987-1994) and Associate Professor (1994-1996), Department of Chemistry, Illinois State University  
Dec. 1985-June 1987, Post-doctoral researcher, University of Nevada-Reno, advisor: L. T. Scott  
1980-1984, Teaching fellow, Harvard University

**Award:**

Henry Dreyfus Teacher-Scholar Award

**Professional Service:**

Governing Board, Reaction Mechanisms Conference, 2006-present  
Councilor, Council on Undergraduate Research, 1999-2002  
Chair of the Organizing Committee for the Undergraduate Research Symposium of the American Chemical Society Puget Sound Section, 1999  
Program Co-Chair for the 1996 Great Lakes Regional Meeting of the American Chemical Society  
Treasurer of the Illinois State Academy of Science, 1990 - 1994  
Committee service at Central Washington University: Chemistry Department Graduate Committee (1996-2003), Chemistry Department Safety Committee (1997-1998), Chemistry/Biology New Building Computer Committee (1996-1998), Chemistry Department New Building Committee (1996-1998), Chemistry Department Website Development (1997-2003), Physical Chemistry Search Committee (1998), Chemistry Department Personnel Committee (1997-1998, 2001-present), Dean of the College of the Sciences Search Committee (1997/1998), Science Occupants Committee Chair (1998/1999), Secretary Search Committee Chair (1999), Inorganic Search Committee (1999/2000), Instrument Technician Search Committee Chair (1999/2000), Physical Chemist Search Committee (2001/2002), Organic Chemist Search Committees (2001-present), Graduate Council (2001-2003), Vice President for University Relations Search Committee (2001/2002), College of the Sciences Committee on Reappointment, Tenure, and Promotion Policies (2002/2003), College of the Sciences Instrument Technician Search Committee (2004/2005), Faculty Code Committee (2005-2008), Douglas Honors College Curriculum Committee (2008 - present)  
Committee service at Illinois State University: Chemistry Department Equipment Committee (1988), Chemistry Department Organic Faculty Search Committee (1991), Chemistry Department Faculty Search Committee (1989), Chemistry Department

Graduate Committee (1988 - 1992), Chemistry Department Undergraduate Curriculum Committee (1992 - 1994, Chair 1996), University Undergraduate Research Symposium Steering Committee (1991 - 1994), Preprofessional Committee (1992 - 1995), Chemistry Department Faculty Status Committee (1994 - 1995, spring 1996), College of Arts and Sciences Laboratory for Instructional Technology Advisory Committee (1994 - 1996)

**Membership in Professional Societies:**

American Chemical Society  
Washington College Chemistry Teachers Association

**Research Funding, External Funding Agencies:**

1. "Imprinting Silica Gel Surfaces Through Reversible Covalent Attachment of Organic Templates," Research Corporation, Cottrell College Science Award, \$50,783 (includes \$9565 institutional match), July 2007.
2. "Reversible Organic Derivatization of Silica: Development of New Methods for Creating Template Imprinted Surfaces," Pacific Northwest National Laboratory-EMSL User Proposal, solid state NMR and DSC/TGA instrument time, September 2006.
3. "Generation of Carbene Intermediates from Ylide Precursors," National Science Foundation-Research at Undergraduate Institutions, \$180,000, July 2000.
4. "Oxonium and Halonium Ylide Intermediates in Reactions of Singlet Carbenes," Henry Dreyfus Teacher-Scholar Award, The Camille and Henry Dreyfus Foundation, April 1997, \$60,000.
5. "Oxonium and Halonium Ylide Intermediates in Reactions of Singlet Carbenes," American Chemical Society-Petroleum Research Fund, Type B, 2/1/96 - 8/31/98.
6. "Second Period Ylide Intermediates in Reactions of Singlet Carbenes," American Chemical Society-Petroleum Research Fund-Type B, 9/1/93 - 8/31/95.
7. "Carbenoid Properties and Reversible Formation of Nucleophile-Carbene Adducts," American Chemical Society-Petroleum Research Fund-Type B, 9/1/91 - 8/31/93.
8. "Purchase of 300 MHz NMR Spectrometer," with Michael Kurz, Gerald Stevenson, Timothy Lash, and Karen Goldberg (Illinois State University), National Science Foundation Chemical Instrumentation Program, 6/1/90.
9. "Effect of Solvents and Nucleophilic Directing Groups on the Reactions of Singlet Carbenes," American Chemical Society-Petroleum Research Fund-Type G, 9/1/89 - 8/31/91.

**Funding, Internal:**

1. "New Method for the Preparation of Template Imprinted Silica Surfaces," Central Washington University Seed Grant, \$2000, May 2006.
2. CWU Faculty Research Appointment, fall 2004.

3. "Iodonium Ylides as Photochemical Precursors for Carbonyl Carbenes", Central Washington University Seed Grant, \$920, April 1998.
4. "Iodonium and Sulfonium Ylides as Photochemical Precursors for Carbonyl Carbenes," Faculty Summer Research Appointment, Central Washington University, 6/15/97 - 8/31/97.
5. Five competitive internal research grants at Illinois State University.
6. Sabbatical leave, Illinois State University, fall 1995.

**Research Publications:**

1. Matthew J. Lenington,<sup>#</sup> Leif Jacobson,<sup>#</sup> Barbara Eaton,<sup>#</sup> Tabitha Liebrecht,<sup>#</sup> and JoAnn Peters "Generation of Dicarboethoxycarbene and Meldrum's Acid Carbene from Iodonium Ylide Precursors" submitted to *The Journal of Organic Chemistry*, in revision.
2. Matthew J. Lenington<sup>#</sup> and JoAnn Peters DeLuca, "Generation of Triplet Carbenes through Photolysis of Iodonium Ylides," *The Spectrum*, winter **2005**.
3. W. von E. Doering and JoAnn Peters DeLuca "Conformational Restraint in Thermal Rearrangements of a Cyclobutane: 3,4-Dicyanotricyclo[4.2.2.0<sup>2,5</sup>]decane," *Journal of the American Chemical Society* **2003**, 125, 10608
4. Margaret B. Camacho,<sup>#</sup> Aurora E. Clark,<sup>#</sup> Tabitha A. Liebrecht,<sup>#</sup> and JoAnn P. DeLuca "A Phenylodonium Ylide as a Precursor for Dicarboethoxycarbene: Demonstration of a Strategy for Carbene Generation," *Journal of the American Chemical Society* **2000**, 122, 5210.
5. Jerry W. Cubbage,<sup>\*</sup> Brian L. Edelbach,<sup>\*</sup> Kan Shuh Kuen,<sup>#</sup> and JoAnn P. DeLuca "Stereodirecting Effects in the Characterization of Ylide Intermediates in Reactions of Singlet Methylene with an Allylic Alcohol and an Allylic Chloride," *Tetrahedron* **1997**, 53, 9823.
6. Lana L. Zub,<sup>#</sup> Jean M. Standard, Jerry W. Cubbage,<sup>\*</sup> and JoAnn P. DeLuca "Theoretical and Experimental Investigations of the Interactions Between Carbenes and Oxygen-Containing Compounds," electronic communication for the *First Electronic Conference on Trends in Organic Chemistry (ECTOC-1)*, ISBN 0 85404 899 5, Eds. H. S. Rzepa and J. M. Goodman, Royal Society of Chemistry Publications, **1995** (published on CD-ROM).
7. Warunee Sobery<sup>\*</sup> and JoAnn P. DeLuca "Intramolecular Trapping of an Ylide Intermediate in the Reaction of  $^1\text{C}:\text{H}_2$  with an Allylic Alcohol," *Tetrahedron Letters* **1995**, 36, 3315.
8. Judith M. Swanson,<sup>\*</sup> Curt A. Dvorak,<sup>#</sup> JoAnn P. DeLuca and Jean M. Standard "Complexation of a Singlet Carbene by a Fluoroalkane. Modification of  $^1\text{C}:\text{HCO}_2\text{Et}$  Selectivity in Perfluorohexane Solution and Ab Initio Calculations," *The Journal of Organic Chemistry* **1994**, 59, 3026.
9. Terry A. Young,<sup>#</sup> Colleen O'Rourke,<sup>#</sup> Nathan B. Gray,<sup>#</sup> Brian D. Lewis,<sup>#</sup> Curt A. Dvorak<sup>#</sup>, Kan Shuh Kuen<sup>#</sup> and JoAnn P. DeLuca "Stereodirecting Effect of a Substrate

Methoxy Substituent on the Addition of Singlet Methylene to a Double Bond," *The Journal of Organic Chemistry*, **1993**, *58*, 6224.

10. Susan M. Neugebauer\* and JoAnn P. DeLuca "A Solvent Effect in Reactions of Singlet Methylene," *Tetrahedron Letters* **1989**, *30*, 7169.
11. Vinayak V. Kane, Arnold R. Martin and JoAnn Peters "Carbon-13 Nuclear Magnetic Resonance Spectra of Cannabichromene, Cannabicitran, and Cannabicyclol and Their Analogues," *The Journal of Organic Chemistry* **1984**, *49*, 1793.
12. Vinayak V. Kane, Arnold R. Martin and JoAnn Peters "The Nonregiospecific Condensation of Citral and 2-Hydroxycarbazoles," *Heterocycles* **1981**, *16*, 1445.

\* M.S. student co-author

# undergraduate student co-author

### Research Presentations:

A total of 45 research presentations have been made at professional meetings, including: International Symposium on Reactive Intermediates and Unusual Molecules (2 talks), Thirteenth NSF Workshop on Physical Organic Chemistry, National ACS Meetings (4 papers, 2 posters), Reaction Mechanisms Conferences (4 posters, 1 talk), Physical Organic Gordon Conference (1 talk, 2 posters), IUPAC Conference on Physical Organic Chemistry (1 poster), Regional ACS Meetings (8 papers, 5 posters), Illinois State Academy of Science Meetings (8 papers), ACS Puget Sound Section Undergraduate Research Symposium (2 posters), National Conference on Undergraduate Research (1 poster), Washington College Chemistry Teachers Association (2 presentations). Many of these papers were presented by undergraduate (15) or M.S. level graduate student (10) coworkers. Student coworkers have also presented their results at research symposia sponsored by Illinois State University and Central Washington University. Presentations are listed below.

#### Presented by JoAnn Peters (DeLuca):

1. JoAnn Peters and Deb Simon, "Teaching Chemistry and Art: Why?!?! And How???", talk presented by J. Peters and D. Simon at the annual meeting of the Washington College Chemistry Teachers Association, Leavenworth, Washington, October 2009.
2. Matthew J. Lenington, # Leif Jacobson, # Barbara Eaton, # Tabitha Liebrecht, # and JoAnn P. DeLuca "Generation of Meldrum's Acid Carbene from an Iodonium Ylide," poster presented by J. DeLuca at the Physical Organic Gordon Conference, Holderness, New Hampshire, June 2005.
3. JoAnn P. DeLuca, Margaret B. Camacho, # Aurora E. Clark, # Barbara Eaton, # Tabitha A. Liebrecht, # Leif D. Jacobson, # and Matthew J. Lenington# "Phenylodonium Ylides as Precursors for Dicarboxylcarbenes," invited presentation by J. DeLuca at the International Symposium on Reactive Intermediates and Unusual Molecules, Reykjavik, Iceland, August 2003.
4. Leif D. Jacobson, # Nathanael G. Palmatier, \* and JoAnn P. DeLuca "C<sub>3</sub>O<sub>3</sub>: Computational Study of an Unusual Aromatic Species and Related Adventures," poster

presented by J. DeLuca at the Physical Organic Gordon Conference, Holderness, New Hampshire, July 2003.

5. Leif D. Jacobson<sup>#</sup> and JoAnn P. DeLuca "C<sub>3</sub>O<sub>3</sub>: Computational Study of an Unusual Aromatic Compound," poster presented by L. D. Jacobson and J. DeLuca at the IUPAC International Conference on Physical Organic Chemistry, San Diego, California, August 2002.
6. Margaret B. Camacho, <sup>#</sup> Aurora E. Clark, <sup>#</sup> Tabitha A. Liebrecht, <sup>#</sup> and JoAnn P. DeLuca "A Phenyliodonium Ylide as a Precursor for Dicarboethoxycarbene: Demonstration of a Strategy for Carbene Generation," poster presented by M. Camacho and J. DeLuca at the 2000 Reaction Mechanisms Conference, Madison, Wisconsin, June 2000.
7. JoAnn DeLuca, John DiBari, Marie Dunn,<sup>\*</sup> John Gerdes, and Richard Logan "Sharing Chemistry Resources Through Distance Technologies," presented by J. DeLuca, J. DiBari, M. Dunn and R. Logan at the annual meeting of the Washington College Chemistry Teachers Association, Leavenworth, Washington, April 2000.
8. Margaret B. Palmatier, <sup>#</sup> Barbara Eaton, <sup>#</sup> Tabitha A. Liebrecht, <sup>#</sup> Aurora E. Clark, <sup>#</sup> Jennifer C. Campbell, <sup>#</sup> and JoAnn P. DeLuca "Phenyliodonium Ylides as Carbene Precursors," invited talk (based on contributed poster), Physical Organic Gordon Conference, Holderness, New Hampshire, July 1999.
9. Aurora Landis, <sup>#</sup> Keri Schultz, <sup>#</sup> Margaret Palmatier<sup>#</sup> and JoAnn P. DeLuca "Carbenoid Reactions Resulting from Photolysis of Phenyliodonium Ylides," poster presented by A. Landis and J. DeLuca at the national meeting of the American Chemical Society, Boston, Massachusetts, August 1998.
10. Aurora Landis, <sup>#</sup> Keri Schultz, <sup>#</sup> Margaret Palmatier, <sup>#</sup> Barbara Eaton, <sup>#</sup> Tabitha Liebrecht, <sup>#</sup> and JoAnn P. DeLuca "Phenyliodonium Ylides as Precursors for dicarbonyl Carbenes: A Progress Report," poster presented at the 1998 Reaction Mechanisms Conference, Asilomar, California, June 28-July 3, 1998.
11. JoAnn DeLuca, John DiBari, John Gerdes, Martha Kurtz, Richard Logan and Ruth Stainbrook<sup>#</sup> "A Collaborative Model for Distance Organic Chemistry Curriculum: MCUs, T1 Lines, Couriers, Adjuncts and Administrators," presented by J. DeLuca, J. diBari, J. Gerdes, M. Kurtz, R. Logan and R. Stainbrook at the Northwest Regional Meeting of the American Chemical Society, Richland, Washington, June 1998.
12. Jerry W. Cubbage,<sup>\*</sup> Brian L. Edelbach,<sup>\*</sup> Kan Shuh Kuen<sup>#</sup> and JoAnn P. DeLuca "Stereodirecting Effects in the Characterization of Ylide Intermediates in Reactions of Singlet Methylene with an Allylic Ether and an Allylic Chloride," invited presentation, 1997 International Conference on Reactive Intermediates and Unusual Molecules, Lake Tahoe, California, July 1997.
13. Jerry W. Cubbage,<sup>\*</sup> Brian L. Edelbach,<sup>\*</sup> Kan Shuh Kuen<sup>#</sup> and JoAnn P. DeLuca "Stereodirecting Effects in the Characterization of Ylide Intermediates in Reactions of Singlet Methylene with an Allylic Ether and an Allylic Chloride," 52nd Northwest Regional Meeting of the American Chemical Society, Moscow, Idaho, June 1997.

14. Jerry W. Cubbage,\* Brian Edelbach,\* and JoAnn P. DeLuca "Stereodirecting Effects in the Study of Carbene-Nucleophile Interactions," poster selected for oral presentation, 26th Reaction Mechanisms Conference, Stony Brook, New York, June 1996.
15. Brian Edelbach,\* Jerry W. Cubbage\* and JoAnn P. DeLuca "Directing Effects of Substrate Substituents on Addition of  $^1\text{C}:\text{H}_2$  to a Double Bond: Effect of a Chloro Substituent and Temperature Dependence," 210th American Chemical Society Meeting, Chicago, Illinois, August 1995.
16. Presentation of recent research results (invited presentation), Thirteenth NSF Workshop on Physical Organic Chemistry, July, 1994, Logan, Ohio.
17. Brian Edelbach,\* Warunee Sobery\* and JoAnn P. DeLuca "Reaction of  $^1\text{C}:\text{H}_2$  with an Allyl Chloride and an Allyl Alcohol: Stereodirecting Ability of the Chloro Substituent and Intramolecular Trapping of an Oxonium Ylide Intermediate", poster, 25th Reaction Mechanisms Conference, Notre Dame, Indiana, June 1994.
18. JoAnn P. DeLuca, Colleen O'Rourke# and Terry Young# "Comparison of the Influence of Methoxy and Methylthio Groups on the Addition of Singlet Methylene to a Nearby Double Bond," 200th American Chemical Society Meeting, Washington, D.C., August 1990.
19. Colleen O'Rourke,# Terry Young# and JoAnn P. DeLuca "Comparison of the Influence of Methoxy and Methylthio Groups on the Addition of  $^1\text{C}:\text{H}_2$  to a Nearby Double Bond," poster, 23rd Reaction Mechanisms Conference, Boulder, Colorado, June 1990.
20. Terry A. Young,# Nathan G. Gray# and JoAnn P. DeLuca "The Effect of a Methoxy Group on Addition of Singlet Methylene ( $^1\text{C}:\text{H}_2$ ) to a Double Bond," 197th American Chemical Society Meeting, Dallas, Texas, April 1989.

Presented by Students or Colleagues :

1. Ryan M. Jorgensen, Robert Jensen, Kim Nielsen, and JoAnn Peters "Reversible Organic Derivatization of Silica: Exploration of a New Method for Creating Template Imprinted Surfaces, poster presented by R. M. Jorgensen, Northwest Meeting in Materials and Physical Chemistry, Pullman, WA, April 2008.
2. Ryan M. Jorgensen,\* Julie A. McNeal, # Debra R. Wilkerson, # and JoAnn P. DeLuca "Preparation of Imprinted Silica Gel Surfaces through Reversible Covalent Attachment of an Organic Template," poster presented by R. M. Jorgensen, American Chemical Society Meeting, Chicago, March 2007.
3. Sidnee-Marie Dunn,\* Scott Fine, # and JoAnn P. DeLuca "Generation of Carbonyl Carbene Intermediates from Ylide Precursors," poster presented by S. M. Dunn, Northwest Regional Meeting of the American Chemical Society, Seattle, June 2001.
4. Margaret Camacho, # Barbara Eaton, # Tabitha Liebrecht, # and JoAnn P. DeLuca "Carbene Intermediates From Photolysis of Phenyliodonium Ylides," poster presented by M. Camacho, Undergraduate Research Symposium of the Puget Sound Section of the American Chemical Society, Bellingham, Washington, May 2000.

5. Margaret Camacho, # Barbara Eaton, # Tabitha Liebrecht, # and JoAnn P. DeLuca "Carbene Intermediates From Photolysis of Phenyliodonium Ylides," poster presented by M. Camacho, National Conference on Undergraduate Research, Missoula, Montana, April 2000.
6. Margaret Palmatier# and Barbara Eaton# "Carbene Intermediates from Photolysis of Phenyliodonium Ylides," poster, Undergraduate Research Symposium of the Puget Sound Section of the American Chemical Society, Ellensburg, Washington, April 1999.
7. Aurora Landis, # Keri Schultz, # and JoAnn P. DeLuca "Carbenoid Reactions Resulting from Photolysis of Phenyliodonium Ylides," poster presented by K. Schultz at the 1998 Northwest Regional Meeting of the American Chemical Society, Richland, Washington, June 1998.
8. Anna Noyes, # Jerry W. Cubbage, \* and JoAnn P. DeLuca "Trapping of Ylide Intermediates in Reactions of an Allylic Alcohol with Singlet Carbenes, poster presented by A. Noyes, 29th Great Lakes Regional Meeting of the American Chemical Society, Normal, Illinois, May 1996.
9. Ralph E. Layman# and JoAnn P. DeLuca "Trapping of a Fluoronium Ylide Intermediate in the Reaction of an Allylic Fluoride with a Singlet Carbene," poster presented by R. E. Layman, 29th Great Lakes Regional Meeting of the American Chemical Society, Normal, Illinois, May 1996.
10. Jerry W. Cubbage\* and JoAnn P. DeLuca "Stereodirecting Effects of Substrate Substituents on Addition of  $^1\text{C}:\text{H}_2$  to a Double Bond," presented by J. W. Cubbage, 29th Great Lakes Regional Meeting of the American Chemical Society, Normal, Illinois, May 1996.
11. Jerry W. Cubbage\* and JoAnn P. DeLuca "Trapping of an Ylide Intermediate in the Reaction of  $^1\text{C}:\text{HCO}_2\text{Et}$  with an Allylic Alcohol," presented by J. W. Cubbage, 30th Central Regional Meeting of the American Chemical Society, Joplin, Missouri, November 1995.
12. Matthew Foes,# Warunee Sobery\* and JoAnn P. DeLuca "Intramolecular Trapping of Oxonium Ylide Intermediates in the Reactions of Allylic Alcohols with Carbenes," presented by M. Foes, 87th Annual Meeting of the Illinois State Academy of Science, Galesburg, Illinois, October 1994.
13. M. A. Jones, S. L. Weldon, M. Baur, V. Williamson, K. Goldberg and J. DeLuca "Expanding Your Horizons - What Chemists Can Do to Participate in this Conference for Middle School Girls on Math and Science," presented by M. A. Jones, 208th American Chemical Society Meeting, Washington, DC, August 1994.
14. Brian Edelbach\* and JoAnn P. DeLuca "Stereodirecting Effect of a Substrate Chloro Substituent on the Addition of Singlet Methylene to a Double Bond," presented by B.

Edelbach, Great Lakes Regional Meeting of the American Chemical Society, Ann Arbor, Michigan, June 1994.

15. Judith M. Swanson\* and JoAnn DeLuca "The Effect of a Perfluorohexane Solvent on Product Distribution in Reactions of an Alkane and Carboethoxycarbene," presented by J. M. Swanson, Great Lakes Regional Meeting of the American Chemical Society, Marquette, Michigan, May 1993.
16. Alexandra Katauskas# and JoAnn DeLuca "Solvent Effects in the Reaction of Carboethoxycarbene with an Alkene," presented by A. Katauskas, 85th Annual Meeting of the Illinois State Academy of Science, Springfield, Illinois, October 1992.
17. Douglas W. Walker\* and JoAnn P. DeLuca "The Influence of Substrate Methoxy and Hydroxy Groups on the Addition of Dichlorocarbene to a Double Bond," presented by D. W. Walker, 85th Annual Meeting of the Illinois State Academy of Science, Springfield, Illinois, October 1992.
18. Curt A. Dvorak,# Joe Arndt,# Mike Sanborn# and JoAnn DeLuca "The Effects of Aromatic Solvents on the Reaction of Carboethoxycarbene with Hydrocarbon Solutes," presented by C. A. Dvorak, 26th Midwest Regional Meeting of the American Chemical Society, Omaha, Nebraska, November 1991.
19. Michael D. Sanborn# and JoAnn P. DeLuca "Solvent-Induced Change in the Selectivity of Carboethoxycarbene Towards Alkane C-H Bonds," presented by M. D. Sanborn, 84th Annual Meeting of the Illinois State Academy of Science, Chicago, Illinois, October 1991.
20. Michael J. Petro\* and JoAnn P. DeLuca "Towards the Formation of Small Ring Oxonium Methylides from Oxonium Salts," presented by M. J. Petro, 1991 Joint Central-Great Lakes Regional Meeting of the American Chemical Society, Indianapolis, Indiana, May 1991.
21. Curt A. Dvorak,# Amy Youngman# and JoAnn P. DeLuca "The Effect of Aromatic Solvents on the Reaction of Carboethoxycarbene with Hydrocarbon Solutes," presented by C. A. Dvorak, 83rd Annual Meeting of the Illinois State Academy of Science, Urbana, Illinois, October 1990.
22. Joe W. Arndt# and JoAnn P. DeLuca "A Solvent Effect in the Reaction of Carboethoxycarbene with an Alkane," presented by J. W. Arndt, 82nd Annual Meeting of the Illinois State Academy of Science, Chicago, Illinois, October 1989.
23. Colleen O'Rourke,# Terry A. Young# and JoAnn P. DeLuca "Effect of a Directing Group on Addition of a Carbene to a Double Bond: Comparison of Methoxy and Methylthio Groups," presented by C. O'Rourke, 82nd Annual Meeting of the Illinois State Academy of Science, Chicago, Illinois, October 1989.
24. JoAnn P. DeLuca and Susan M. Neugebauer\* "Effect of Solvent on Product Distribution in Reactions of Singlet Methylene," presented by S. M. Neugebauer, 23rd Midwest Regional American Chemical Society Meeting, Iowa City, Iowa, November 1988.

25. JoAnn P. DeLuca, Nathan G. Gray<sup>#</sup> and Terry A. Young<sup>#</sup> "Evidence for Directing Effect of Methoxy Group on Methylene Addition to a Double Bond," presented by T. A. Young, 81st Annual Meeting of the Illinois State Academy of Science, Peoria, Illinois, October 1988.

**Dion Rivera, Assistant Professor of Chemistry**

Central Washington University  
Department of Chemistry  
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**Education**

*B.S. Chemistry*

GPA 3.5

Cal Poly State University, San Luis Obispo, CA

*Ph.D. Physical/Analytical Chemistry*

GPA 3.9

University of Utah

**Instrumentation and Informatics Knowledge**

FT-IR/near-IR

Infrared Microscopy/Imaging

Photoacoustic Step-Scan FT-IR

Raman Spectroscopy

Absorbance/Fluorescence Spectrometers with Fiber Optics and CCD detectors

Multivariate Curve Resolution

Factor based modeling (PCA and PLS)

Hybrid Least Squares Techniques (CLS/PLS; Augmented CLS)

**Job Experience**

9/2006-Present: *Assistant Professor of Chemistry*

Central Washington University

Instructor of analytical and physical chemistry lectures and laboratories. Research of processes occurring at the water/solid interface and trace fluorescence detection.

7/2004-8/2006: *Limited Term Member of Technical Staff*

Sandia National Laboratories

Developing quantitative infrared techniques for in situ measurement of gases produced in the sulfur-iodine process used for production of hydrogen.

Developing diffuse reflectance FT-IR spectroscopy as a technique for understanding the surface chemistry and aging of non-evaporable getter materials used in MEMS devices.

10/2001-7/2004: *Postdoctoral Appointee*

Sandia National Laboratories

Research Projects:

Development of multivariate calibration models for micro sensor systems that will be used for environmental monitoring.

Using FT-IR to understand surface chemistry of barium films after exposure to reactive gases and the implications for electronic components that employ barium as a gettering material.

Development of photoacoustic step-scan FT-IR and FT-IR imaging microscopy as spectroscopic techniques for understanding polymer aging.

5/2000-8/2001: *Postdoctoral Associate*

Energy and Geosciences Institute and the Department of Chemistry, University of Utah

Research Projects:

Development of an HPLC adsorption based detection scheme to analyze trace amounts (part per trillion) of tracer dyes extracted from geothermal test wells.

Synthesis and characterization of surface modified quantum dots along with development of analytical detection methods for trace concentrations of the materials. Evaluate feasibility of using the materials as environmental tracers.

6/94-5/2000: *Graduate Student*

Department of Chemistry, University of Utah

Thesis Research:

Application of attenuated total internal reflection Fourier transform infrared spectroscopy and chemometric techniques towards understanding adsorption and chemical binding kinetics at the liquid/silica interface.

**Awards:**

2003 Sandia Employee Recognition Team Award for Development of In-Situ Chemresistor Sensors

1998 Coblenz Society of Vibrational Spectroscopy Student Award

Henry Eyring Fellowship; University of Utah 1994

Los Angeles Coating Society Scholarship; 1992

**External Grants Funded At CWU:**

ACS-PRF Type B Grant Awarded for spring of 2008 to summer o 2011. Grant title "In situ spectroscopic studies of the behavior of polyelectrolyte/surfactant mixtures at the water/TiO<sub>2</sub> interface using attenuated total internal reflection Fourier transform infrared spectroscopy (ATR-FTIR) and multivariate least squares data analysis." Peer Reviewed Grant, National Competition

**Presentations Given on Research performed at CWU:**

"Use of in situ IR and UV spectroscopies to understand the behavior of poly(sodium 4-styrene sulfonate) in the presence of cationic surfactants at the TiO<sub>2</sub>/water interface." M. Hase; R. Scheffelmaier; Sarah Hayden; Brittany Best; D. Rivera American Chemical Society conference March 2008, Salt Lake City, Utah.

"Synthesis and characterization of zinc based quantum dot materials with green to blue fluorescence." H. Durkee; D. Rivera American Chemical Society conference March 2008, Salt Lake City, Utah.

"Kinetics of the formation of zinc based quantum dots with green fluorescence" H. Durkee; D. Rivera Murdock Conference October 2008, Tacoma, WA

"In Situ Attenuated Total Internal Reflection Fourier Transform Infrared (ATR FT-IR) Spectroscopy Coupled with Multivariate Least Squares Analysis for the Study of Polyelectrolytes/Surfactant Systems at the TiO<sub>2</sub>/Water Interface" M. Hase; D. Rivera SOURCE May, 2008 Central Washington University

"Optimization of the synthesis of zinc based quantum dots" C. Gyselinck; D. Rivera SOURCE May, 2008 Central Washington University

"In Situ Attenuated Total Internal Reflection Fourier Transform Infrared (ATR FT-IR) Spectroscopy Coupled with Multivariate Least Squares Analysis for the Study of Polyelectrolytes/Surfactant Systems at the TiO<sub>2</sub>/Water Interface" M. Hase; D. Rivera Pittcon2008 New Orleans, LA March 2008.

"In situ ATR-FTIR studies of polyelectrolyte/surfactant systems at the TiO<sub>2</sub>/water Interface" M. Hase; D. Rivera Murdock Undergraduate Research Conference, October 2007, Salem, OR.

## Papers:

“In situ ATR-FTIR studies of the effects of surfactant concentration on the adsorption of the polyelectrolyte poly(sodium 4-styrene sulfonate) to the surface of TiO<sub>2</sub>” M. Hase; S. Hayden; R. Scheffelmaier; and D. Rivera *Manuscript submitted to Langmuir*10/6/09

"Characterization of Water and Ammonia Adsorption by 3A Zeolite Samples Using TG-FTIR and X-Ray Diffraction" Dion A. Rivera, Jason R. Brown, Rachel M. Rohde, Mark A. Rodriguez, and M. Kathleen. Alam SAND: 2007-5727 September **2007** Sandia National Laboratories *Classified Publication*

“Use of Fourier Transform Infrared (FT-IR) Spectroscopy and Alternating Least Squares with Rigorous Application of Constraints to Understand the Reactions of Barium Metal with O<sub>2</sub>, CO, CO<sub>2</sub>, and CH<sub>4</sub> as a Function of Temperature” D. Rivera, J. R. Brown, M. K. Alam, and S. M. Thornburg, *Vibrational Spectroscopy*, **2007**, 44, 9-18.

“In Situ Monitoring of Sulfuric Acid Decomposition by Fourier Transform Infrared (FT-IR) Spectroscopy in the Sulfur Iodine Thermochemical Reaction for the Production of Hydrogen” Rivera, D *Proceedings of the SPIE*, **2005**, 5998, 59980 F-1 – F-12.

“Use of Classical Least Squares/ Partial Least Squares (CLS/PLS) Hybrid Algorithm for Calibration and Calibration Maintenance of Surface Acoustic Wave (SAW) Devices.” D. Rivera, M. K. Alam, W. G. Yelton, R. J. Simonson, *Sensors and Actuators B*, **2004**, 99, 480-490.

“Use of Step Scan FT-IR and Multivariate Curve Resolution to Understand of Propellant Binder as a Function of Depth into the Polymer Material” D. A. Rivera and M. K. Alam, SAND Report, SAND2003-4151, January **2004**, Sandia National Laboratories.

“Characterization of the ability of polymeric chemiresistor arrays to quantitate trichloroethylene using partial least squares (PLS): effects of experimental design, humidity, and temperature” D. Rivera, M. K. Alam, C. E. Davis, C. K. Ho, *Sensors and Actuators B*, **2003**, 92, 110-120.

“Characterization of Water and CO<sub>2</sub> Adsorption by Stores 3A Desiccant Samples Using Thermal Gravimetric Analysis and Fourier Transform Infrared Spectroscopy” D. Rivera, M. K. Alam, L. Martin, J. R. Brown, SAND Report, SAND2003-0398, February **2003**, Sandia National Laboratories.

“In Situ Adsorption Studies at the Silica/Solution Interface of Cyano Derivatized Silica Surfaces by Attenuated Total Internal Reflection Fourier Transform Infrared Spectroscopy: Implications for Normal-Phase Liquid Chromatography” D. Rivera and J. M. Harris; *Langmuir* **2001**, 17, 5527.

“In Situ ATR-FTIR Kinetic Studies Molecular Transport and Surface Binding in Thin Sol-Gel Films: Reactions of Chlorosilane Reagents in Porous Silica Materials” D. Rivera and J. M. Harris; *Analytical Chemistry* **2001**, 73, 411. *Accelerated Publication*.

“In Situ Adsorption Studies At Silica/Solution Interfaces by Attenuated Total Internal Reflection Fourier Transform Infrared Spectroscopy: Examination of Adsorption Models in Normal-Phase Liquid Chromatography” D. Rivera, P. E. Poston, R. H. Uibel, and J. M. Harris *Analytical Chemistry* **2000**, 72, 1543.

“In Situ Detection of Adsorbates at Silica/Solution Interfaces by Fourier Transform Infrared Attenuated Total Reflection Spectroscopy Using a Silica-Coated Internal Reflection Element” P. E. Poston, D. Rivera, R. H. Uibel, and J. M. Harris *Applied Spectroscopy* **1998**, 52, 1391.

**Graduate Student Committees at CWU:**

Lindsay Shank, committee member fall 07-Summer 08, MS Chemistry, Successfully Defended

Zhen Zang, committee member spring of 07-summer 08, MS Chemistry, Successfully Defended.

Ryan Jorgensen, committee member fall 07-winter 08, MS Chemistry, Successfully Defended

Justin Johnson, committee member spring 07-summer 08, MS Chemistry, Successfully Defended

Jacob Johnston, committee member spring 07- has not yet defended, MS Chemistry, second year student

Lindsay Groce, committee member fall 08-has not yet defended, MS Chemistry, part time MS student

Brittany Best, committee chair spring 09- has not yet defended, MS Chemistry, first year student

Daniel Hall, committee chair spring 09- has not yet defended, MS Chemistry, first year student

# Curriculum Vita – Timothy L. Sorey

**Name:**  
Timothy L. Sorey

**Date:**  
9/15/08

**Current Employment:**  
Central Washington University

**Rank or Title:**  
Assistant Professor

**Department:**  
Department of Chemistry and Science Education Program

**Office Location and Campus Mail Stop:**  
Science Building, #302H  
# 7539

**Office Phone:** 1-509-963-2814  
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**E-mail:** soreyt@cwu.edu

## Education Beyond High School:

- **Summer 2005** – Montana State University –PhD in Chemistry
- **Spring 1999** - Eastern Oregon University – B.A. in Chemistry
- **Spring 1995** - Graduated from Walla Walla Community College with A.A.

## Teaching Experience:

### *University Coursework*

#### Central Washington University – (Fall 2004-present)

- CHEM 183: Third Quarter of General Chemistry
  - Offerings: Fall '04, Spring '05, Fall '05
- CHEM 183L: Third Quarter of General Chemistry Laboratory
  - Offerings: Fall '05, Fall '06, Fall '06, Spring '07, Fall '07
- CHEM 182: Second Quarter of General Chemistry
  - Offerings: Winter '06, Winter '07, Winter '08
- CHEM 182L: Second Quarter of General Chemistry Lab
  - Offerings: Winter '06, Winter '07, Winter '08
- CHEM 181L: First Quarter of General Chemistry Lab
  - Offerings: Winter '05, Fall '07
- CHEM 492/592: Laboratory Experience in Teaching Chemistry
  - Offerings: Winter '05, Spring '05, Fall '05, Winter '06, Spring of '06, Fall '06, Spring '07, Fall '07, Winter '08, Spring '08
- SCED 301: Interdisciplinary Science Inquiry
  - Offering: Green River Community College, Summer '06, Summer '08
- SCED 322: Science Education in the Elementary Schools.
  - Offerings:
    - Ellensburg - Fall '04, Winter of '05, Spring '05, Fall '05, Fall '06, Winter '07, Spring '07, Fall '07
    - Des Moines Center - Winter '06, Spring '06, Winter '08

- SCED 323: Science Education in the Middle Schools.
  - Offerings: Winter '05, Winter '06, Winter '07
- SCED 324: Science Education in the High School.
  - Offerings: Winter '08
- CHEM 541: Chemistry Concepts for Teaching with Technology.
  - Offerings: Spring '07
- CHEM 295, 395, and 495: Undergraduate Research
  - Offerings: Fall '05 through Spring '08

Montana State University – (1999-2004)

- CHEM 131E : *Chemistry Laboratory for Engineering Track Students Development*
  - Offerings: Fall '03 and Spring '04
- CHEM 121 : *Freshman General Chemistry – Major Instructor*
  - Offerings: Summer '02

**Professional Development Outreach Courses:**

- CHEM 580(Part II): *Integrating Environmental Measurement into the Classroom*. Co-Developed and team taught with Dr. J. Amend with primary dissemination to middle schools, high schools, and tribal colleges on or near the Northern Cheyenne and Crow Reservations.
  - Offering: Spring Semester 2003  
Dissemination: - Onsite, ONLINE (WebCT), and ITV (Interactive Television)
- MATH 580 : *TI Ag-Prep*. Co-Developed and team taught with TI Instructor, Nancy Nichols, with primary dissemination to middle school and high schools on or near the Northern Cheyenne and Crow Reservations with the course.
  - Offering: Summer Semester 2003  
Dissemination: - Onsite, ONLINE (WebCT), and ITV(Interactive Television)
- CHEM 580 (Part I): *Integrating Environmental Measurement into the Classroom*. Co-Developed and team taught with Dr. J. Amend with primary dissemination to middle schools, high schools, and tribal colleges on or near the Northern Cheyenne and Crow Reservations.
  - Offering: Fall Semester 2002  
Dissemination: - Onsite and ONLINE (WebCT)

**Professional Development Workshops**

- **August 4<sup>th</sup>-8<sup>th</sup> of 2008.** – Learning Empowering Networking in Science (LENS) Second Annual Summer Workshop. Co-Developed and team taught a day-long hands-on inquiry lesson on *Ohm's Law* and *Electrochemistry* with Dr. B. Palmquist with primary dissemination to middle school and high school science teachers.

The following workshops, entitled “*Integrating Research into Laboratory Instruction*”, were sponsored by The Department of Chemistry and Biochemistry at M.S.U- Bozeman, Burns Telecommunication Center, and MicroLAB. The primary foci for these workshops included: (a) Curriculum, Technology and Learning Strategies and (b) Sensors and Electronics for Environmental Measurement with participants ranging from middle school Broadfield Science Teachers to University Chemistry and Physics Instructors.

Dissemination: - Onsite, ONLINE (WebCT), and ITV (Interactive Television)

- **July 2003** - M.S.U.- Bozeman, MT.- 2 Weeks
- **July 2002** - M.S.U. - Bozeman, MT.- 2 Weeks
- **April 2002** -The Biennial Conference on Chemical Education at Western Washington University- Bellingham, WA- Half Day
- **July 2001** - M.S.U. - Bozeman, MT.- 2 Weeks
- **August 2000** - M.S.U. - Bozeman, MT.- 2 Weeks
- **July 2000** - M.S.U.- Bozeman, Montana. - 2 Weeks
- **April 2000** -The Biennial Conference on Chemical Education at University of Michigan - Ann Arbor, MI – Half Day
- **Sept. 1999** - Pendleton, OR. - 1 Week

### Fellowship and Awards:

#### Graduate Fellowship:

- Recipient of a Doctoral Fellowship through Centers for Learning and Teaching in the West in **Spring Semester 2002**. (CLTWest, a consortium five universities within the states of Oregon, Colorado, and Montana, is one of ten recipients of a 5 year/10 million dollar National Science Foundation grant. One of its primary goals is to increase ‘leadership capacity’ within the field of science and math education.)

#### Teaching:

- Recipient of A.R. Johansson Teaching Award for “Outstanding Chemistry T.A” in the **Spring Semester 2000** at M.S.U. - Bozeman.

#### Academic:

- Recipient of the “Outstanding Chemistry Student Award” upon graduating from E.O.U.-La Grande in **Spring Quarter 1999**.
- Recipient of a *Meritorious* award for our team’s submission of a math modeling paper in the **Spring Quarter 1999** international *Consortium For Mathematics and its Application* (COMAP) contest.

#### Service:

- Recipient of Native American Higher Education & Career (NAHECA) Workshop Organizer’s Award- From Native American Program at E.O.U.- La Grande in **Spring Quarter 1999**.  
(*Co-organized opportunities for Native American students from the Umatilla Indian Reservation to attend a ‘Day in the Life of a College Student’, which is currently an annual event at E.O.U. that is now referred to as college ‘Preview Day’.*)

### Scholarly Accomplishments:

#### Monograph:

T. Sorey and J. Amend, “A Research-Based Approach to Solving Problems in General Chemistry”, invited chapter in *Best Practices and Lessons Learned: Highlights from the NSF Collaboratives for Excellence in Teacher Preparation Program and Other Innovative Programs Around the Country*, edited by Diane Smith and Elisabeth Swanson (Montana State University, Bozeman, MT, **September 2005**).

#### Published Manuals:

- T. Sorey "CHEM 181 LAB MANUAL", Wildcat Shop Custom Publishing, **2007-08**.
- T. Sorey "CHEM 183 LAB MANUAL", Wildcat Shop Custom Publishing, **2007-08**.
- J. Amend, D. Hammond, R. Furstenau, and T. Sorey, "Measurements: The Basic Science, An Introduction to Computer Based Measurements", MicroLab Inc., Jan.**2002**.

#### Published Journal Articles:

1. Quitadamo, I., Kurtz, M., Sorey, T., Pratt-Sitaula, B. & Palmquist, B., **2006**, *Using e-Portfolio to Assess Pre-Service Teacher Performance*. Journal of Washington Science Teachers Association, 46(4).
2. M. Nishina, T Sorey, R. Lancaster, and Y.E. Rhodes, "Theoretical Observations of Aluminum Analogues of Carbocations", *E.O. Science Journal*, Vol. 15, **1998-1999**, pg. 9-13.
3. T. Sorey, M. Nishina, and R. Lancaster, "Theoretical Models of Substituent Effect Stabilization of Aluminum Analogues of Carbocations", *E.O. Science Journal*, Vol. 15, **1998-1999**, pg. 14-18.
4. T. Sorey and R. Hermens, "Experimental Conditions for the Synthesis of  $(\text{NH}_4)_2\text{S}_2\text{O}_4$ ", *E.O. Science Journal*, Vol. 15, **1998-1999**, pg. 19-21.
5. T.M. Rogers, B. Fritz, and T. Sorey, "A Model for Chloride Marker Testing to Deduce Chemical Dynamics and Ground Water Flow Rates", *E.O. Science Journal*, Vol. 15, **1998-1999**, pg. 61-66.

#### Manuscripts Submitted for Publication in 2006-2007:

1. T. Sorey and J. Amend, "Identifying General Chemistry Laboratory Content and Learning Objectives for One-Semester Engineering Students", *The Chemical Educator*. Assigned reference number T0705037. **Status:** Currently under revision for resubmission. Resubmission projected for Fall 2008-Winter 2009.
2. T. Sorey and J. Amend, "Problem Solving Using a Research-Based Approach in General Chemistry Laboratories", *The Chemical Educator*. Assigned reference number T0705038. **Status:** Currently under revision for resubmission. Resubmission projected for Fall 2008-Winter 2009.

#### Manuscripts Submitted for Publication in 2007-2008:

1. T. Sorey, T. Willard, and B. Kim, "Hands-On Environmental Sensors and Calibration: Important Relationships between Science and Mathematics". Target Journal is for NSTA, SCOPE for Middle Level Science Teachers. Assigned reference number #2008-Sep-SCOPE-TT-004 **Status:** Outstanding

#### Manuscripts in Preparation for 2008-2009:

1. T. Sorey, T. Willard, D. Scholz, "The Chromatography of Resistors: Integrating Math and Science". Target Journal – NSTA's The Science Teacher for High School Science and Mathematics Teachers.
2. T. Sorey, J. Amend, D. Nguyen, L. Skanse, G. Baran, and G. Overby, "Determination of Reduction Potentials at Non-standard States for Aqueous Metallic Ions via Coulometry". Target Journal - The Chemical Educator.

3. T. Sorey, J. Amend, E. Scott, K. Bjorge, C. J. Warren, and H. Meyer, “Kinetics in the General Chemistry Learning Laboratories: A Model for Teaching Reaction Order and the Pseudo-Rate Constant Method”. Target Journal - American Chemical Society, The Journal of Chemical Education.

#### Software and HTML-based Help:

- **Spring 2000 to Spring 2001 -**  
Initial work on html-based Help files to support students’ use of educational software, Watershed Resources Management Simulator, with developmental support through United States Geological Services.
- **Spring 2000 to Fall 2001 -**  
Developed html-based Help files to support students’ use of MicroLAB’s 10-Color Colorimeter hardware and software, with developmental support through the University of British Columbia’s Freshman General Chemistry program.
- **Fall 1999 to present -**  
Member of MicroLAB’s software/hardware development team

#### Professional Meeting Papers and Workshops:

- **June 2008 – (Peer Reviewed)**  
**ACS - Northwest Regional Meeting (NORM) – Park City, UT**  
Presentation of 5 Undergraduate Posters  
“Hydrolysis and Coulometry” – Grant Overby, and Timothy L. Sorey\*  
“Chemical Kinetics: A Turbidimetric Approach to Solving Rate Order with MicroLAB 10-Color Colorimeter” – Kellie Mullen, Terry Helland Jr., and Timothy L. Sorey\*  
“Pseudo-Rate Reaction: Reaction of Ni/PADA with  $NH_3$ ”, Terry Helland Jr., Kellie Mullen, and Timothy L. Sorey\*  
“Lemon Batteries”, Zhenya Balandova and Timothy L. Sorey  
“Projecting Polarimeter for Classroom and Laboratory”, Edward Bain, Duane Scholz, and Timothy L. Sorey\*
- **May 2008 – (Peer Reviewed)**  
**Symposium on University Research & Creative Expression (SOURCE)**  
Presentation of 5 posters at Central Washington University, Ellensburg, WA  
“Metal Plating of Silver and Copper via Gravimetric Coulometry”, – Grant Overby, and Timothy L. Sorey\*  
“Chemical Kinetics: A Turbidimetric Approach to Solving Rate Order with MicroLAB 10-Color Colorimeter” – Kellie Mullen, Terry Helland Jr., and Timothy L. Sorey\*  
“Lemon Batteries: An Exploration and Application of the Electrochemical Series”, Zhenya Balandova and Timothy L. Sorey

*“Pseudo-Rate Reaction: Reaction of EDTA with Ni/PADA”*, Terry Helland Jr., Kellie Mullen, and Timothy L. Sorey\*

*“Synthesis and Analysis of Biodiesel”* – Josh Proulx, Ian O’Brien, and Timothy L. Sorey\*

- **March 2008 – (Peer Reviewed)**  
**National Council of Teachers of Mathematics National Meeting – NCTM**  
Workshop Presentation will be in Salt Lake City, UT  
*“Integrating Math and Science: The Statistics of a Population of Resistors”*
- **June 2007 – (Peer Reviewed)**  
**ACS - Northwest Regional Meeting (NORM) – Boise, ID**  
Presentation for “Active Learning Strategies in Chemical Education Symposium”  
*“A Research-Based Teaching Approach to General Chemistry Labs”*  
Presentation of 3 Undergraduate Posters  
*“Electroplating and Determination of Charge by Coulometry”* – Geoff Baran, Grant Overby, and Timothy L. Sorey\*  
*“Spectroscopy & Kinetics: An Inquiry-Based Determination of Reaction Order”* – Cassandra J. Warren, Edward Bain, and Timothy L. Sorey\*  
*“The Importance of Calibration – A Relationship between Mathematics and Science”*, Bom Kim, Zhenya Balendova, and Timothy L. Sorey\*
- **April 2007 – (Invited Speaker)**  
**Eastern Oregon University Lecture Series – La Grande, OR**  
50 minute Presentation  
*“A Research-Based Teaching Approach to General Chemistry Labs”*
- **March 2007 – (Peer Reviewed)**  
**National Council of Teachers of Mathematics National Meeting – NCTM**  
Workshop Presentation will be in Atlanta, GA  
*“Integrating Mathematics and Science: The Mathematics behind CBL™ and Probeware”*, co-presenter with Dr. Teri Willard
- **May 2006 – (Peer Reviewed)**  
**ACS Puget Sound Undergraduate Research Symposium**  
Presentation of 2 Posters at Western Washington University, Bellingham, WA  
*“Kinetics in the General Chemistry Learning Laboratories: A Model for Teaching Reaction Order and the Pseudo-Rate Constant Method”* – Elizabeth Scott, Krista Bjorge, Cassandra Warren, and Tim Sorey\*  
*“Determination of Reduction Potentials at Non-standard States for Aqueous Metallic Ions via Coulometry”* – David Nguyen and Tim Sorey\*
- **May 2006 – (Peer Reviewed)**  
**Symposium on University Research & Creative Expression (SOURCE)**  
Presentation of 4 posters at Central Washington University, Ellensburg, WA  
*“Determination of Reduction Potentials at Non-standard States for Aqueous Metallic Ions via Coulometry”* – David Nguyen and Timothy L. Sorey\*  
*“Spectroscopy and Kinetics: Determining Reaction Order via Colorimetry”* – Elisabeth Scott and Timothy L. Sorey\*

*“Kinetics and Spectroscopy: Determining Rate Order Reaction Via Fluorimetry” – Krista Bjorge and Timothy L. Sorey\**

*“Kinetics and Spectroscopy: Determination of Reaction Order via Turbidity” – Cassandra Warren and Dr. Tim Sorey\**

- **April 2006** –  
*Washington State Technology Summit - 2006*  
Attended “New Energy Technologies” and “Cutting edge R&D”
- **October 2005**  
*Conference of the Washington College Chemistry Teachers Association (WCCTA)*  
Co-Facilitator of Chemical Education Publications discussion with Mary Whitfield of Edmond’s Community College
- **October 2004**  
*Conference of the Washington College Chemistry Teachers Association (WCCTA)*  
60 minute Presentation – *(Contributed to Published Chapter)*  
*“Solving Problems in Freshman General Chemistry: A Model for Interdisciplinary Collaboration”*
- **April 2004**  
*National Association for Research in Science Teaching (NARST)*  
Annual International Conference  
Single Publication within a 4-part paper set that is accompanied by a 90 minute Presentation in Vancouver B.C.  
*“Centers for Learning and Teaching in the West: A Model towards Building and Supporting Science and Math Teacher Communities via CONTINUOUS Professional Development Outreach to rural and Native American Populations.”*
- **June 2003**  
*Northwest Regional Meeting - American Chemical Society*  
Presentation of 2 Posters in Bozeman, MT.  
*“A ‘Community of Science Teachers’ on or near the Northern Cheyenne and Crow Reservations”*  
And  
*“An Approach to understanding Kinetics and Reaction Order”*
- **October 2003**  
*National Indian Education Association Conference*  
Part of a 90 minute Presentation in Greensboro, NC.  
*“Centers for Learning and Teaching in the West: Professional Development and outreach to rural and Native American science and math teachers in Montana ”*
- **November 2003**  
*M.S.U.-Bozeman - Department of Chemistry and Biochemistry*  
60 minute API Seminar Series  
*“A Research Approach to Solving Laboratory Problems in Freshman General Chemistry”*

- **May 2003** –  
*Meeting in Miniature - American Chemical Society*  
Presentation of a 20 minute oral presentation in Bozeman, MT.  
“An Approach to understanding Kinetics and Reaction Order”
- **March 2003**  
*Montana-Wyoming Indian Education Association*  
Presentation of a 90 minute workshop in Helena, MT.  
“Integrating Environmental Measurement into the Classroom: A Professional Development Cooperation Between Middle Schools, High Schools, a Tribal College, and Montana State University”
- **December 2002**  
*Centers for Learning and Teaching - National Science Foundation*  
Presentation of a Poster in Washington D.C.  
“Building a Community of Science Teachers on or near the Northern Cheyenne and Crow Reservations: A Preliminary Report”
- **June 1999**  
*Northwest Regional Meeting - American Chemical Society*  
Presentation of 2 Posters in Portland, OR.  
“Theoretical Observations of Aluminum Analogues of Carbocations”  
And  
“Theoretical Models of Substituent Effect Stabilization of Aluminum Analogues of Carbocations”
- **May 1999**  
*American Chemical Society National Meeting*  
Presentation of Poster in Anaheim, Ca.  
“Experimental Conditions for the Synthesis of  $(\text{NH}_4)_2\text{S}_2\text{O}_4$ ”
- **June 1998**  
*Northwest Regional Meeting - American Chemical Society*  
Presentation of Poster in Richland, Wa.  
“Synthesis of  $(\text{NH}_4)_2\text{UF}_6$ ”

**Grant Activity:**

**Principal PI – C.O.T.S. Instructional/Research Equipment – February 2008**

A Laboratory Measurement Technology Initiative for CWU General Chemistry Labs  
(**Requested \$17,246 – Successful:**Including match money from Chemistry Dept.)

**Co-PI – N.S.F. - CWU Robert Noyce Teacher Scholarship Program – April 2008**

This is a 6 year scholarship program that is funded through the NSF that was created to support college students in the completion of secondary mathematics and science preparation and to mentor them into their first year of teaching.

Co-PI's – Chris Black, Leslie Elsaesser, and Mark Oursland

(**Requested \$750,000 – Not Successful**)

**Principal PI – ACS Mini Grant – April 2008**

This grant was written for the launch of Scientific Team to Advance the Readiness in Technology's (S.T.A.R.T.) Seminar and Fieldtrip Series that would support travel costs for junior college, 4 year, and 4 year/masters institutions to visit Pacific Northwest National Laboratories.

*(Requested \$500 – Not Successful)*

**Co-PI – Recruiting Washington Teachers Partnership Grant – December 2007**

K-20 Recruitment through Inquiry and Propagation through Peer Learning (RIPPL) was a grant proposal sponsored by the Professional Educator Standards Board of Washington State.

CoPI's – Mark Oursland and Teri Willard

*(Requested \$100,000 – Not Successful).*

**Principal PI – C.E.S.M.E. Faculty Grant Application – January 2007**

Centers of Excellence in Science and Mathematics Education faculty development grant for one workload unit for 2006-2007 and one workload unit for 2007-2008 academic school year for generating and implementing new computer-based lab curriculum at CWU.

*(2 Workload Units requested – Successful)*

**Principal PI – COTS Instructional/Research Equipment – December 2006**

A Laboratory Measurement Technology Initiative for CWU General Chemistry Labs Grant written in collaboration with Anthony Diaz, Eric Bullock, David Lygre, and Martha Kurtz.

*(Requested \$10,000 – Not Successful)*

**Central Washington University's Sphere of Distinction Proposal – May 2006**

Energy Studies Program

CoPI's – Anne Johansen, Carey Gazis, Bill Bender, Jim Huckabay, Tim Sorey, and Mike Braunstein

*(Requested \$ 47,988 – Not Successful)*

**Chemistry Component for Yakima WATERS Grant – May 2006**

Yakima Watershed Activities To Enhance Research in Schools (WATERS)

CoPI's – Carey Gazis, Martha Kurtz, Ian Quitadamo, and Steve Wagner

Co-Author for Chemistry Component with Anne Johansen

*(Chemistry Requested \$22,000 – Successful)*

**Principal PI – CWU Instructional/Research Equipment – March 2005**

A Laboratory Measurement Technology Initiative for CWU General Chemistry Labs Grant written in collaboration with Carin Thomas, Interim Department Chair of the Department of Chemistry

*(Requested \$29,494 – Not Successful)*

### **Professional and Scholarly Organizations:**

- **Spring of 2007 to present** – National Council for Teaching Mathematics (NCTM)
- **Summer of 2006** – Teachers of Teachers of Science (TOTOS)
- **Fall 2005 to present** – Washington State Teacher's Association (WSTA)
- **Fall 2005 to present** – National Science Teachers Association (NSTA)
- **Fall 2005 to present** – Rotary Club International – Ellensburg Chapter
- **2004 to present** – Member of National Association for Research on Science Teaching (NARST)
- **Fall 2004 to present** – Member of Washington College Chemistry Teacher's Association (WCCTA)

# Curriculum Vitae

## CARIN THOMAS, PhD

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**Address:** Department of Chemistry MS-7539  
Central Washington University  
400 E. University Way  
Ellensburg, WA 98926

**Telephone:** (509) 963-2815  
**FAX:** (503) 963-1050  
**Email:** cthomas@cwu.edu

### Education:

- PhD 1991 Biochemistry, University of Nevada, Reno, NV.  
Dissertation title: *Hypericin as a Potential Photosensitizer in Photodynamic Therapy of Cancer.*
- MA 1986 Biology, Humboldt State University, Arcata, CA.  
Thesis title: *High Pressure Liquid Chromatographic Resolution of Chemosystematic Markers in Western North American Polystichum.*
- 1986 California Single Subject Clear Teaching Credential  
Subjects: Life Science and French; Humboldt State University, Arcata, CA.
- BA 1983 BA, Botany, *Summa Cum Laude*;  
BA, French, *Magna Cum Laude*  
Humboldt State University, Arcata, CA.

### Professional Experience:

- 2003-2006 Associate Dean for Resource Development, College of the Sciences, Central Washington University (CWU), Ellensburg, WA 98926.
- 2004-2005 Chair, Department of Chemistry, CWU.
- 2001- present Associate Professor, Department of Chemistry, CWU.
- 1995- 2001 Assistant Professor, Department of Chemistry, CWU.
- 1993-1995 Faculty Research Associate, Department of Biochemistry and Biophysics, Oregon State University, Corvallis, OR 97331.
- 1991-1993 Research Fellow, Department of Pathology, Free Radical Research Unit, Christchurch School of Medicine, Christchurch, New Zealand.
- 1986-1991 Graduate Research/Teaching Assistant, Allie M. Lee Laboratory for Cancer Research, Department of Biochemistry, University of Nevada, Reno, NV 89557.
- 1985-1986 Student Teacher, Eureka High School, Eureka, CA 95501.
- 1983-1985 Lecturer, Biological Sciences, Humboldt State University, Arcata, CA 95521.

### Awards:

- 2007 Certificate of Merit, American Chemical Society (ACS), Division of Environmental Chemistry. The oral paper I presented was judged outstanding for material content and for manner of presentation given at the 233<sup>rd</sup> National ACS Meeting.
- 2007 Presidential Faculty Award, Center for Excellence in Leadership, President Jerilyn McIntyre, CWU.
- 2002 TIAA-CREF/SOURCE Distinguished Faculty Mentor Award, CWU.

### My Students' Awards:

I have mentored the following students who have won awards for their research presentations.

- 2007 Posters on the Hill, Rayburn House Office Building in Washington, D.C. Stephanie Bryner, a junior majoring in chemistry, and one of 75 students from across the nation who was selected by the Council on Undergraduate Research for the poster, *Correlation of atmospheric ultrafine particle iron and mitochondrial toxicity*.
- 2006 SOURCE (Symposium on University Research and Creative Expression) at CWU, Stephanie Bryner, undergraduate student Best Poster in Geology-Chemistry section, *The effect of crystal violet on cellular respiration*.
- 2005 SOURCE (Symposium on University Research and Creative Expression) at CWU, Amy Diaz, Honorable Mention graduate student oral presentation, *Is salicylate a selective chemical trap for hydroxyl radical?*
- 2003 CWU 2<sup>nd</sup> Conference of Graduate Student and Faculty Scholarship, Mitzi Mackey won an "Outstanding Student Presentation Award" for her oral presentation, *The Role of Iron in Mitochondrial Hydroxyl Radical Generation*.
- 2002 PANWAT (Pacific Northwest Association of Toxicologists annual meeting at PNNL in Richland, WA, September). Mitzi Mackey, graduate student, Best platform/oral presentation award.
- 2002 SOURCE at CWU, Dave Cox, undergraduate student, best poster award.
- 1996 SOURCE at CWU, Sandra Schoenberg, undergraduate student, best poster award.

### Courses taught at CWU

(19 total which excludes independent study courses, master's thesis direction, and undergraduate research project mentoring):

CHEM 512.01	(3 Credits)	Biochemical Toxicology
CHEM 511.01	(3 Credits)	Advanced Biochemistry: Oxidative Stress
CHEM 505.01	(1 Credit)	Mitochondrial generation of oxygen radicals.
CHEM 505.01	(1 Credit)	Mitochondrial function in apoptosis and necrosis.
CHEM 505.01	(1 Credit)	Current Topics in Chemistry: Nanotoxicology
CHEM 488.01	(1 Credit)	Chemistry Colloquium
CHEM 388.01	(1 Credit)	Chemistry Colloquium
CHEM 432.01	(3 Credits)	Biochemistry I
CHEM 431.01	(3 Credits)	Biochemistry II
CHEM 431L.01	(2 Credits)	Biochemistry Laboratory
CHEM 311.01	(3 Credits)	Principles of Organic Chemistry
CHEM 312.01	(3 Credits)	Organic Chemistry
CHEM 312L.01-02	(2 Credits)	Organic Chemistry Laboratory
CHEM 181L.01-03	(1 Credit)	General Chemistry Laboratory
CHEM 112.01	(4 Credits)	Intro to Organic Chemistry
CHEM 112L.01-02	(1 Credit)	Intro to Organic Chemistry Laboratory
CHEM 111.01	(4 Credits)	Introduction to Chemistry
CHEM 111L.01-03	(1 Credit)	Introduction to Chemistry Laboratory
SHP 301	(2 Credit)	Science Honors Junior Seminar

**Masters Thesis and Undergraduate Research Projects Directed at CWU:**

**Masters Theses (CHEM 595, CHEM 599, CHEM 700):**

- Stephanie Bryner, Chemistry, Thesis Advisor, *The effect of a high-fat diet on mitochondrial function in C. elegans*. Committee Chair. In progress 2008-10.
- Justin Johnston, Chemistry, *Mitochondrial toxicity of atmospheric ultrafine particles*, Thesis Advisor, Committee Chair. Graduated Summer 2008.
- Grant Ivan Barker, Chemistry, *Computer modeling and neural networks used in the design of novel  $\beta$ -secretase inhibitors for the therapeutic treatment of Alzheimer's disease*. Committee member. In progress 2006-08.
- Pei-Mien, Chen, Chemistry, Synthesis of cyclic boronates as potential HIV-1 protease inhibitors. Committee member. In progress 2006-08.
- Amy Diaz, Chemistry. *Measurement of Highly Reactive Oxygen Species in a Mitochondrial Model*. Thesis Advisor, Committee Chair. Graduated Summer 2006.
- Jia, Yinshan, Chemistry. *Investigation of Potential Boronated HIV-1 Protease Inhibitory Compounds*. Committee Member, Graduated Spring 2006.
- Dawn Myers, Biology. *A comparison of herbal and traditional treatments for Salmonella infections using a murine model*. Committee member. Graduated Spring 2005.
- Jennifer Key, Chemistry. *A laboratory investigation of the potential feedback cycle between iron and dimethyl sulfide in marine aerosols*. Committee member. Graduated spring 2004.
- Mitzi Mackey, Chemistry. *The role of iron in hydroxyl radical generation in submitochondrial particles*. Thesis Advisor, Committee Chair. Graduated Spring 2003.
- Man Shun Lai, Chemistry. *Screening of Environmental Contaminants by On-Line Supercritical Fluid Synchronous Luminescence Spectroscopy*. Committee Chair. Graduated 2001.
- Tyson Miller, Chemistry. *Studies of Ligands for the Serotonin Transporter: Preparation of Stereochemically defined and Constrained Inhibitor Probes*. Committee member. Graduated, 1999.
- Christopher Wendtland, Health, Physical Education, and Leisure Studies. *The Effect of Glycerol Augmented Overhydration on Prolonged, Varied Intensity Cycle Ergometry*. Committee member. Graduated, 1996.

**Select Undergraduate Research Projects and Theses (CHEM 495):**

Recent Undergraduate researchers, 2006-2009 Academic Years:

- Wells, Josie. (Science Honors Thesis 2005-2007) *Is mitochondrial lipid peroxidation initiated by ultrafine particles?*
- Bryner, Stephanie. *Correlation of atmospheric ultrafine particle iron and mitochondrial toxicity: inhibition of mitochondrial function by ultrafine particles*.
- Rosario, Sara. (Science Honors Thesis 2007-2009) *The Effects of Buckminster Fullerenes on Mitochondrial Function*.

**Publications in Peer-Reviewed Journals:****Graduate student<sup>#</sup> and undergraduate student\* co-authors are indicated.****In preparation:**

Carin Thomas and Andrew Piacsek. Elements of a science honors research program for upper division undergraduates. *CUR Quarterly*. In preparation, 2009.

Carin Thomas, Justin Johnston<sup>#</sup>, Stephanie L. Bryner\*, Drake Mitchell, Anne Johansen and Josie Wells. Effects of atmospheric ultrafine particles on mitochondrial membranes. *Toxicological Sciences*. In preparation, 2009.

Justin Johnston<sup>#</sup>, Stephanie L. Bryner\*, Eric Bullock, Anne Johansen and Carin Thomas. The chemical signature of atmospheric ultrafine particle toxicity in mitochondria. *Toxicological Sciences*. In preparation, 2009.

**Published:**

Thomas, C., Mackey, MM<sup>#</sup>, Diaz, AA<sup>#</sup> and Cox, DC\*. Hydroxyl radical is produced via the Fenton reaction in submitochondrial particles under oxidative stress: implications for diseases associated with iron accumulation. *Redox Reports* 14(3): *in press*, June 2009.

Thomas C, Will Y<sup>#</sup>, Schoenberg SL\*, Sanderlin D\*, and Reed DJ. Conjugative metabolism of 1,2-dibromoethane in mitochondria: disruption of oxidative phosphorylation and alkylation of mtDNA. *Biochemical Pharmacology* 61:595-603, 2001.

Visser, MC and Thomas, C. Hypochlorous acid disrupts the adhesive properties of subendothelial matrix. *Free Radical Biology & Medicine* 23:401-411, 1997.

Thomas C, Carr AC, and Winterbourn CC. Free radical inactivation of rabbit muscle creatine kinase: catalysis by physiological and hydrolyzed ICRF-187 (ICRF-198) iron chelates. *Free Radical Research* 21:387-397, 1994.

Thomas C, Vile GF, and Winterbourn CC. The hydrolysis product of ICRF-187 promotes iron-catalyzed hydroxyl radical production via the Fenton reaction. *Biochemical Pharmacology* 45:1967-1972, 1993.

Elliott AE\*, Scheiber SA<sup>#</sup>, Thomas C, and Pardini RS. Inhibition of glutathione reductase by flavonoids: a structure-activity study. *Biochemical Pharmacology* 44:1603-1608, 1992.

Thomas C and Pardini RS. Oxygen dependence of hypericin-induced phototoxicity to EMT6 mouse mammary carcinoma cells. *Photochemistry Photobiology* 55: 831-837, 1992.

Thomas C, MacGill RS\*, Miller GC, and Pardini RS. Photoactivation of hypericin generates singlet oxygen in mitochondria and inhibits succinoxidase. *Photochemistry Photobiology* 55: 47-53, 1992.

**Published Abstracts:****Graduate student<sup>#</sup> and undergraduate student\* co-authors are indicated.**

Thomas C, Bryner, SL\*, Bullock EL, Johansen AM, Johnston JM<sup>#</sup>, and Wells JK\*. Correlation of atmospheric ultrafine particle iron and mitochondrial toxicity. *American Chemical Society, Division of Environmental Chemistry, Extended Abstracts*, Vol. 47 (1), 2007.

Thomas C and Mackey M<sup>#</sup>. Is hydroxyl radical generated in mitochondria via the Fenton reaction? *Free Radic Biol Med*. 35(S1):S29, 2003.

Thomas C, Weller M\*, and Knowles J\*. Hydroxyl radical generation in mitochondria requires a

- soluble iron chelate. *Free Radic Biol Med.* 27(S1):S28, 1999.
- Thomas C, Will Y<sup>#</sup>, Schoenberg S\* and Reed D. The adverse effects of 1,2-dibromoethane metabolism in isolated rat liver mitochondria. *Fundamental and Applied Toxicology Suppl. Vol 36(1), part 2, p. 161*, 1997.
- Thomas C, MacGill RS\*, Neill P, Pardini RS (1992) In vitro and in vivo light induced antineoplastic activity of hypericin. *Proceedings of the Eighty Third Annual Meeting of the American Association for Cancer Research* Vol. 33, p. 500.
- Thomas-Bradley CJ (1992) Hypericin as a potential photosensitizer in photodynamic therapy of cancer. *Dissertation Abstracts International B 52(9):4715-B*.
- Thomas CJ, MacGill RS\*, Miller GC, and Pardini RS (1990) Hypericin-induced photosensitization of mitochondrial respiration. *Free Radicals in Biology & Medicine* Vol 9, Supl. 1, p.79.
- Thomas CJ, Pardini L, and Pardini RS (1989) Photodynamic therapy of MX-1 human mammary carcinoma using hypericin, a potential antineoplastic quinone. *Proceedings of the 80th Annual Meeting of the American Association for Cancer Research* Vol. 30., p. 547.

### Grants:

- Co-PI, April 2009, in collaboration with Ian Quitadamo, Martha Kurtz, Jim Johnson. *Building Student Critical Thinking and Faculty Capacity Using Community-based Inquiry in STEM Courses*. Requested, \$. In preparation.
- Co-PI, February 2007, in collaboration with Co-PIs Andy Piacsek and Wendy Bohrsen. *Sustaining and Enhancing the Science Honors Program*. Requested, \$82,525. Denied.
- PI, December 2006, *Centrifugation: a critical technique for separating particles*. Essential Instructional/Research Equipment Grant. CWU College of the Sciences Deans's Office. **Funded \$4,962.**
- Co-PI, May 2006, in collaboration with Co-PIs Andy Piacsek and Mike Braunstein. *The Science Honors Sphere of Distinction*. Central Washington University President's Office. \$82,000 in university base dollars. **Funded, \$86,000.**
- Co-PI, May 2006, Eric Bullock, Anne M. Johansen, Carin Thomas, Surface and bulk characterization of ambient ultrafine particles, Environmental Molecular Sciences Laboratory, Pacific Northwest National Lab, May 2006-April 2009, **Funded instrument time** for external grant, XPS, TOF-SIMS. National Peer Review.
- Co-PI, August 2005, in collaboration with Co-PIs Anne Johansen and Eric Bullock. *Ultrafine particles and Mitochondrial Dysfunction*. NIH (NIEHS) AREA. National Institutes of Health (National Institute of Environmental Health Science) Academic Research Enhancement Award proposal. **\$203,169. Funded.**
- PI, May 2004, *Mitochondrial oxidative Stress: iron & hydroxyl radical*. NIH (NIA) AREA. National Institutes of Health (National Institute on Aging) Academic Research Enhancement Award proposal. \$202,062. Denied.
- PI, May 2004. *Oxidative Stress and Aging*. Essential Instructional/Research Equipment Grant. CWU Provost's Office. **Funded \$9,592.**
- PI, April 2004. *Using Scatchard Analysis to Quantify Hydroxyl Radical in a Model of the Aging Heart*. Seed Grant. CWU Office of Graduate Studies and Research Faculty Research.

**Funded \$1,795.**

- PI, August 2004. *Scientific Discovery Through Inquiry-Based Research: Establishing the Science Honors Research Program at CWU*. M J Murdock Charitable Trust, **\$225,000, Funded.**
- PI, January 2002. *Professional Poster Presentations by CWU Students Using Adobe Illustrator*. CWU Foundation Leonard Thayer Small Grants Program. **Funded \$250.**
- PI, March 1999. *Symposium on Undergraduate Research and Creative Expression (SOURCE) Poster Presentation Media*. CWU Foundation and Alumni Association Grants Program. **Funded \$550.**
- PI, Nov 1998. *The Role of Iron Chelates in the Generation of Hydroxyl Radical in Mitochondria*. Revised and resubmitted to Research Corporation. Requested \$41,578. Denied.
- PI, Oct 1998. *Chemistry Seminar Series*. Leonard Thayer Small Grants Program, CWU Foundation. **Funded \$2500.**
- PI, Feb 1998. *Role of Iron Chelates in the Generation of Hydroxyl Radical in Mitochondria*. Small Grants, Office of Graduate Study and Research, CWU. **Funded \$1150.**
- PI, April 1997. *Generation of Hydroxyl Radical in Mitochondria: Effect of Xenobiotics*. Small Grants, Office of Graduate Study and Research, CWU. **Funded \$1289.**
- PI, Feb 1996. *Chemically Induced Toxicity and Mitochondrial Dysfunction*. Summer Faculty Research Leave, Office of Graduate Study and Research, CWU. **Funded \$3500.**
- PI, August 1996. *A Renaissance in Chemistry Research at CWU*. M.J. Murdock Trust. **Funded \$309,000.**

**Invited Seminars/Presentations:**

- March 2009 *Mitochondrial Metabolism of an Environmental Contaminant: the good, the bad, and the ugly*. Chemistry Department, Whitworth University, Spokane, WA.
- March 2007 *Correlation of atmospheric ultrafine particle iron and mitochondrial toxicity* with co-authors Stephanie L. Bryner, Eric L. Bullock, Anne M. Johansen, Justin M. Johnston, and Josie K. Wells. American Chemical Society National Meetings, Environmental Chemistry Division, Chicago, IL.
- Jan 2005 *Mitochondrial Metabolism of an Environmental Contaminant: the good, the bad, and the ugly*. Chemistry Department, California State University, Chico.
- Feb 2004 *Exploring New Zealand*, CWU CALL Program, Central Adult Lifelong Learning, Ellensburg Inn, Ellensburg, WA.
- April 2002 *Mitochondrial Metabolism of Environmental Contaminants*. Chemistry Department Seminar Series, CWU, Ellensburg, WA.
- March 2002 *Mitochondrial Metabolism of Environmental Contaminants*. Chemistry Department Seminar Series. Willamette University, Salem, Oregon.
- June 2001 *Bioactivation of 1,2-dibromoethane involves glutathione conjugation in mitochondria*. Northwest Regional American Chemical Society Meeting. NORM 2001. Bioactivation and Chemical Toxicology Session. Seattle University, Seattle, WA.
- April 1997 *Possible Adverse Effects of Environmental Contaminants in Foods: Mitochondria as a Cellular Target*. American Dietetics Association, Yakima, WA.

- Jan 1997 *Carcinogenesis: environments for the growth of cancer*. City of Ellensburg, Environmental Commission, WA.
- May 1996 *Chemically Induced Toxicity and Mitochondrial Dysfunction*. Natural Science Seminar Series, CWU, Ellensburg, WA.

### Conference presentations:

#### Graduate student<sup>#</sup> and undergraduate student\* co-authors are indicated.

- 2008 Sara Rosario\* and Carin Thomas. *The effects of Buckminster fullerenes on mitochondrial function*. Department of Chemistry, Central Washington University, Ellensburg, WA 98926, the Murdock College Science Undergraduate Research Program Conference, Tacoma, WA, Nov. 7-8.
- 2008 Carin Thomas<sup>1</sup>, Justin Johnston<sup>1</sup>, Stephanie Bryner<sup>1</sup>, Anne Johansen<sup>1</sup>, Eric Bullock<sup>1</sup> and Mark Engelhard<sup>2</sup>. *Inhibition of mitochondrial electron transport by atmospheric ultrafine particles: ferrous iron, quinones and ROS production*. <sup>1</sup>Department of Chemistry, Central Washington University, Ellensburg, WA 98926, <sup>2</sup>Environmental Molecular Sciences Laboratory, Pacific Northwest National Laboratory, Richland, WA 99352. Federation of Societies for Experimental Biology (FASEB) International Meetings, San Diego, CA, April 6-10.
- 2007 Justin Johnston<sup>#</sup>, Stephanie L. Bryner\*, Eric Bullock, Anne Johansen and Carin Thomas. *Chemical Signature of Atmospheric Ultrafine Particle Toxicity in a Mitochondrial Model*. Society of Toxicology, Pacific Northwest Association of Toxicologists (PANWAT) Regional Meeting, Nanotechnology and Health, Seattle, WA. September, 14-15.
- 2007 Stephanie L. Bryner\*, Eric L. Bullock, Anne M. Johansen, Justin M. Johnston<sup>#</sup>, and Carin Thomas, and Josie K. Wells. *Atmospheric ultrafine particles inhibit mitochondrial electron transport: correlation of ferrous ion and mitochondrial dysfunction*. American Chemical Society Northwest Regional Meetings (NORM), Boise, ID, June, 17-20.
- 2007 Josie K. Wells\*, Stephanie L. Bryner\*, Eric L. Bullock, Anne M. Johansen, Justin M. Johnston<sup>#</sup>, and Carin Thomas. *Ultrafine Particle Initiation of Lipid Peroxidation in Mitochondria*. American Chemical Society Northwest Regional Meetings (NORM), Boise, ID, June, 17-20.
- 2007 Stephanie L. Bryner\*, Eric L. Bullock, Anne M. Johansen, Justin M. Johnston<sup>#</sup>, Carin Thomas and Josie K. Wells\*. *Correlation of atmospheric ultrafine particle iron and mitochondrial toxicity*. Posters on the Hill, Washington, DC, April 24.
- 2007 Carin Thomas, Stephanie L. Bryner\*, Eric L. Bullock, Anne M. Johansen, Justin M. Johnston<sup>#</sup>, and Josie K. Wells\*. *Correlation of atmospheric ultrafine particle iron and mitochondrial toxicity*. American Chemical Society 233<sup>rd</sup> National Meeting, Chicago, IL. March 2007. Platform. **This presentation was awarded Certificate of Merit by the Environmental Chemistry Section, ACS.**
- 2006 Josie Wells\* and Carin Thomas. *Detection of lipid peroxidation in mitochondria exposed to ultrafine particles*. 13th Regional Conference on Undergraduate Research of the Murdock College Science Research Program. Portland State University, Portland, OR. November, 2006.

- 2006 PANWAT Annual Meeting, Pacific Northwest Association of Toxicologists, University of Montana. As Councilor, I assisted in organizing and attended the meeting. I presented awards and checks at the graduate student & post-doc awards ceremony.
- 2005 ACE, American Council on Education. Academic Department Chairs National Meeting. Washington, DC.
- 2004 PANWAT Annual Meeting, Pacific Northwest Association of Toxicologists, Mount Bachelor Village Resort and Conference Center, Bend, OR. Attended Officers meeting and as Secretary/Treasurer of PANWAT, as Secretary/Treasurer, I organized meeting registration and financing.
- 2003 Tenth Annual Meeting of the Society for Free Radical Biology and Medicine, Seattle, WA. Mitzi Mackey<sup>#</sup> and Carin Thomas, *Is hydroxyl radical is produced in mitochondria via the Fenton Reaction? Free Radic Biol Med.* 35(S1):S29, 2003.
- 2003 PANWAT, Pacific Northwest Association of Toxicologists, Mount Bachelor Village Resort and Conference Center, Bend, OR. As Secretary/Treasurer of PANWAT, as Secretary/Treasurer, I organized the conference location, registration and financing.
- 2002 PANWAT, Pacific Northwest Association of Toxicologists, "Cellular and Organismal Responses Oxidative Stress", September 19-20, 2002, Pacific Northwest National Laboratory (PNNL), Richland, WA. Mitzi Mackey<sup>#</sup> and Carin Thomas, *Hydroxyl radical is produced in mitochondria only when electron transport is inhibited.*
- 2001 Northwest Regional ACS Meeting. NORM 2001. Bioactivation and Chemical Toxicology Session. Seattle University, Seattle, WA. *Bioactivation of 1,2-dibromoethane involves glutathione conjugation in mitochondria.*
- 2001 Tenth Regional Conference on Undergraduate Research of the Murdock College Science Research Program. Gonzaga University, Spokane, WA.
- 2000 NCUR, 14<sup>th</sup> National Conference on Undergraduate Research, University of Montana, Missoula, MT.
- 1999 Oxygen 99: Sixth Annual Meeting of the Oxygen Society, New Orleans, LA.
- 1999 American Chemical Society Puget Sound Section Undergraduate Research Symposium April 24, 1999, CWU, Ellensburg, WA. Organizing committee member.
- 1998 American Chemical Society NORM regional meetings, Pasco, WA. *The lipophilic, cationic agent dequalinium chloride uncouples mitochondria and inhibits electron transport.* Julia A. Knowles\*, Dawn Sanderlin\*, and Carin Thomas. June 17-20, 1998. American Chemical Society NORM regional meetings, Pasco, WA.
- 1997 Society of Toxicology 36th Annual Meeting, Cincinnati, OH. *The adverse effects of 1,2-dibromoethane metabolism in isolated rat liver mitochondria.* Thomas C, Will Y, Schoenberg S and Reed D.
- 1997 American College of Sports Medicine Annual Meeting, Denver CO. Wendtland, C.<sup>#</sup> Nethery, V.; D'Aquisto, L.; and Thomas, C. Glycerol-induced hyperhydration does not provide cardiovascular or thermoregulatory benefit during prolonged exercise.
- 1996 Fifth Regional Conference on Undergraduate Research of the Murdock College Science Research Program, Pacific Lutheran University.
- 1996 BioSciences Symposium. University of Utah, Salt Lake City, UT.
- 1995 Project Kaleidoscope Workshop: The Research-Rich Environment, Harvey Mudd

- College, Claremont, CA. Poster presented: Undergraduate Research at CWU.
- 1995 International Congress of Toxicology-VII. Seattle, WA. Poster presented: *Inhibition of respiration and DNA alkylation in isolated mitochondria exposed to 1,2-dibromoethane.*
- 1994 International Conference on Bioreductive Drug Activation. Tahoe City, CA. Poster presented: *Superoxide and Adriamycin radical-induced inactivation of rabbit muscle creatine kinase: catalysis by physiological and hydrolyzed ICRF-187 (ICRF-198) iron chelates.*

### Professional Affiliations and Service:

Society for Free Radical Biology and Medicine, member.

Society of Toxicology (SOT), member.

Pacific Northwest Association of Toxicologists (PANWAT), a Regional Chapter of SOT.

May 2003-May 2005, Officer, Secretary/Treasurer.

May 2005-May 2007, Officer, Councilor.

Organized annual meetings.

American Chemical Society, member.

American Association for the Advancement of Science, member.

External reviewer for Organic Chemistry/Bio-Organic tenure track faculty position at Whitman College, Walla Walla, WA, 2006-2007, 2007-2008, 2008-2009.

National Science Foundation, Course, Curriculum & Laboratory Improvement. NSF- CCLI Phase I Review Panel: reviewer 2008.

### University Service (CWU):

#### Departmental (Chemistry)

2004-2005 Chemistry Department Chair

1999-2007 Personnel Committee, Chair in 2002-2003, 2008-09.

2001-2007 Chemistry Tenure Track Faculty Search Committees: Biochemist Search Committee, Chair, (2007-08; and 08-09); Organic Chemist Search Committee, member, (2006-2007); Organic Chemist Search Committee, member, (2002-2003); Analytical Chemist Search Committee, Chair, (2001-2002); Organic Chemist Search Committee, Member, (2001-2002); Physical/Organic Chemist Faculty Search Committee, member, (1995-1996).

1995-2007 Graduate Committee, member, 8 hours/month, Sept 1996- June 1997.  
Reinstated Master's Program in Chemistry at CWU 1998,  
discussed program goals and developed a graduate program  
proposal in the format required for the HEC Board.

1998-1999 American Chemical Society Puget Sound Section Undergraduate Research Symposium Organizing Committee, member.

1998-1999 Undergraduate Curriculum Committee, member.

1998-2001 Chemistry Seminar Series, Chair, 12 hours/month.

1996-1999 Murdock Grant PI and Coordinator, *A Renaissance in Chemistry Research*, Chair.

- 1997-1998 Biochemistry Laboratory Committee for Science Facility equipment acquisition, Chair.  
 1995-1998 Faculty Senate, Chemistry Department Senator.

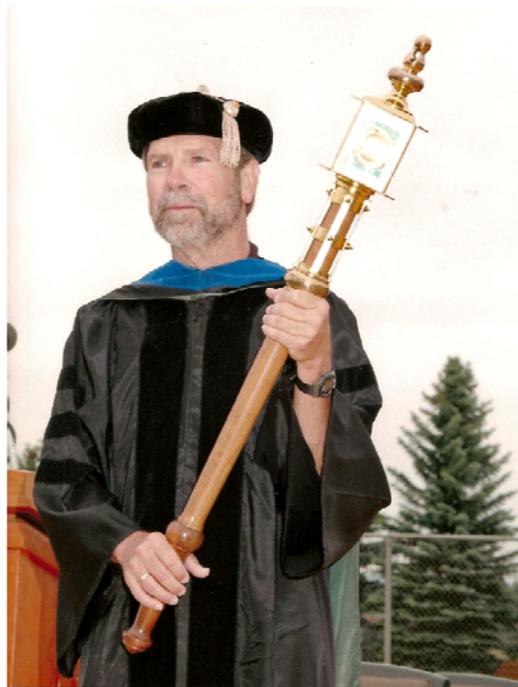
### **College of the Sciences (COTS)**

- 2007 Start-up request reviewed for Andrew Koppisch, applicant for Organic chemistry tenure track assistant professor position.  
 2003-2006 Associate Dean for Resource Development  
 2002-2006 COTS Undergraduate Research Committee, Chair.  
 2000-2001 Geneticist Search Committee, member, Biology Department.  
 1998-2003,  
 2007-2008 Pre-Medical Student Interview Committee, member. Regular participant in the Pre-Medical Student Interviews.  
 1999-2002 College of the Sciences committee for Undergraduate Research, member.  
 1998 Lectern Console for new science building rooms 101, 142, 147, 201, 203, 216, 240. Coordinated all parties involved in design. Facilitated communication with faculty and designing crew.

### **University**

- 2004-2008 Science Honors Advisory Council, ex officio member.  
 As PI of the grant funded by the M.J. Murdock Charitable Trust, I initiated the Science Honors Research Program at CWU and have served on the Advisory Council. The Advisory Council is charged with program governance and development, curriculum enhancement, and financial support.  
 2004-2008 Science Honors Review Committee, ex officio member.  
 2005-2006 Diversity Council, member.  
 2002-2003 Douglas Honors College Re-Vision committee, Co-Chair.  
 1995-2003 SOURCE organizing committee (Symposium on Undergraduate Research and Creative Expression), member.  
 2001-2003 Senior Director of Development Search committee, member.  
 2001-2002 Farrell Pre-Medical Scholarship Committee, member.  
 1999-2001 HEC Board, Competency Based College Admissions Standards in Science, member.  
 1995-1998 Faculty Senate, Chemistry Department Senator.  
 1996-1997 Provost Search Committee, member.

# Reappointment/ Promotion/ Tenure



## **7.2 Departmental Standards**

University-approved standards guide evaluation of each faculty member by the department personnel committee and the department chair. These are developed in accordance with 20.1.1 of the CBA, and require approval of the dean and the office of the provost.

7.2.1 Departmental standards for reappointment, tenure, and promotion, and for post-tenure review shall align with the university and college standards.

7.2.1.1 The department will ensure that its personnel policy document is consistent with, and in no case less stringent than college and university provisions.

7.2.1.2 Periodic revision may be required.

7.2.2. Modification of approved criteria for reappointment, tenure, promotion, or post-tenure review for an individual position may sometimes be warranted. A split appointment between science education and a discipline department is a typical example. The modified criteria are agreed upon by the faculty member, the department chair in consultation with the department personnel committee, and the dean; and approved in advance by the provost. Approval at all levels must be in writing (Collective Bargaining Agreement, section 27.3) and the modification must be stipulated in documents such as the initial contract letter or subsequent letters of agreement.

### **7.2.3 Department of Chemistry**

All faculty members in the Chemistry Department must be collegial by conducting themselves in a nondiscriminatory and professional manner while exhibiting excellent communicative and interactive skills. All recommendations for reappointment, promotion, tenure and post-tenure shall be made according to procedures in the CWU – UFC CBA, the College of the Sciences Policy Manual, and this document, and shall be based on evaluation of teaching effectiveness, scholarship, and service as indicated below. Separate recommendations shall be submitted, in writing, by the Chemistry Department Chair and by the Personnel Committee.

In the case of changes to the university, college or department Reappointment, Promotion and Tenure criteria, in accordance with 20.1.3 of the Collective Bargaining Agreement, the dean will discuss implementation with the department chair, and notify faculty of the ways in which those changes will be applied to pending probationary and Post-TR periods. The Chemistry Department chair will consult with the department Personnel Committee prior to discussing implementation of said changes with the Dean.

#### **7.2.3.1. Instruction: Standard and Evaluation**

All faculty, including temporary and part-time faculty, shall be evaluated with respect to teaching effectiveness during the appropriate review period. Teaching effectiveness will be evaluated on the basis of organization, clarity, and presentation of instructional material, response to student needs, and the methods used to evaluate student learning. The Chemistry Department recognizes mentoring of undergraduate and graduate student research, mentoring of student civic engagement and service learning activities,

participation in continuing education, and course and curriculum development as important aspects of teaching. It is also anticipated that all faculty will share the responsibility for student academic and/or professional advising.

Tools to evaluate teaching include:

1) A review of course materials. Course materials submitted for review shall include all course syllabi. Faculty under review should also include examples of: examinations, handouts, assignments, and laboratory exercises; any materials associated with curriculum development activities; appropriate documentation of civic engagement and service learning activities; examples of student research products (e.g., reports, posters, etc.). In addition, instructors shall prepare a written reflection on their teaching performance, identifying areas of strength, as well as problems or areas for improvement. This statement shall include goals for improvement or professional growth, and specific steps that will be taken in the following year to attain these goals.

2) Peer review. There will be a mutually agreed upon class visitation by a member of the Chemistry Department or closely related discipline during each review period. A written summary and evaluation will be provided to the faculty member being evaluated and this will be placed in the file for review.

3) Student Evaluation of Instruction. SEOI will be administered according to COTS guidelines, by a designee other than the instructor, during the last week of the quarter or during the final exam period. The instructor shall not be present and the results will not be made available to the instructor until after grades for the course have been submitted. Comments shall be typed by the department secretary before being made available to the instructor. The SEOI summaries and comments shall be placed in the review file.

4) ACS exam scores. Instructors shall administer the American Chemical Society exams in courses for which they are available, and the results (including course mean, national mean and national percentile) shall be included in the review file. Some ACS exams are intended for use with semester-based courses and include material that is not covered in the CWU quarter-based courses. Course content may also reasonably vary from one instructor to another. Instructors are therefore encouraged to include an explanation of the material covered on the exam relative to their course, and are required to report any accommodations that are made in reporting the test scores.

*Tenure in the Chemistry Department, as well as promotion to Associate Professor, requires knowledge of the material taught; demonstrated concern for student learning and effectiveness as an instructor as evidenced by the items listed above; and a record of continued improvement and growth. Promotion to Professor requires evidence of a sustained record of teaching effectiveness, as well as a record of continued efforts to remain current in subjects associated with the faculty member's teaching responsibilities. Satisfactory post-tenure review requires evidence of a sustained record of teaching effectiveness, as well*

*Approved by dept 1/14/2008*

*as continued effort by the faculty member to remain current in subjects associated with the faculty member's teaching responsibilities.*

#### **7.2.3.2. Research and Scholarly Activity: Standard and Evaluation**

It is anticipated that faculty in the Department of Chemistry will develop a sustainable program of scholarly activity. Some portion of this program shall be accomplished on the CWU campus and will involve students as collaborators.

During the first probationary year at CWU, faculty members shall develop and present to the department a proposal for a program of scholarly activity, including targets for external funding, that is consistent with the mission and goals of the department. The program should be based on a faculty member's experience and interests, as well as departmental needs. Subsequent years should produce evidence of continued scholarly activity, including efforts to obtain external funding, and peer recognition of scholarly contributions. The Department of Chemistry also values collaborative activity within the department, with colleagues from other departments, and with professionals outside of the university. Scholarly products resulting from such collaborations, in cases where the faculty member has made substantive contributions to the authorship and intellectual merit of such products, are as valued as contributions resulting from individual effort. In this context, substantive contributions that establish the faculty member as a co-PI are those that (1) are regarded as essential to the project design and execution, and (2) include responsibility for project oversight and reporting.

In accordance with the University Faculty Performance Standard, scholarly products and activities are divided into two categories:

**Category A** are discipline-recognized products, for which the faculty member is the primary contributor, and that are formally peer-reviewed and disseminated outside the university. Products resulting from collaborative work for which the faculty member has made a substantive contribution to the authorship and intellectual merit and/or design also fall into Category A:

- Refereed journal articles
- Research monographs
- Scholarly books and chapters
- Textbooks
- Funded peer-reviewed external grants (lead PI or substantive co-PI)
- Contributions to conference proceedings that are full-length manuscripts subjected to traditional peer-review before acceptance

**Category B** includes other formal activities that support a faculty member's program of scholarly effort:

- Proposal submission for a peer-reviewed external grant (lead PI or substantive co-PI)
- Serving in a contributing role on a funded external peer-reviewed grant, but not as a co-PI
- Authoring publicly available research and technical papers

- Grant reports and technical reports
- Conference presentations
- Successful patent applications
- Study guides published by a recognized publisher or professional society
- Book reviews
- Conference proceedings that do not fall into Category A of this document

*The faculty member's scholarly work during the probationary period should reflect continued effort, progress, and acceptance by peers as evidenced by the dissemination of research results. To receive tenure and promotion to associate professor, the faculty member is expected to produce at least two Category A products, one of which is a peer-reviewed article in a national or international scientific publication that includes at least one CWU student as a co-author. Early in the probationary period the faculty member is also expected to submit at least one external grant proposal in support of their research program. If not funded, the faculty member is expected to submit another or a revised proposal. Finally, the strength and sustainability of the candidate's research program should be evidenced by additional Category A or Category B products. In particular, it is expected that the faculty member will continue to pursue external funding in accordance with the needs of their scholarly program.*

*Promotion to Professor requires at least two Category A products, one of which is a peer-reviewed article in a national or international scientific publication. The faculty member will demonstrate work with CWU students through externally disseminated scholarly products. The faculty member is also expected to submit at least one external grant proposal in support of their research program during the review period. Finally, the strength and sustainability of the candidate's research program should be evidenced by additional Category A or Category B products. In particular, it is expected that the faculty member will continue to pursue external funding in accordance with the needs of their scholarly program.*

*Satisfactory post-tenure review requires evidence of a sustained record of scholarly activities over the course of a faculty member's career.*

#### **7.2.3.3. Service: Standard and Evaluation**

All tenured and tenure-track faculty in the Chemistry Department are expected to provide service to the university, to the public or community, to students, or to their profession. Examples of service may include, but are not limited to:

Serve as a contributing member in departmental academic and development issues.

Provide professional expertise to assist in community improvement or improvement to one's profession.

Serve as an advisor to a student organization.

Serve as a pre-professional advisor.

Serve on a college or university committee or organization.

Serve the department and university through academic service learning and outreach efforts.

Serve in a professional organization (e.g. officer, board member).

Provide professional expertise to improve science education.

Faculty under review should include in their review file appropriate documentation of service activities (e.g., committee products, acknowledgment letters, conference programs, etc.).

*Tenure in the Chemistry Department, as well as promotion to Associate Professor, requires membership on departmental committees and service on at least one college or university committee for a minimum of one year. Promotion to Professor requires evidence that the faculty member has remained active in university, public, and/or professional service, and has taken a leadership role in service activities. Satisfactory post-tenure review requires a sustained record of participation in service activities over the course of a faculty member's career, in particular faculty are expected to routinely contribute to departmental service needs.*

## **7.1. College Standards for Faculty Review**

Tenured and tenure track faculty members are reviewed for reappointment, tenure, promotion, award of merit, and ongoing professional development after tenure. The process and schedules for each type of review are specified in the collective bargaining agreement (CBA Article 20.2), the Academic Affairs policy manual, and the Academic Affairs annual calendar; the required materials are detailed on the COTS cover sheet appropriate to each type of review. The office of the provost maintains the official copy of the Professional Record for COTS faculty. Notification of required periodic review follows the timelines laid out in the annually published academic affairs calendar.

In conformance with university standards, review of tenured and tenure-track faculty centers on the three required performance areas: instruction, scholarship, and service. Work performed in all three areas is expected to meet professional standards including collegiality. Non-tenure track faculty and phased retirees are evaluated for instruction; other duties are evaluated when they are part of their contract.

### **7.1.1. Instruction: Standard and Evaluation**

- 7.1.1.1. Effective instruction is the central element of faculty work.
- 7.1.1.2. Effective instruction requires thoughtful and responsive course design, development of appropriate instructional techniques, articulation of student learning objectives, assessment of student learning, and maintenance of the completeness and currency of a faculty member's understanding of his or her discipline. Effective teaching is shaped by formal evaluation and by ongoing professional development.
- 7.1.1.3. The college values multiple modes of instruction and recognizes that student learning occurs in a variety of field, laboratory, research, classroom, and other settings and contexts. Delivery of instruction and its evaluation should reflect this diversity.
- 7.1.1.4. The administration of the Student Evaluation of Instruction (SEOI) is required in all courses with five or more students. Departments and individual faculty may develop their own instruments and means of teaching evaluation to complement but not to replace the SEOI.
- 7.1.1.5. Departments must retain summaries of SEOI including transcription of written comments, using the university's SEOI forms and other evidence of teaching effectiveness, in accordance with college and department policies.
- 7.1.1.6. In conformance with accreditation standards, all teaching faculty are evaluated using multiple methods that typically include student evaluation, peer evaluation through classroom observation, review of syllabi and/or course materials, self-reflection, and assessment of student learning objectives. The instruments and results of evaluation are included in the personnel file.
- 7.1.1.7. Non-tenure track faculty members are expected to maintain effective teaching, as demonstrated through such evaluation.
- 7.1.1.8. Candidates for reappointment shall demonstrate concrete evidence of effective teaching and professional growth.

- 7.1.1.9. Candidates for tenure shall demonstrate a pattern of productivity that demonstrates effectiveness in teaching and promises sustained productivity throughout their career.
- 7.1.1.10. Candidates for promotion are evaluated in accordance with the University Faculty Performance Standard. Effective teaching demonstrated through the evaluation specified in 7.1.1.6 and through progressive professional growth is required for promotion to Associate Professor. Teaching that consistently exceeds expectations and commands the respect of faculty and students is required for promotion to professor.

**7.1.2 Research and Scholarly Activity: Standard and Evaluation**

- 7.1.2.1. Research and scholarly activity are essential duties of university faculty, and are valued for their contribution to instruction, service, professional development, and the advancement of knowledge. Scholarship takes many forms and is characterized by validation of rigor and dissemination outside the university.
- 7.1.2.2. University and accreditation standards recognize publication in national peer-reviewed venues as an essential form of such validation and dissemination for all faculty members. These correspond to Category A products identified by the University Faculty Performance Standard or discipline-specific, equivalent products established by departmental standards that have been approved at the college and university levels.
- 7.1.2.3. Other forms of faculty scholarship enrich the intellectual life of the faculty, the students, and the university. These correspond to “other products” identified by the University Faculty Performance Standard, herein referred to as Category B products or discipline-specific, equivalent products established by departmental standards that have been approved at the college and university levels.
- 7.1.2.4. In the context of the University Performance standard, departments may establish discipline-specific faculty scholarship standards that support the programmatic goals of the department. These standards require approval of the dean and provost.
- 7.1.2.5. Candidates for reappointment shall demonstrate concrete evidence of progress towards scholarly contributions.
- 7.1.2.6. Candidates for tenure shall demonstrate a pattern of productivity that demonstrates substantive scholarly contributions and promises sustained productivity throughout their career.
  - 7.1.2.6.1. This record should include regular contributions in both 7.1.2.2 and 7.1.2.3 above.
  - 7.1.2.6.2. Among the regular contributions, at least one category A product shall demonstrate the candidate’s ability to initiate scholarly work at CWU and lead it to peer-reviewed dissemination.
  - 7.1.2.6.3. The pattern of productivity is further substantiated by evidence of projects in different stages of development.
- 7.1.2.7. Candidates for promotion shall provide evidence of regular and substantive contributions of peer-reviewed scholarly work in the categories listed in 7.1.2.2 or comparable products when these have been established by university-approved department personnel standards. These products shall be complemented by scholarly activities such as those listed in 7.1.2.3 in accordance with the University Faculty Performance Standard. Faculty

members are especially encouraged to mentor students in research leading to external dissemination.

- 7.1.2.8. In accord with accreditation standards, all tenured faculty members are expected to sustain scholarly activity, during any given post-tenure review period. The balance of instruction, scholarship, and service may evolve throughout an individual's career and performance expectations in each category are established through the workload plan that is assigned by the department and approved by the dean.
- 7.1.2.9. When departments request the evaluation of scholarship by external experts as part of the tenure, promotion, or post-tenure review consideration special procedures for soliciting and handling external evaluations apply. These are detailed in 7.2.5.

### **7.1.3. Service: Standard and Evaluation**

- 7.1.3.1 Service is an essential element of faculty life; faculty service contributes expertise and effort to departments, the university, professional communities of scholars, and the citizenry.
- 7.1.3.2. University service is assigned in accordance with university policy. The dean, in consultation with the department chair, assigns college level service. The department chair assigns department level service.
- 7.1.3.3. Service activities are defined in CBA Article 13.3.3 and may include participation in university governance, public lectures, service as chair or program director, unremunerated consultancies, community activities related to one's discipline, advisement of student organizations, service to professional organizations, and contributions to department operations and activities. Faculty members are especially encouraged to mentor and collaborate with students in community service. Departments may establish tailored guidelines for appropriate types and levels of discipline-specific faculty service activities established by departmental standards that have been approved at the college and university levels.
- 7.1.3.4. Faculty members are responsible for providing documentation of service activities and contributions in their professional files.
- 7.1.1.11. Candidates for reappointment shall demonstrate progressive growth towards appropriate service contributions.
- 7.1.1.12. Candidates for tenure shall demonstrate a pattern of productivity that demonstrates appropriate contributions in service and promises sustained productivity throughout their career.
- 7.1.1.13. Candidates for promotion are evaluated in accordance with the University Faculty Performance Standard, which requires a substantive contribution to university, professional and/or community service for promotion to Associate Professor, and sustained contributions to university life, and increasing service to professional organizations and/or the community for promotion to Professor.

## **UNIVERSITY FACULTY PERFORMANCE STANDARD FOR REAPPOINTMENT, TENURE, PROMOTION, AND POST-TENURE REVIEW**

Central Washington University faculty members contribute to the mission and goals of the university in the three areas of faculty work: instruction, scholarship, and service. This work is framed by university and program accreditation standards and conducted with collegiality and professionalism (CBA Article 11). College criteria for faculty performance in these areas will reflect disciplinary standards within the college. Department criteria will, in turn, align with college and university criteria and standards. Professional librarians shall constitute a college for administrative purposes, in accordance with CBA Article 13.4.4.

### **Tenure and/or Promotion in Rank:**

Tenure is the right to continuous appointment at the University with an assignment to a specific department in accordance with the provisions of CBA Article 9.2. The tenure decision is based upon faculty performance and the potential benefit to the university. Performance towards tenure is annually reviewed through the reappointment process. A positive tenure review requires a pattern of productivity that promises sustained contributions in all three areas of faculty performance throughout a career, and is based on the benefits to the university of entering into the commitment to tenure. For an Assistant Professor, tenure is awarded with promotion to Associate Professor.

Promotion to the rank of Associate Professor recognizes an established record of effective teaching, a demonstrated ability to lead independent, peer-reviewed scholarship to dissemination outside the university, and a substantive contribution to university, professional and/or community service.

Promotion to the rank of Professor recognizes excellent teaching that commands the respect of the faculty and students; an accumulated record of superior peer-reviewed scholarship since the previous promotion; and sustained contributions to university life, and increasing service to professional organizations and/or the community.

### **Post-tenure review**

Post-tenure review assures continued performance in assigned areas of faculty work at appropriate rank and consistent with the university mission and accreditation standards. Performance in the three areas of faculty work is typically expected during any three-year post-tenure review cycle.

College and department standards will articulate discipline-specific expectations for tenure, promotion, and post-tenure review.

## **PERFORMANCE**

### **Instruction:**

Effective instruction is the central element of faculty work. It requires thoughtful and responsive course design, development of appropriate instructional techniques, articulation of student learning objectives, assessment of student learning, general advising, and is informed by active scholarship. Effective teaching is shaped by formal evaluation using multiple measures and by ongoing professional development.

Instruction activities are specified in Article 13.3.1 of the Collective Bargaining Agreement.

College and department standards shall articulate multiple measures of review that include peer evaluation of content, pedagogy, and responsiveness to assessment; student feedback; and other measures appropriate to the content area.

### **Scholarship:**

Faculty scholarship informs instruction and service, contributes to professional development, and advances knowledge. It includes sustained professional activities leading to regular publication, performance, formal presentation, or external funding in the field of the faculty member's academic assignment. It may include contributions in the four basic areas of discovery, integration, application and teaching, as appropriate to that assignment. Scholarship is characterized by external peer review and dissemination outside the university.

Scholarship activities are specified in Article 13.3.2 of the Collective Bargaining Agreement.

College standards shall articulate periodically expected activities in two or more categories.

Category A includes disciplined-recognized products that are formally peer-reviewed and disseminated outside the university. e.g.:

- refereed journal articles
- research monographs
- scholarly books and chapter
- textbooks
- juried exhibitions and performances
- peer-reviewed external grant (for the lead principal investigator)

Another category or other categories specified by the colleges include formal activities that lead to or support such products or other scholarly contributions, e.g.:

- peer-reviewed conference proceedings
- proposal submission for peer-reviewed external grant (lead principal investigator)
- serving as co-investigator or co-principal investigator on funded external peer-reviewed grant
- principal investigator on other grants and contracts
- authoring publicly available research and technical papers
- conference presentations
- textbook chapters
- externally published study guides
- book reviews

Department standards shall align with university and college criteria.

**Service:**

Faculty service contributes academic and professional expertise and effort to the university community, to professional communities of scholars, and to the citizenry.

University, professional, and public service activities are specified in Article 13.3.3 of the Collective Bargaining Agreement.

College and department standards shall articulate professional and public service activities appropriate to the academic discipline, and the basis for their evaluation.

# Masters Thesis



EFFECT OF DIMETHYL SULFIDE OXIDATION PRODUCTS  
ON IRON SPECIATION IN PHOTOCHEMICAL  
SIMULATION EXPERIMENTS

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A Thesis

Presented to

The Graduate Faculty

Central Washington University

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In Partial Fulfillment

of the Requirements for the Degree

Master of Science

Chemistry

---

by

Jennifer Michelle Key

March 2005

CENTRAL WASHINGTON UNIVERSITY

Graduate Studies

We hereby approve the thesis of

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## ABSTRACT

### EFFECT OF DIMETHYL SULFIDE OXIDATION PRODUCTS ON IRON SPECIATION IN PHOTOCHEMICAL SIMULATION EXPERIMENTS

by

Jennifer Michelle Key

March 2005

Dust-derived aerosol particles deposited into remote oceans supply essential iron (Fe) to phytoplankton. The speciation of Fe determines its bioavailability, and thus affects primary productivity and the associated release of biogenic gases which, in turn, impacts global climate. Laboratory simulation experiments were conducted to characterize Fe speciation changes imparted by the biogenic gas dimethyl sulfide (DMS). Selected water soluble DMS oxidation products were added to synthesized ferrihydrite in the presence of light, while reactants and products were analyzed with ion chromatography, UV-visible absorption spectroscopy, and a hydrogen peroxide sensitive electrode. Results indicate that methane sulfinic acid, an intermediate oxidation product of DMS, is specific in forming a photoactive surface complex with Fe(III), thus undergoing ligand-to-metal charge transfer and enhancing Fe(II) concentrations. Such an increase in bioavailable Fe may explain current discrepancies between observed and modeled soluble Fe concentrations in the marine atmosphere.

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# CHAPTER 1

## BACKGROUND

### 1.1. Composition of the Atmosphere

The earth's atmosphere is composed of 78% nitrogen, 21% oxygen, ~1% argon, and various other trace gases that are present at low and varying concentrations commonly reported in units of parts per million volume ( $1 \text{ ppmv} = 1 \times 10^{-6} \text{ mol/mol air}$ ). This composition has remained surprisingly stable over time, in spite of the fact that the atmosphere is a dynamic system, with its gases continuously undergoing exchange with vegetation, the oceans, and biological organisms through physical and chemical processes (Seinfeld and Pandis, 1997). The important atmospheric gases and the nature of their global cycles are listed in Table 1 according to atmospheric concentration. In addition, the atmosphere contains variable amounts of particulate matter (aerosols), which arise from natural sources, such as windblown dust, sea spray, and volcanoes, and anthropogenic activities (e.g., incomplete combustion of fuels).

The atmosphere is vertically partitioned into domains separated by reversals of the temperature gradient with increasing altitude (Figure 1). The *troposphere* extends from the earth's surface to the range of 8 to 18 km altitude, depending on latitude and season. It is characterized by a decrease in temperature with altitude due to solar heating of the earth's surface. The *stratosphere* extends beyond the troposphere to ~50 km, increasing in temperature with altitude due to the absorption of solar UV radiation by ozone ( $\text{O}_3$ ) within the ozone layer.  $\text{O}_3$  filters out most of the sun's harmful radiation in the UV-C region (200-280 nm) and a small fraction in the UV-B region (280-320 nm)

Table 1. Atmospheric Composition

Gas	Mixing Ratio (mol/mol)	Cycle
Major components		
N <sub>2</sub>	0.78	} Biological and microbiological
O <sub>2</sub>	0.21	
Ar	0.0093	No cycle
Minor components		
CO <sub>2</sub>	365 x 10 <sup>-6</sup>	Anthropogenic and biogenic
CH <sub>4</sub>	1.7 x 10 <sup>-6</sup>	Biogenic and chemical
H <sub>2</sub>	0.6 x 10 <sup>-6</sup>	} Biogenic and chemical
N <sub>2</sub> O	0.3 x 10 <sup>-6</sup>	
CO	0.1 x 10 <sup>-6</sup>	Anthropogenic and chemical
O <sub>3</sub>	10 <sup>-8</sup> -10 <sup>-7</sup>	Chemical
NH <sub>3</sub>	10 <sup>-10</sup> -10 <sup>-9</sup>	Biogenic and chemical
SO <sub>2</sub>	10 <sup>-11</sup> -10 <sup>-10</sup>	} Anthropogenic, biogenic, chemical
NO	10 <sup>-12</sup> -10 <sup>-8</sup>	
NO <sub>2</sub>	10 <sup>-12</sup> -10 <sup>-8</sup>	

Note: Adapted from Seinfeld and Pandis (1997).

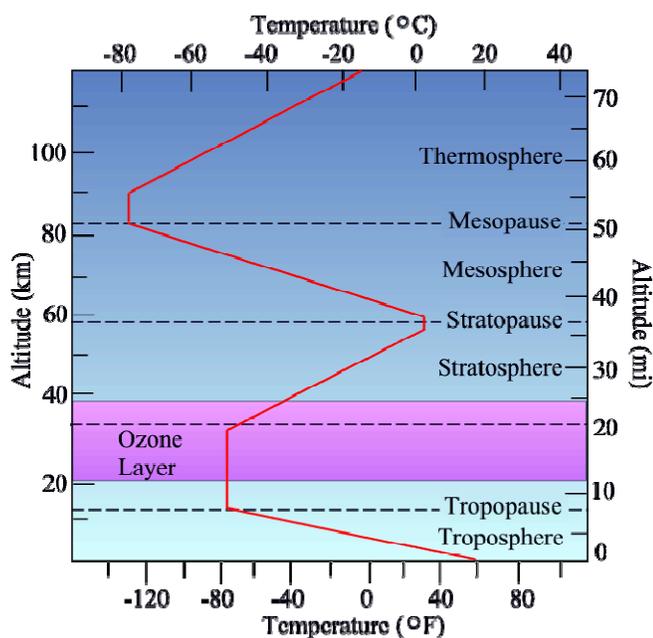


Figure 1. Vertical partitioning and temperature profile of the atmosphere with increasing altitude. Source: Ritter (2004).

(Baird, 1999, pp 22-30). The *mesosphere* extends up to 80 km and again decreases in temperature with altitude. Beyond the mesosphere, a temperature inversion is observed due to the absorption of strong UV radiation by  $N_2$  and  $O_2$  in the *thermosphere*. The troposphere and stratosphere together comprise 99.9% of the total atmospheric mass and thus are the domains of interest in terms of atmospheric chemistry (Jacob, 1999, p 17).

### 1.1.1. *Properties of Atmospheric Aerosol Particles*

Aerosol particles range in size from a few nanometers to tens of micrometers in diameter (Seinfeld and Pandis, 1997) and include dust, smoke, and organic and inorganic compounds (Table 2). These particles are emitted to the atmosphere directly as

Table 2. Global Emission Estimates for Major Aerosol Types in the 1980s

Source	Estimated Flux (Tg y <sup>-1</sup> )	Particle Size
Natural		
Primary		
Soil dust	1500	Mainly coarse
Sea salt	1300	Coarse
Volcanic dust	30	Coarse
Biological debris	50	Coarse
Secondary		
Sulfates from biogenic gases	130	Fine
Sulfates from volcanic SO <sub>2</sub>	20	Fine
Organic matter from biogenic VOC	60	Fine
Nitrates from NO <sub>x</sub>	30	Fine and coarse
Total natural	3100	
Anthropogenic		
Primary		
Industrial dust and soot	110	Fine and coarse
Secondary		
Sulfates from SO <sub>2</sub>	190	Fine
Biomass burning	90	Fine
Nitrates from NO <sub>x</sub>	50	Mainly coarse
Organics from anthropogenic VOC	10	Fine
Total anthropogenic	450	

Note: VOC = volatile organic compound. Adapted from Seinfeld and Pandis (1997).

particles (primary aerosol) or are formed in the atmosphere by gas-to-particle conversion processes (secondary aerosol). Their size distribution is typically bimodal, with the two main size fractions being the fine (accumulation mode) and coarse modes. Ultra-fine particles < 100 nm in diameter are the smallest size range in Figure 2 with short lifetimes

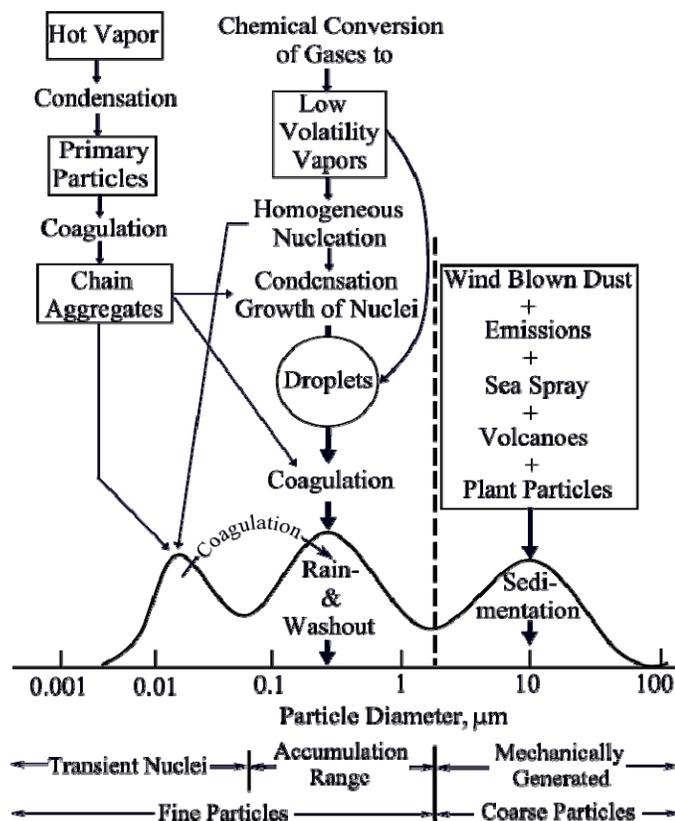


Figure 2. Typical aerosol distribution according to particle diameter. Source: Ritter (2004) and Seinfeld and Pandis (1997).

on the order of a few hours due to their ability to agglomerate and grow into fine particles in the accumulation mode. Coarse particles are typically mechanically derived and have short lifetimes due to their large gravitational settling velocities. Thus particles between 2.5 and 0.1 μm diameter accumulate and can remain in the atmosphere for days to weeks.

While suspended in the atmosphere, crustal aerosols can *directly* and *indirectly* alter atmospheric reflectivity and thus the earth's surface temperature (Jacob, 1999, p 151). To maintain a stable climate, the earth must be in equilibrium between the radiation received from the sun and the radiation emitted to outer space. Atmospheric aerosols partly absorb and scatter a fraction of incoming solar radiation back to space. This reflection of solar radiation, referred to as albedo, can lead to a cooling of the surface beneath the dust cloud, and therefore, impart a direct negative forcing (cooling) effect on global climate.

Less obvious but of potentially greater impact is the indirect effect that aerosols have on global climate (Intergovernmental Panel on Climate Change [IPCC], 2004) (see Appendix A for common abbreviations). For instance, in many parts of the remote open oceans, iron (Fe) is believed to be the rate-limiting micronutrient in the process of photosynthesis for marine phytoplankton, microscopic plants responsible for about half of the earth's photosynthesis in oceanic surface waters (Schlesinger, 1997). These microorganisms, which constitute a large fraction of the earth's biomass, regulate the biogeochemical cycling of C, N, and S between the ocean and atmosphere. Thus, alterations in their micronutrient supply, whether natural or anthropogenic, have the potential to directly impact the marine ecosystem, the rates of ocean-atmosphere gas exchange, and the emission of various biogenic gases that can affect global climate.

### 1.1.2. *Pollutants in the Atmosphere*

The lifetime of a gas molecule in the atmosphere can range from 1 s to millions of years, depending on the efficiency of the removal process. A species is considered to be an atmospheric pollutant only when concentrations substantially exceed background levels; such pollutants originate from both natural and man-made sources. For example, the present day concentration of carbon dioxide (CO<sub>2</sub>) is 365 ppmv; this value has slowly increased since the beginning of the industrial revolution as a result of industrial and automobile emissions and deforestation (Hartmann, 1996) (Figure 3).

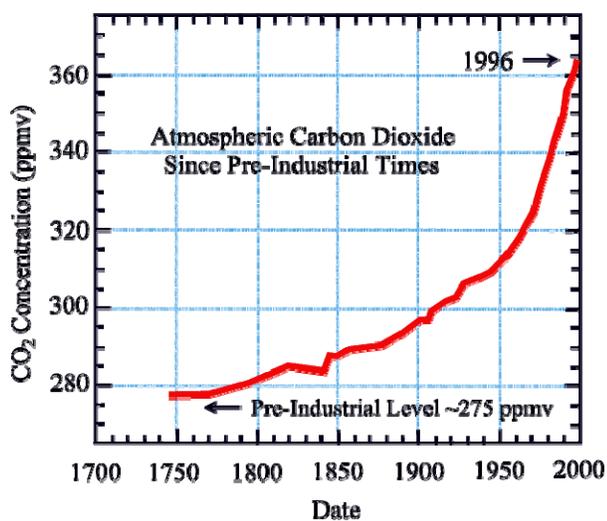


Figure 3. Human influence on the atmosphere in terms of carbon dioxide concentration during the industrial era. Source: Hartmann (2005).

Despite their low concentrations, trace gases (e.g., CO<sub>2</sub>), play a critical role in global climate forcing in such environmental issues as the greenhouse effect, the ozone layer, and smog. Other less obvious atmospheric components that could have a profound effect on global climate are atmospheric aerosols and mineral dusts. For these constituents, the current level of scientific understanding of their indirect effect on global climate is very low (Figure 4) (IPCC, 2004). The present study serves to further elucidate aspects of biogeochemical cycles that play a role in the indirect effect of aerosol particles on global climate.

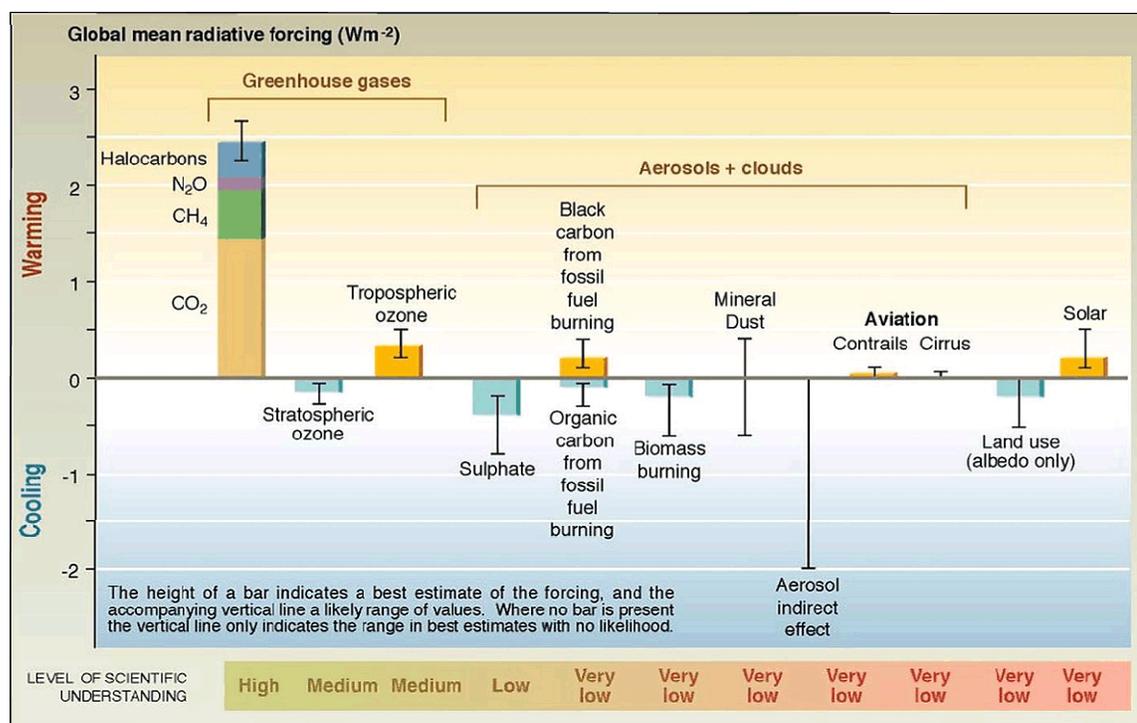


Figure 4. Anthropogenic and natural forcing of the climate for the year 2000.  
Source: IPCC (2004).

## 1.2. Atmospheric Transport and Circulation

Air motions play a key role in determining the distributions of chemical species and particulate matter in the atmosphere. These motions are determined by three principal forces: gravity, pressure-gradients, and the Coriolis force. The vertical mass distribution in the atmosphere is governed by the balance between gravity and the pressure-gradient; disruption of this balance results in *buoyant motions*. In the horizontal direction, the balance between the pressure-gradient and the Coriolis force results in a steady flow of air or *geostrophic flow*. Below 1 km in altitude, horizontal flow is affected by friction with Earth's surface. Since the atmosphere is considerably thinner in the vertical direction, the largest scales of motion occur in the horizontal direction and constitute the basis for general circulation in the atmosphere (Seinfeld and Pandis, 1997).

Large-scale movement of air is driven by horizontal pressure gradients resulting from differential heating of the earth's surface. Vertical pressure gradients also influence air motion and weather conditions. High-pressure regions are characterized by the divergence of air at the surface, resulting in sinking motions. Sinking air is heated by compression, lowering relative humidity, which leads to sunny and dry conditions. In contrast, low pressure regions exhibit convergence near the surface, resulting in an upwelling of air. As air rises, it cools by expansion while relative humidity increases. Thus clouds and rain may result (Figure 5).

In addition, as air moves from high to low pressure on the surface of the rotating Earth, it is deflected by the Coriolis force. An object moving in the horizontal direction would be deflected toward the equator as a result of the Coriolis force (Figure 6).

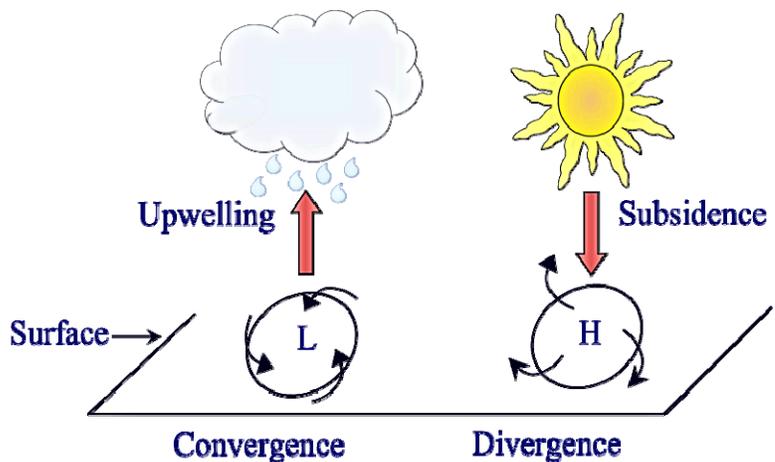


Figure 5. Weather associated with highs and lows. Source: Jacob (1999, p 49).

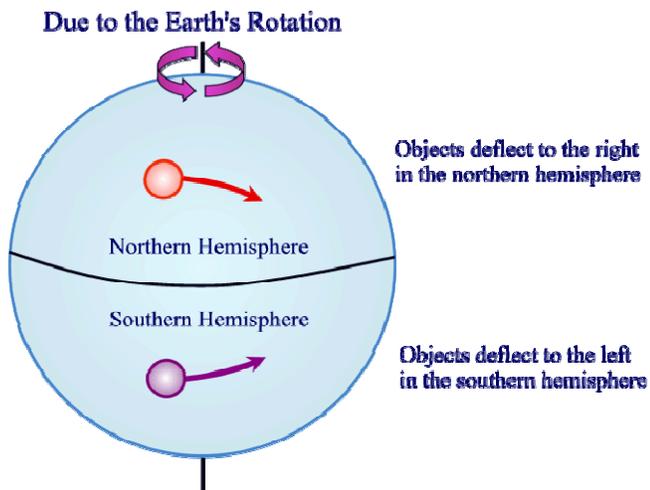


Figure 6. Effect of the Coriolis force on an object in horizontal motion. Source: Jacob (1999, p 44).

To predict the general pattern of macroscale air circulation on the earth, thermal circulation and the Coriolis force must be considered. As warm tropical air rises near the equator, cool northern air descends and flows toward the equator. This type of air flow forms thermal circulation cells, or Hadley cells, that lie on either side of the equator. The Coriolis force acting on these cells leads to easterly winds, called the trade winds, along the equator or the intertropical convergence zone. Likewise, Ferrell circulation cells lead to the westerlies, near each of the poles (Figure 7).

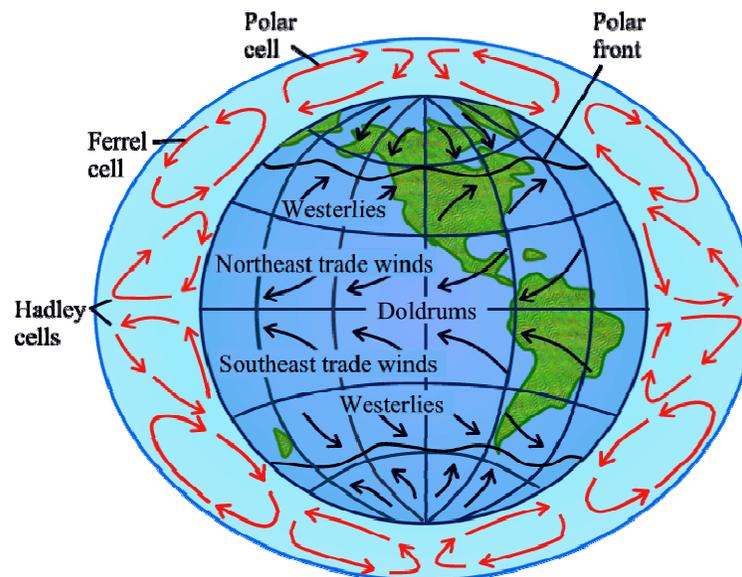


Figure 7. Schematic representation of the general circulation of the atmosphere. Source: Berner and Berner (1987, p 28).

On a smaller scale, small circulation cells found in the atmosphere play a role in the high elevation (~3 km) transport of dust across oceans. Of particular interest to this study is the biogeochemical feedback of atmospheric-derived crustal Fe that reaches the open oceans in this manner. This atmospheric dust plays a crucial and complex role in current climate models, making conclusive climate change prediction difficult (Hand et al., 2004; Mahowald and Kiehl, 2003).

## CHAPTER 2

### INTRODUCTION

#### 2.1. Summary and Purpose

Over the past century, human activities have been changing not only the composition of the earth's atmosphere, but also the rates of exchange between atmospheric C, N, and S species. Industrial and automobile emissions, increased agricultural activities, and deforestation have altered the earth's atmosphere by increasing the concentration of pollutants (i.e., smoke and greenhouse gases) and crustal aerosol particles (Mahowald and Luo, 2003; Tegen et al., 2004). Airborne mineral dust contributes significantly to particulate loading and optical thickness in the atmosphere, and thus, plays an important role in global climate (IPCC, 2004). These tiny airborne dust particles, originating from both natural and anthropogenic sources, can remain suspended in the atmosphere for weeks and travel thousands of miles, undergoing chemical and physical alterations through photochemical and weathering processes, before settling out on land or in the oceans through dry and wet deposition.

While in the atmosphere, aerosols also participate in numerous biogeochemical feedback cycles, many of which play a part in regulating global climate. The focus of the present study is on the investigation of one such feedback cycle which potentially ties the production of biogenic S gases to the bioavailability of crustal derived Fe in the atmosphere (Charlson et al., 1987; Johansen et al., 2000; Zhuang et al., 1992). Dust particles deposited in the oceans provide phytoplankton micronutrients, such as Fe (Coale et al., 1998; Cooper et al., 1996; Martin et al., 1994; Turner et al., 1996). Fe fertilization

studies have shown that the availability of Fe to remote oceanic regions leads to an increase in marine phytoplankton primary productivity, CO<sub>2</sub> uptake, and emissions of various biogenic gases (e.g., S species) that can affect global temperature (Boyd et al., 2000; Coale et al., 1996).

Presently, little is known about the potential link between Fe and reduced biogenic S species and the effect of increased anthropogenic dust aerosols on global climate. A recent attempt to model Fe speciation in the marine atmosphere has revealed no clear dependence on cloud or photochemical processing (Hand et al., 2004). This study did not take into consideration feedback or reactions from marine-derived constituents that may further modify Fe speciation in these dust particles.

This discrepancy between modeling efforts and observed atmospheric Fe concentrations exemplifies the need for more studies of the chemical interactions between Fe and other components in the marine atmosphere (i.e., S species) that may govern Fe speciation on the surface of marine aerosols, and hence, its bioavailability after deposition in the ocean surface. To further investigate this link, a two-pronged approach is presently being pursued by collecting field measurements on the one hand and by running laboratory simulation experiments on the other. The latter is the subject of this thesis. The laboratory experiments consist of performing photochemical batch experiments mimicking the Fe-S chemistry that occurs on the surface of marine aerosols.

## 2.2. Biogeochemical Link between Atmospheric Iron and Sulfur

### 2.2.1. *Dust as a Source of Iron*

Dust source regions are mainly deserts, dry lake beds, and semi-arid desert fringes, where fine particles are eroded by winds. Depending on surface conditions and the force of winds, large scale dust plumes can potentially be generated and travel thousands of miles. Most of these arid regions are found in the mid-latitudes of the northern hemisphere. Other sources include areas in drier regions where vegetation has been reduced or soil surfaces have been disturbed by human activities. It has been estimated that up to 50% of the current atmospheric dust load originates from anthropogenically disturbed soil surfaces, with < 10% of the global dust load attributed to disturbances from agricultural areas (Tegen et al., 2004).

Estimates of the amount of dust deposited in the oceans worldwide range from 1 to 5 billion tons per year, with very high spatial and temporal variability (Duce, 1995, p 43). The large desert areas of North Africa and the Arabian Peninsula significantly contribute to dust inputs to the oceans both because of their scale and also because they are located close to, and upwind of, the North Atlantic Ocean. Dust storms often occur in the Sahara Desert and are swept out toward the Atlantic Ocean by the easterlies, the strong winds blowing east to west between 20° and 30° latitude (Jacob, 1999, p 51). Considerable evidence demonstrates that Saharan dust reaches such regions as the Caribbean (Prospero et al., 1970; Talbot et al., 1990) and western North Atlantic Ocean (Duce et al., 1975). It has been estimated that the Sahara Desert produces  $300 \times 10^{12} \text{ g y}^{-1}$ , an amount equivalent to 20% of global dust production (Turner and Hunter, 2001).

Likewise, in the eastern hemisphere during the spring months (i.e., March, April, May), strong prevailing winds sweep across the Gobi Desert, located on the border between Mongolia and northern China, toward the Pacific Ocean. Since the 1950s, the frequency of these dust storms have increased as a result of deforestation, cultivation, grazing and overuse of the land in general, which has accelerated desertation (Zhao, 2000). In April of 2001, one of the largest dust storms observed, referred to as the “Perfect Dust Storm,” was tracked by the sea-viewing wide field-of-view satellite sensor (SeaWiFS) and the total ozone mapping spectrometer (TOMS). SeaWiFS provides quantitative data on global ocean bio-optical properties while TOMS is capable of measuring the aerosol optical index. The storm began on April 4, 2001 and eventually settled out on the east coast of the United States by April 16, 2001 (Figure 8).

During these episodic storms, dust aerosols can be swept as high as 3 to 5 km in the troposphere. The lifetime of atmospheric dust is typically ~10 days, depending on size (Tegen et al., 1996). Large particles are rapidly lost by gravitational settling near the source, while smaller particles (< 10  $\mu\text{m}$  in diameter) can remain suspended in the atmosphere for weeks, traveling thousands of miles, until particle dissipation occurs from deposition and/or precipitation scavenging (Gao et al., 2003). Studies reveal that the chemical composition of dust aerosols over the Pacific is similar to the composition of sea floor sediments found in the Pacific and that dust from the Loess Plateau region, including the Gobi and Takla Makan deserts, is the main source of these sediments (Blank et al., 1985). The estimated amount of dust aerosols from China transported to the central North Pacific is 6 to  $12 \times 10^6$  tons  $\text{y}^{-1}$  (Zhuang et al., 2002).

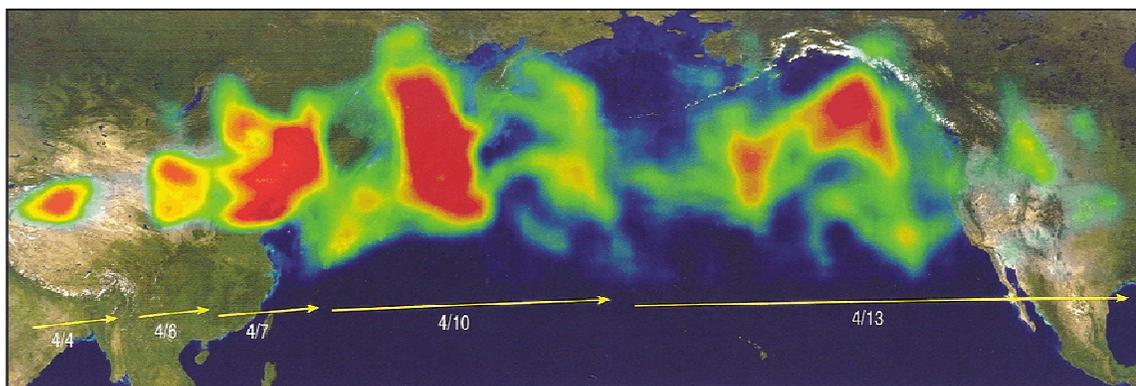


Figure 8. SeaWiFS satellite image (superimposed with the dust aerosol index measured by TOMS) of the “Perfect Dust Storm” event of April 2001. The areas in red represent the highest optical density and, therefore, the highest concentration of dust aerosols. Source: Earth Observatory (2004).

Dust aerosols consist of a wide array of minerals, sea salt, elements, anions, and cations. One study of the chemical composition of North Atlantic dust aerosols found an average mineral dust concentration of  $19.3 \pm 16.4 \mu\text{g m}^{-3}$  (Johansen et al., 2000). In the same study, total Fe derived from mineral dust accounted for  $0.84 \pm 0.61 \mu\text{g m}^{-3}$  and was distributed evenly between the coarse and fine fractions. Fe(II) accounted for  $0.51 \pm 0.56\%$  of total Fe, with 86% of the Fe(II) found in the fine fraction. These are typical values for Fe(II) seen over other parts of the oceans (Johansen and Hoffmann, 2003; Siefert et al., 1999). However, a recent study by Chen and Siefert (2004) over the Atlantic Ocean, revealed Fe(II) percentages much larger than typically observed. The highest percent of labile Fe (readily undergoes chemical, physical, or biological change) to total Fe was observed in the winter (mean value 32%) while the lowest was observed in the summer (5%). Once these aerosols are deposited into the oceans, soluble Fe becomes available for marine phytoplankton.

### 2.2.2. *Impact on Marine Phytoplankton*

Phytoplankton are typically observed in large blooms near nutrient-rich coastlines abundant with Fe, where organic matter and sediment are churned up by tides or washed to sea by rivers. Remote ocean environments, though, are generally recognized as Fe-limited regions of low primary productivity (Turner and Hunter, 2001). The subarctic Pacific, the equatorial Pacific, and the Southern Ocean are regions recognized for their year-round abundance of macronutrients (P and  $\text{NO}_3^-$ ) and remarkably low productivity levels (Martin and Fitzwater, 1988). These regions are referred to as high nutrient low chlorophyll (HNLC) waters, with bioavailable Fe, in particular, limited to levels of 1 nM or less (Martin and Fitzwater, 1988; Turner and Hunter, 2001). It is believed that bioavailable Fe encompasses the soluble fraction of Fe, which is easily accessible to phytoplankton, and includes  $\text{Fe(II)(aq)}$  and the small amounts of  $\text{Fe(III)(aq)}$ .

In Fe-limited regions, phytoplankton have adapted a mechanism for acquiring less soluble or colloidal Fe by releasing siderophores (“iron bearers”). Siderophores are low molecular weight ligands that have a high binding affinity for  $\text{Fe(III)}$ . In general, it is known that the siderophore is released into seawater under conditions of Fe stress, where it chelates and solubilizes Fe present as Fe hydroxide ( $\text{Fe(OH)}_3$ ) or other various bound forms. The Fe-siderophore chelate is transported into the cell by specialized membrane proteins, where the Fe is released for synthesis of Fe-proteins and the free siderophore is exported back into the seawater (Turner and Hunter, 2001). Examples of siderophore binding mechanisms are shown in Figure 9.

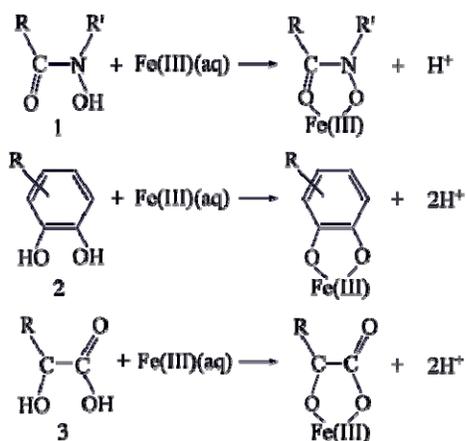


Figure 9. Examples of iron(III) chelation by siderophores containing (1) hydroxamic acid, (2) catechol, and (3)  $\alpha$ -hydroxycarboxylic acid. Source: Albrecht-Gary and Crumbliss (1998).

The chemical structure of the siderophore alterobactin A, produced by the marine bacterium *Alteromonas luteoviolacea*, is shown in Figure 10. The active sites responsible for binding Fe(III) are denoted by arrows. Notice the presence of  $\alpha$ -hydroxycarboxylic acids within the chemical structure. It is the ionized oxygen on the carboxylic acid functional group that is the site of Fe(III) complexation. Phytoplankton can obtain essential Fe through this mechanism as long as they have sufficient energy to produce siderophores (Barbeau et al., 2003).

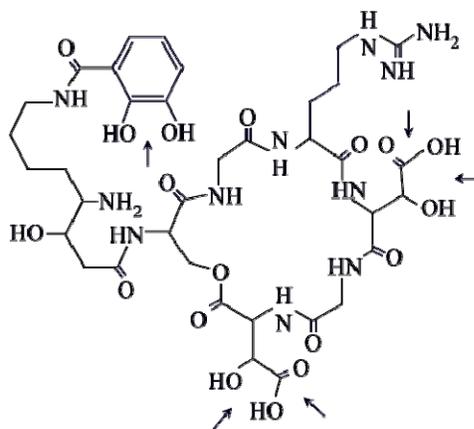


Figure 10. Chemical structure of the siderophore alterobactin A produced by the free-living marine bacterium, *Alteromonas luteoviolacea*. Source: Reid et al. (1993).

Phytoplankton blooms in HNLC waters generally only occur as a result of either upwelling or atmospheric deposition. Upwelling currents originating from the seafloor help to replenish the supply of Fe and other nutrients to the ocean surface. Likewise, Fe is supplied to remote surface regions through atmospheric deposition of long-range transient dust plumes originating from preceding continental dust storms in arid regions. According to estimates from calculations, atmospheric deposition appears to be the primary source of Fe, aside from upwelling, to these remote Fe-limited regions where phytoplankton growth is low (Turner and Hunter, 2001).

After dust events, such as the Perfect Dust Storm, where the concentration of aerosols over the Pacific is more than ten times greater than on other days, marine phytoplankton have an increased supply of Fe from atmospheric deposition. This Fe resides primarily on the surface of dust particles in both soluble and insoluble phases

(Falkovich et al., 2001). The more soluble forms of Fe will be more bioavailable, while precipitated and colloidal forms are less accessible to phytoplankton.

It is not uncommon for satellite remote sensors, such as SeaWiFS, to observe an increase in phytoplankton blooms in remote and even coastal regions where deposition has occurred (Zhuang et al., 2002). Because the color in most of the world's oceans is in the visible light region (400 to 700 nm) and this color varies with the concentration of chlorophyll and other plant pigments, subtle changes in ocean color that signify various types and amounts of marine phytoplankton can potentially be quantified. Figure 11 represents a recent example of a large phytoplankton bloom observed by SeaWiFS near Vancouver Island, British Columbia and the coast of Washington State.

Little is known about the effect of the increased availability of Fe on photosynthetic marine phytoplankton and the indirect role that atmospheric particles play on the global climate. However, it has been shown that an increase in the supply of bioavailable Fe through artificial additions has significantly increased biological activity in marine phytoplankton and therefore photosynthesis (Timmermans et al., 2001; Watson et al., 2000). More than a dozen in situ Fe fertilization studies in HNLC regions have resulted in phytoplankton blooms, reporting increases in *chlorophyll a* concentrations, nutrient and C uptake, and the release of dimethyl sulfide (DMS,  $\text{CH}_3\text{SCH}_3$ ) (Buesseler et al., 2004; Coale et al., 2004; Cooper et al., 1996; Turner et al., 2004).

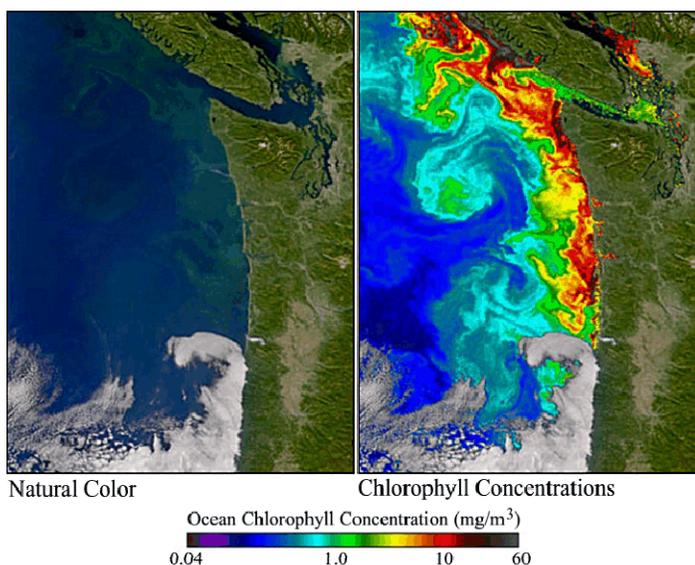


Figure 11. SeaWiFS image of a phytoplankton bloom observed October 1, 2004, near Vancouver Island, British Columbia and Washington. Source: Earth Observatory (2004).

The fixation of the greenhouse gas  $\text{CO}_2$  during photosynthesis, in addition to emissions of DMS (a biogenic byproduct of photosynthesis), counteracts global warming. Since it is estimated that the oceans serve as a sink for 33% of the anthropogenic  $\text{CO}_2$  emissions, this ocean-atmosphere gas exchange is clearly a fundamental regulator of global climate (Schlesinger, 1997). The effects of the escalating anthropogenic perturbation (i.e., increase in atmospheric dusts/aerosols) on the Fe-S biogeochemical cycle, in conjunction with concurrent increases in  $\text{CO}_2$  uptake, could significantly impact global climate.

### 2.2.3. Proposed Iron-Sulfur Feedback Cycle

Aside from global cooling caused by an increase in sulfate ( $\text{SO}_4^{2-}$ ) aerosols, biogenic S gases, such as DMS, also play a significant role in biogeochemical cycles that indirectly affect global climate (Andreae et al., 1995; Charlson et al., 1987). A recent

study of the chemical and mineralogical characteristics of dust aerosols indicates that S and, to a lesser extent, Fe tend to reside on the particles' surface, thus S may be involved in governing the speciation of Fe (Falkovich et al., 2001). Fe speciation in the marine atmosphere, therefore, may be affected by the presence of DMS and its oxidation products. A potential mechanism for this feedback cycle has been proposed through the DMS mediated aerosol acidification which stabilizes Fe(II) (Zhuang et al., 1992). The Fe(II) deposited into the ocean, due to its larger solubility compared to Fe(III), is thought to be more bioavailable and could lead to more DMS released, which provides more sulfur dioxide ( $\text{SO}_2$ ) and acidic  $\text{SO}_4^{2-}$  aerosol and, again, more dissolved Fe(II), thus closing the feedback cycle.

Presently in this study, other more prevalent mechanisms that increase bioavailable Fe and involve DMS and Fe are being investigated. Data from samples collected over the Atlantic reveal a weak linear relationship between Fe(II) present in the fine fraction ( $< 3 \mu\text{m}$ ) and methane sulfonic acid (MSA,  $\text{CH}_3\text{SO}_3\text{H}$ ), another oxidation product of DMS (Figure 12) (Johansen et al., 2000). Based on this evidence and the fact that eight electrons are available for transfer in the sequence from DMS to  $\text{SO}_4^{2-}$ , we propose that DMS oxidation intermediates (i.e., dimethyl sulfoxide (DMSO,  $\text{CH}_3\text{SOCH}_3$ ), and MSA) could interact directly with Fe(III) on the surface of marine aerosols (Figure 13).

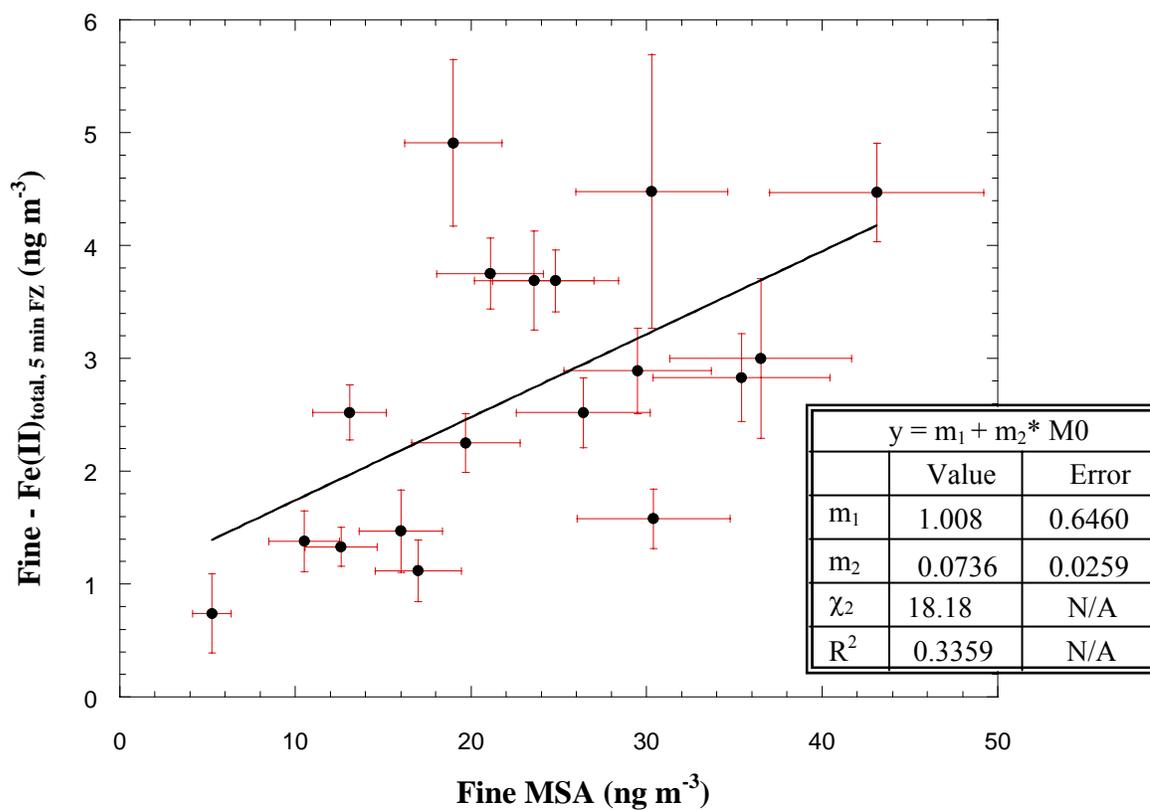


Figure 12. Relationship between iron(II) and methane sulfonic acid in the fine fraction of aerosols collected over the Atlantic. Source: Johansen et al. (2000).



## 2.3. Relevant Iron and Sulfur Chemistry

### 2.3.1. General Iron Chemistry

Fe is the fourth most abundant element in the earth's crust and it exists in two oxidation states, Fe(II) and Fe(III), which are also referred to as ferrous and ferric Fe, respectively. Fe(II)(aq) is more soluble, while Fe(III)(aq) is less soluble and will easily precipitate out of solution to form colloidal Fe(OH)<sub>3</sub>. The oxidation state of Fe is governed by parameters such as the environment (i.e., aerobic versus anaerobic), pH, or redox reactions.

In oxygenated environments, Fe is primarily found in its most oxidized form, Fe(III), as solid Fe oxides or Fe oxyhydroxides. Various compositions and crystal structures of these Fe oxides and oxyhydroxides represent some of the diverse minerals found in the earth's crust, and therefore, marine aerosols. The major Fe oxides and oxyhydroxides are listed in Table 3 along with their corresponding solubility products

Table 3. Major Iron Oxides and Oxyhydroxides with Corresponding Solubility Products ( $K_{sp}$ )

Oxyhydroxides			Oxides		
Formula	Mineral	$pK_{sp}$	Formula	Mineral	$pK_{sp}$
$\alpha$ -FeOOH	Goethite	43.3-44.0	Fe <sub>3</sub> HO <sub>8</sub> ·4H <sub>2</sub> O	Ferrihydrite	37.0-39.4
$\beta$ -FeOOH	Akaganeite	not known	$\alpha$ -Fe <sub>2</sub> O <sub>3</sub>	Hematite	42.2-43.3
$\gamma$ -FeOOH	Lepidocrocite	40.6-42.5	$\gamma$ -Fe <sub>2</sub> O <sub>3</sub>	Maghemite	40.5
$\delta'$ -FeOOH	Feroxyhyte	not known	Fe <sub>3</sub> O <sub>4</sub>	Magnetite	not known

Note: Adapted from Schwertmann and Cornell (1991).

( $K_{sp}$ ). The basic structural unit for all Fe oxides is an octahedron in which one Fe atom is surrounded either by six O atoms or by both O and OH atoms. The O and OH ions form

layers, which are closely packed in either a hexagonal or cubic manner. The more stable hexagonal forms are termed  $\alpha$ -phases, while the cubic forms are referred to as the  $\gamma$ -phases (Schwertmann and Cornell, 1991).

Ferrihydrite is presumably the first Fe oxide phase to precipitate out of solution when Fe(III)(aq) is formed (Schwertmann and Cornell, 1991), and, though a formula is given in Table 3, the amorphous structure of ferrihydrite is currently not completely understood, thus a chemical formula for ferrihydrite has not been fully established. In this thesis, the formula *am*-FeOOH is used to denote ferrihydrite. In addition, a range of *am*-FeOOH compounds with different degrees of structural order exist; these compounds are often named according to the number of broad X-ray peaks observed from X-ray diffraction (XRD) analysis (i.e., 2-line *am*-FeOOH and 6-line *am*-FeOOH). Six-line *am*-FeOOH is relatively crystalline, while 2-line *am*-FeOOH, a common precipitate found along mid-ocean ridges, is almost X-ray amorphous (Kennedy et al., 2003).

The pH also dictates the speciation of Fe. Figure 14 shows the stability fields of species in the Fe-O-H<sub>2</sub>O system for different electron activity ( $pe = -\log a_{e^-}$ ) and pH conditions. Higher  $pe$  values indicate lower electron activity and higher tendency for oxidation. At higher pH, the Fe(III)-hydroxides complexes dominate, while at lower pH and lower  $pe$ , Fe exists in the more soluble Fe(II) oxidation state. Thus, solutions with lower pH aid in stabilizing Fe(II)(aq). However, in the presence of O<sub>2</sub>, which leads to higher  $pe$  levels, hydrolyzed forms of Fe(III) will be present, even at very low pH.

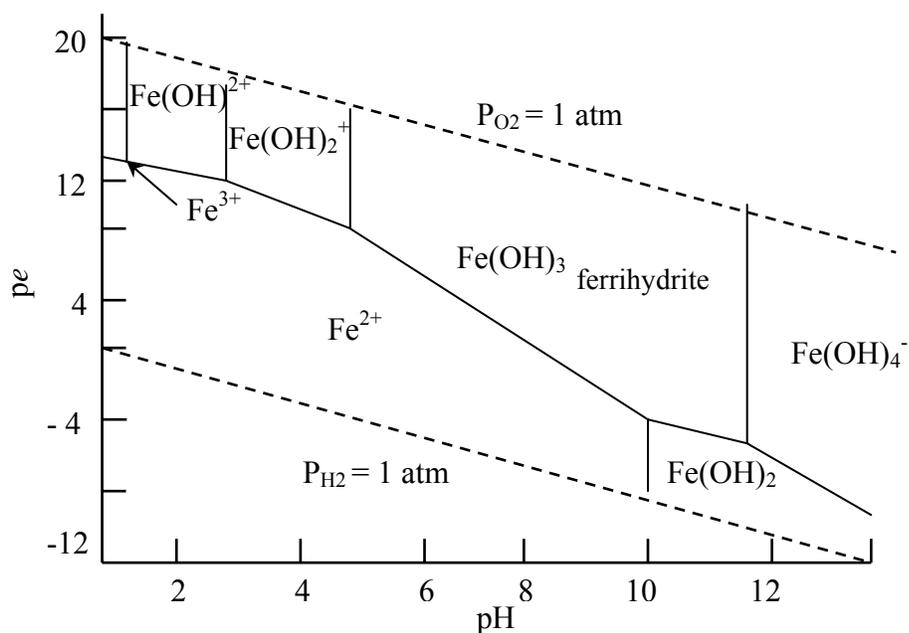


Figure 14.  $pe$ - $pH$  diagram with ferrihydrite. Solid-solution boundaries are drawn for a dissolved iron species activity of  $10^{-6}$  at 1 atm and 25 °C. Source: Drever (1997, p 144).

Figure 15 is a template for  $pe$ - $pH$  diagrams, which contains the  $H_2O$  stability boundaries and approximate  $pe$ - $pH$  regions for a variety of environments. According to Figures 14 and 15, all Fe in equilibrium with the atmosphere should be present as Fe(III) and, from  $K_{sp}$  values (Table 3), only minute amounts are dissolved as Fe(III).

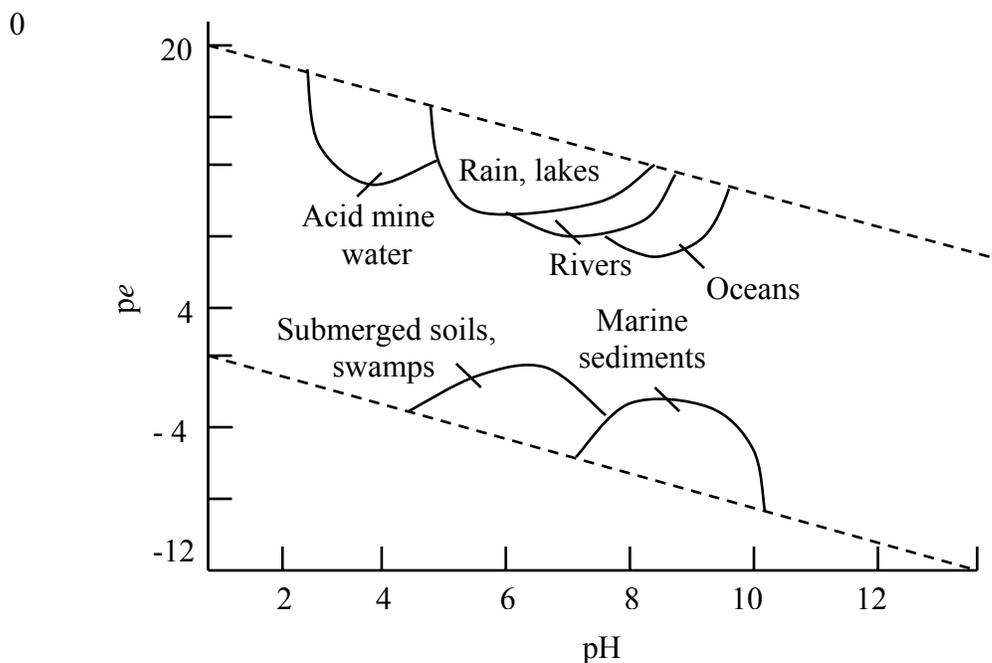


Figure 15. Template for use with  $pe$ -pH plots. Indicated areas show typical  $pe$  and pH values for commonly encountered aqueous, soil, and sediment environments. Source: vanLoon and Duffy (2000, p 218).

However, under certain circumstances, Fe(II) can be stabilized and Fe(III) concentrations can exceed what is expected. For example, through complexation with a ligand (e.g., siderophores), Fe(II) can be stabilized and Fe(III) can be solubilized. A ligand is defined as the anions or molecules that form a coordination complex with a metal cation (e.g., Fe(II) or Fe(III)). By definition, a ligand must contain at least one ligand atom with a lone pair of electrons that are attracted to the metal cation. If more than one ligand atom is present which can occupy more than one coordination position, it is referred to as a multidentate ligand. Chelation is the complex formation with multidentate ligands. Fe(III) and Fe(II) can in this way be solubilized beyond what their  $K_{sp}$  indicate (Table 3).

### 2.3.2. Iron Chemistry in the Atmosphere

Fe(III) is thermodynamically the most stable form of Fe in aerobic environments, including atmospheric aerosols (Figure 14). In spite of its high tendency for oxidation, Fe(II) is present at concentrations larger than those expected from thermodynamic equilibrium calculations in the atmosphere (e.g., Fe(II)(aq) and Fe(III)(aq) concentrations range from  $10^{-7}$  M to  $10^{-4}$  M in rain and cloud water (Zuo and Hoigné, 1992)). Known mechanisms responsible for Fe(II) production and stabilization are mainly driven by photochemistry and include: 1) direct photolysis of  $\text{Fe}(\text{OH})^{2+}$  (Faust and Zepp, 1993; King et al., 1993), 2) photoreduction in the presence of organic acids (Pehkonen et al., 1993; Zuo, 1995), 3) catalytic oxidation of  $\text{SO}_2$  and sulfur trioxide ( $\text{SO}_3$ ) to  $\text{SO}_4^{2-}$  and the resulting Fe(II) stability from the lowered pH (Conklin and Hoffmann, 1988; Zhuang et al., 1992), 4) Fenton chemistry (Stumm and Morgan, 1996), and 5) redox cycling with other trace metals (e.g., Cu(II)/Cu(I) with Fe) (Moffett and Zika, 1983; Sedlak and Hoigné, 1993).

In the presence of light, Fe(III) on the surface of marine aerosols photochemically reduces to Fe(II) in an irreversible dissolution reaction (King et al., 1993). In acidic atmospheric water, where the pH ranges from 2 to 5,  $\text{Fe}(\text{OH})^{2+}$  is the dominant hydrolyzed form of Fe(III) when organic ligands are absent (Figure 16).  $\text{Fe}(\text{OH})^{2+}$  is a photochemically reactive species within the charge transfer band of 290 to 400 nm (maximum absorption at 295 nm) that produces hydroxyl radical ( $\text{HO}^\bullet$ ) (Faust and Hoigné). This direct photoreduction of Fe(III) is postulated to be a significant source of  $\text{HO}^\bullet$  through Reaction 1 (Faust and Zepp, 1993; King et al., 1993).

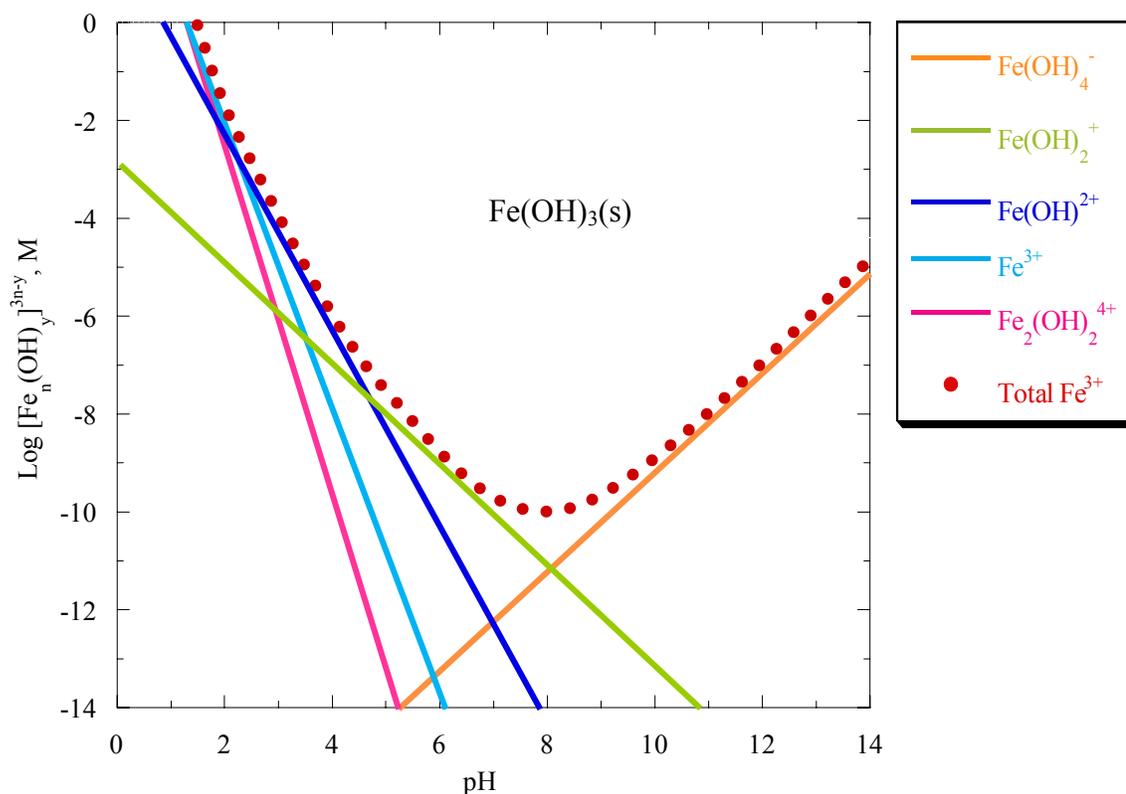
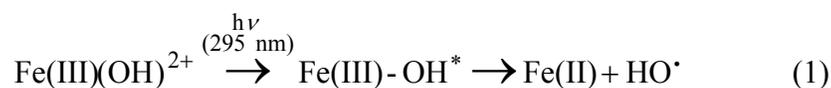


Figure 16. Iron solubility in solution as a function of pH. Adapted from Stumm and Morgan (1996) using MINEQL+ software.

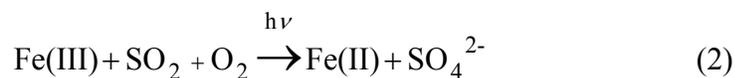


It is important to note that the rate of photoreductive dissolution of Fe(III)-oxyhydroxides is strongly pH dependent, decreasing rapidly with increasing pH. This trend is observed because only the predominant soluble form of Fe(III) present under acidic conditions (i.e.,  $\text{Fe(OH)}^{2+}$ ) reacts in the presence of light to produce Fe(II).

In the presence of organic ligands, photochemical reduction of surface Fe occurs either by a ligand-to-metal charge transfer (LMCT) of the surface complex, or by an O-to-Fe charge transfer transition of the Fe(III) hydroxide (Emmenegger et al., 2001;

Sulzberger et al., 1990). Studies have shown that the photo redox chemistry of ferric oxides and oxyhydroxides in the presence of electron donors, such as organic acids (i.e., oxalic acid (C<sub>2</sub>H<sub>2</sub>O<sub>4</sub>)), results in the production of Fe(II) and HO<sup>•</sup> (Pehkonen et al., 1993; Siefert et al., 1994; Zuo, 1995). This LMCT reaction, in particular, plays an important role in Fe reduction, not only in atmospheric water droplets, but also in surface waters. LMCT reactions have been seen in particular between Fe and oxalate (C<sub>2</sub>O<sub>4</sub><sup>2-</sup>), a final product that accumulates from the oxidation of organic pollutants, present in cloud and fog water (Johansen et al., 1999, 2000; Zuo and Hoigné, 1992). The coordination complex between Fe(III) and C<sub>2</sub>O<sub>4</sub><sup>2-</sup> exhibits strong charge transfer absorptions in the UV and/or visible regions of the spectrum, which result in LMCT (Miessler and Tarr, 1999) in which light absorption promotes an electron from an occupied orbital of the ligand to an unoccupied orbital of the metal ion. The presence of the ligand shifts the spectrum of light absorption to longer wavelengths, thus lowering the energy necessary for the reduction reaction. Fe(II), CO<sub>2</sub>, and hydrogen peroxide (H<sub>2</sub>O<sub>2</sub>) are produced in this reaction (Figure 17) (Stumm and Morgan, 1996; Zuo and Hoigné, 1992). Similar Fe(III) photochemistry is observed for other carboxylic acids and α-hydroxycarboxylic acid groups of siderophores (Barbeau et al., 2003) (see Chapter 2.2.2.).

Furthermore, Fe(II) can be produced through the Fe(III) mediated oxidation of SO<sub>2</sub> and SO<sub>3</sub> to SO<sub>4</sub><sup>2-</sup> at the gas-liquid phase boundary on the surface of aerosols (Faust and Hoffmann, 1986; Zhuang et al., 1992). Fe(III) is known to catalyze the oxidation of S(IV) by oxygen, which is shown in Reaction 2 (Conklin and Hoffmann, 1988).



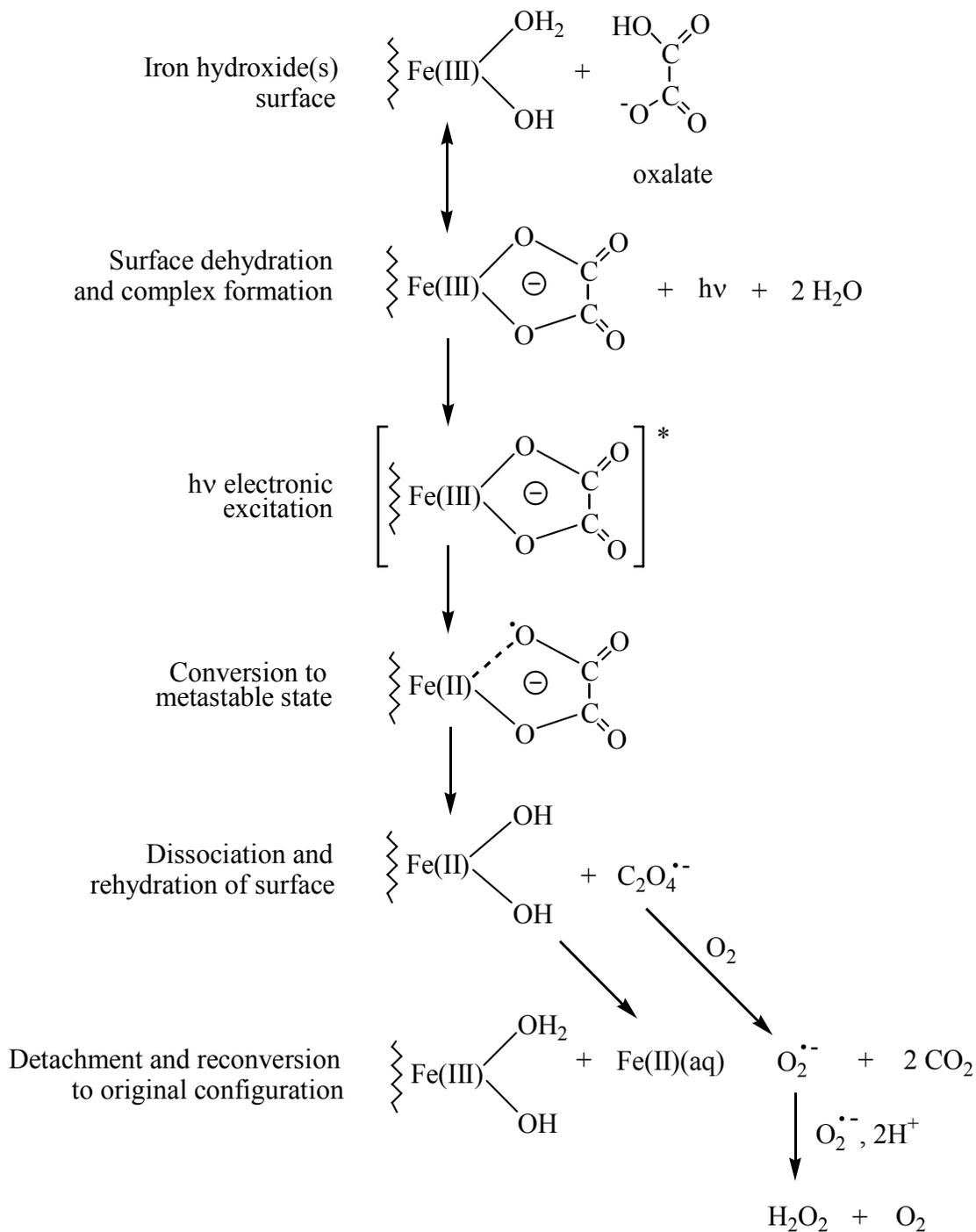


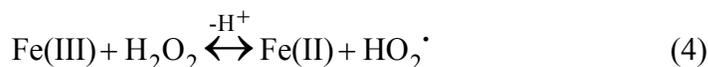
Figure 17. Schematic representation of the steps involved in the light-induced reductive dissolution of an iron oxide in the presence of oxalic acid. Source: Stumm and Morgan (1996).

Acidification, due to the formation of  $\text{SO}_4^{2-}$  and associated protons, may further promote dissolution of Fe(III) while increasing the stability or lifetime of Fe(II) (Zhuang et al., 1992). Thus, Fe(III) provided by aeolian dust is thought to be photo-reduced to yield Fe(II) and  $\text{HO}^\bullet$  in the droplet phase, and this process may be mediated by S(IV).

Fe may also be involved in cyclical oxidation-reduction reactions with other photochemically produced reactive species, such as  $\text{H}_2\text{O}_2$  and hydroperoxyl radical ( $\text{HO}_2^\bullet$ ) on the surface of marine aerosols. The potential interaction between  $\text{H}_2\text{O}_2$  and Fe(II)(aq) on the surface of marine aerosols in the atmosphere produces  $\text{HO}^\bullet$  stoichiometrically in Reaction 3, also known as the Fenton reaction:



Fe(III)(aq) produced from the reaction can then catalyze the decomposition of  $\text{H}_2\text{O}_2$  to  $\text{O}_2$  (Reactions 4 and 5), which leads to a steady-state concentration of Fe(II) as  $\text{HO}^\bullet$  is generated (Stumm and Morgan, 1996).

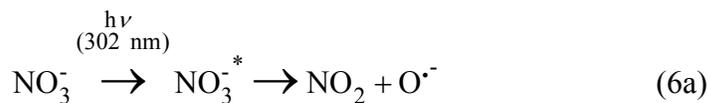


The Fenton reaction (Reaction 3) requires reduced Fe(II)(aq) to initiate the homolytic cleavage of  $\text{H}_2\text{O}_2$  to produce  $\text{OH}^-$  and  $\text{HO}^\bullet$ . This reduced Fe is available as long as  $\text{HO}_2^\bullet$  or superoxide radical ( $\text{O}_2^{\bullet-}$ ) are present to reduce oxidized Fe(III) generated from Reaction 3. Fenton chemistry allows Fe to act as a catalyst in these reactions, as it is continually recycled through oxidation by  $\text{H}_2\text{O}_2$  (Reaction 3) and reduction by  $\text{HO}_2^\bullet$  (Reaction 5) or  $\text{O}_2^{\bullet-}$ .

It is also well known that Fe(II) can be produced through rapid redox cycling with trace metals, such as Cu(II)/Cu(I), that are present in aerosol particles (Moffett and Zika, 1987; Sedlak and Hoigné, 1993). All of these reactions lead to an increase in the bioavailability of Fe and are believed to occur to different degrees on marine aerosols.

Fe(II) produced by the mechanisms described above is continuously oxidized by an abundance of photo oxidants in the atmosphere. Important photo oxidants formed in the atmosphere include  $\text{HO}_2^\bullet$ ,  $\text{HO}^\bullet$ , and  $\text{O}_3$ , which are present in atmospheric water droplets (i.e., clouds, fog, dew, etc.) and in surface waters. Many of these photochemically produced reactive species are listed in Table 4 with Henry's Law Constants ( $K_H$ ) and possible production processes (Stumm and Morgan, 1996).

In the troposphere, gaseous  $\text{HO}^\bullet$  is the dominant photooxidant (Stumm and Morgan, 1996).  $\text{HO}^\bullet$  is produced predominantly from photolyzed  $\text{O}_3$ , followed by  $\text{O}^\bullet$  reacting with  $\text{H}_2\text{O}$ . It is also produced from the photolysis of  $\text{NO}_3^-$  (maximum absorption at 302 nm) and  $\text{H}_2\text{O}_2$  (maximum absorption at  $\sim 250$  nm) (Arsene et al., 1999; Bertelli and Selli, 2004; Turnipseed et al., 1993), shown in Reactions 6a and 6b and 7, respectively.



Reactive atmospheric  $\text{HO}^\bullet$  can also potentially be generated on the surface of marine aerosols through Fenton chemistry as described above.

Table 4. Photochemically Produced Reactive Species in Natural Waters

Products	$K_H$ (M atm <sup>-1</sup> )	Possible Production Processes
Singlet oxygen	$^1O_2$ 1.3×10 <sup>-3</sup> <sup>a</sup>	Sensitized by light-absorbing dissolved organic matter
Superoxide radical	$O_2^{\bullet-}$	Photolysis of Fe(III) complexes; deprotonation of $HO_2^{\bullet}$
Hydroperoxyl radical	$HO_2^{\bullet}$ 4.0×10 <sup>3</sup> <sup>b</sup>	Uptake from atmosphere; protonation of $O_2^{\bullet-}$
Hydrogen peroxide	$H_2O_2$ 8.3×10 <sup>4</sup> <sup>c</sup>	Photolysis of Fe(III) complexes; disproportionation of superoxide anion; exchange with atmosphere
Ozone	$O_3$ 1.1×10 <sup>-2</sup> <sup>d</sup>	Formed in the atmosphere; uptake from atmosphere
Hydroxyl radical	$HO^{\bullet}$ 3.0×10 <sup>1</sup> <sup>b</sup>	Photolysis of hydroxo/Fe(III) complexes; of $NO_3^-$ , $NO_2^-$ ; decomposition of $O_3$ , photolysis of $H_2O_2$
Nitrate radical	$NO_3^{\bullet-}$ 1.8 <sup>e</sup>	Derived from $O_3$

Note: Adapted from Stumm and Morgan (1996).

<sup>a</sup>Lide and Frederikse (1995).

<sup>b</sup>Hanson et al. (1992).

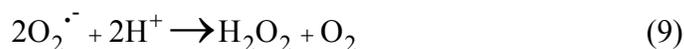
<sup>c</sup>O'Sullivan et al. (1996).

<sup>d</sup>Kosak-Channing and Helz (1983).

<sup>e</sup>Thomas et al. (1998).

The LMCT reaction of the Fe(III)- $C_2O_4^{2-}$  complex also produces  $H_2O_2$ , another important photo oxidant in the atmosphere, through subsequent reactions (Reactions 8 and 9). In the presence of  $O_2$ , the oxalate radical anion ( $C_2O_4^{\bullet-}$ ), a byproduct of the LMCT reaction, will react with  $O_2$  to produce  $CO_2$  and  $O_2^{\bullet-}$ , which reacts with  $H^+$  to form  $H_2O_2$ .  $H_2O_2$  formed by these reactions can oxidize  $SO_2$  to  $SO_4^{2-}$  in the aqueous atmosphere, increasing acidity and producing  $SO_4^{2-}$  aerosols that can affect global climate

as previously described (Stumm and Morgan, 1996).  $\text{H}_2\text{O}_2$  can also be formed from the recombination of  $\text{HO}^\bullet$  (Reaction 10).



Marine aerosols are a complex mixture of sea-salt, anthropogenic and biogenic compounds, and many of the Fe-based minerals listed in Table 3. Their surface is of aqueous nature as a result of the high relative humidity (~80%) found over the ocean (von Glasow and Sander, 2001). An example of a mineral that is predominantly formed from the precipitation of dissolved Fe(III)(aq) on the surface marine aerosols is ferrihydrite (*am*-FeOOH) (Table 3) (Drever, 1997, p 141; Schwertmann and Cornell, 1991). *am*-FeOOH is a poorly crystalline Fe oxide with a very small particle size that forms in low-temperature surface environments such as water wells, lake-bottom sediments, and hot- and cold-spring deposits (Janney et al., 2000). *am*-FeOOH is also observed where crystallization inhibitors, such as organics, phosphates, and silicates, some of which are also in the atmosphere, are present. Inhibitors stabilize *am*-FeOOH and retard its transformation to more stable minerals, such as goethite and lepidocrocite (Schwertmann and Cornell, 1991).

Weathering processes and chemical reactions in the atmosphere aid in breaking down the parent material of these aerosol particles as they travel. In fact, the process of low pH cloud cycling, producing acidic hygroscopic aerosols, seems to be a crucial

process by which the lability of crustally derived Fe is believed to increase in the atmosphere over that observed in parent material (Turner et al., 1996). Thus, longer-traveled aerosols, that have undergone further cloud processing, are expected to supply a higher amount of bioavailable Fe to surface waters after deposition. However, no clear correlation has been shown between aerosol interactions and Fe solubility in modeling studies of Fe solubility in marine aerosols (Hand et al., 2004).

### 2.3.3. *Iron Chemistry in the Ocean*

The average pH of the ocean is 8.2 to 8.3 (Miller et al., 1995), while the pH in aerosol particles is in the acidic range, with typical pH ranges of 2 to 5 (von Glasow and Sander, 2001), where Fe(II) is stabilized against oxidation. Once the aerosol particle is deposited into the ocean, oxidation occurs with a Fe(II) half life of 4.5 min (Millero et al., 1991). The newly formed Fe(III) will precipitate out into suspended colloidal particles, which are believed to be more bioavailable than larger oxyhydroxide particles that have larger gravitational settling velocities and are thus removed from the euphotic zone. To acquire less soluble Fe(III), phytoplankton use siderophores. Siderophores that contain  $\alpha$ -hydroxycarboxylate groups have been shown to undergo direct light-induced LMCT reactions, which may be a significant source of Fe(II) in surface waters after atmospheric deposition once the Fe(II) supply has been depleted (Barbeau et al., 2003) (see Chapter 2.2.2.).

It is known that an increase in the supply of bioavailable Fe to Fe-limited marine surface waters increases the rate of photosynthesis (Timmermans et al., 2001; Watson et al., 2000). Therefore, this availability of Fe to remote oceanic regions from atmospheric

deposition initiates CO<sub>2</sub> uptake through atmospheric C fixation by marine phytoplankton (primary productivity) and results in emissions of biogenic gases that can affect global temperature (e.g., N<sub>2</sub>O, CH<sub>4</sub>, and DMS).

#### 2.3.4. *Sulfur Chemistry in the Atmosphere*

DMS, a reduced S species, has gained global recognition for its role in climate forcing. DMS is the largest natural (i.e., biogenic and volcanic) emission of a S gas to the atmosphere globally and has been estimated to account for ~60% of the natural S compounds released. In the atmosphere, DMS is rapidly oxidized by HO<sup>•</sup>, produced from photochemical reactions, to form completely oxidized SO<sub>4</sub><sup>2-</sup> aerosols in a series of steps in which, ultimately, eight electrons are given up (Schlesinger, 1997). Many of the important atmospheric S gases are listed in Table 5 along with the S oxidation state, pK<sub>a</sub>, and Henry's Law constants.

DMS is a product of dimethylsulfoniopropionate (DMSP, (CH<sub>3</sub>)<sub>2</sub>S(CH<sub>2</sub>)<sub>2</sub>COOH) decomposition. DMSP functions as an osmolyte in marine algae and has also been proposed to serve as a grazing deterrent through its cleavage to acrylate (Sunda et al., 2002). DMSP and its breakdown products (i.e., DMS, acrylate, DMSO, and MSIA) readily scavenge HO<sup>•</sup> and other reactive oxygen species, and thus may serve as an antioxidant system. It has been shown that oxidative stressors, solar UV radiation, CO<sub>2</sub> limitation, Fe limitation, high Cu(II), and H<sub>2</sub>O<sub>2</sub> increases cellular DMSP and/or its lysis to DMS (Sunda et al., 2002).

The main interest in DMS has been on its ability to produce cloud condensation nuclei (CCN), and thus affect global climate through increased albedo and decreasing temperatures (Andreae et al., 1995; Charlson et al., 1987; Liss et al., 1997). This increase in CCN can therefore lead to greater cloudiness, depending on the type of cloud formed and the altitude at which formation occurs, and global cooling (Charlson et al., 1987).  $\text{SO}_4^{2-}$  aerosols also play an important role in climate forcing because of properties such as size and scattering efficiency. Thus, DMS gas phase chemistry has been studied extensively (Ravishankara et al., 1997; Sørensen et al., 1996; Turnipseed et al., 1996) and shows a complex set of mechanisms in terms of oxidation reactions (Figure 18) (Davis et al., 1999; Nowak et al., 2001); however, the number of studies in liquid phase are relatively few (Barcellos da Rosa et al., 2000, 2003; Bardouki et al., 2002).

Biogenic  $\text{SO}_4^{2-}$  contributes considerable to the  $\text{SO}_4^{2-}$  pool over remote oceans. In a study from the Indian Ocean during the southwest monsoon, 75% of the non-sea-salt (NSS)  $\text{SO}_4^{2-}$  (~2.4% of the total suspended particulate (TSP) mass) was found to be of biogenic origin, while the remaining 25% was anthropogenic. During the intermonsoon, NSS- $\text{SO}_4^{2-}$  accounted for ~9.2% of TSP with only 21% of biogenic origin, while 65% was anthropogenic, and 14% was gypsum derived (Johansen et al., 1999). In another Atlantic Ocean study, NSS- $\text{SO}_4^{2-}$  concentrations averaged  $1.03 \pm 0.60 \mu\text{g m}^{-3}$ , with 87% found in the fine fraction. From the analysis, ~22% of NSS- $\text{SO}_4^{2-}$  was of biogenic origin and the remainder of anthropogenic. In the coarse fraction, a comparable amount of ~24% of NSS- $\text{SO}_4^{2-}$  was of biogenic origin (Johansen et al., 2000).

## 2.4. Significance

Human activities have the potential to significantly alter Earth's global climate, in both the warming and cooling directions. However, the extent to which these activities

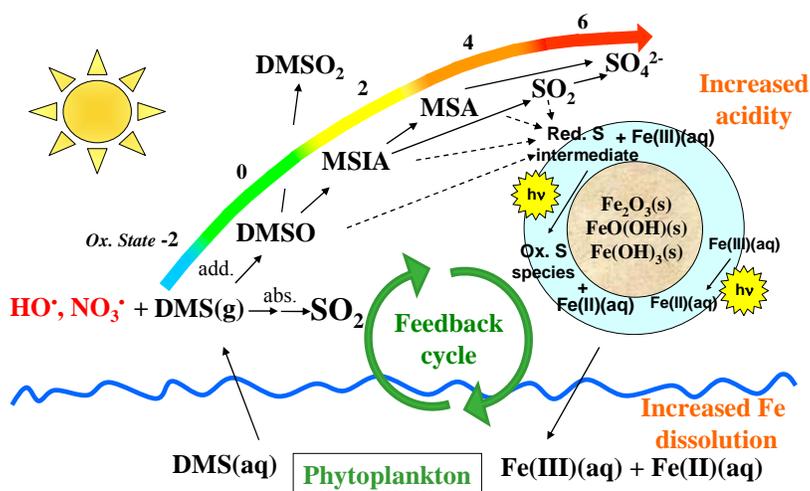


Figure 18. Abbreviated dimethyl sulfide oxidation scheme. DMS = dimethyl sulfide; DMSO = dimethyl sulfoxide; DMSO<sub>2</sub> = dimethyl sulfone; HMSIA = hydroxymethane sulfinic acid; MSIA = methane sulfinic acid; MSA = methane sulfonic acid; HMSA = hydroxymethane sulfonic acid. Adapted from Davis et al. (1999) and Nowak et al. (2001).

affect dust aerosols and thus alter global climate remains unknown. The proposed research will help to shed some light on this subject. The primary objective of this thesis is to characterize the chemical reactions between Fe and S in the atmosphere over remote oceans that may impact the bioavailability of Fe after deposition into ocean water. Many studies have been conducted on Fe in solution phase (Millero et al., 1995; O'Sullivan et al., 1995; Pehkonen et al., 1993; Siefert et al., 1994; Spokes and Liss, 1995; Voelker and Sedlak, 1995); however, this is the first study in which *am*-FeOOH particles have been

exposed to a series of reduced S species to simulate the Fe-S chemistry that can occur in the marine atmosphere.

It is known that the addition of Fe will influence the productivity of marine phytoplankton by increasing photosynthesis (Timmermans et al., 2001; Watson et al., 2000). The proposed research will help elucidate certain mechanisms by which Fe bioavailability is controlled. Identifying Fe speciation in the remote marine atmosphere and its redox chemistry after aerosol deposition is key to understanding the uptake mechanism of Fe by marine phytoplankton (Hudson and Morel, 1993). This information will help constrain biogeochemical models on Fe speciation in the marine atmosphere and consequently determine the changes in primary productivity which affect global climate.

## 2.5. Scope of the Study

The goal of this thesis is to obtain results in the laboratory that compliment data obtained in the field. The conditions in which photochemical reactions may occur between Fe and S species on the surface of marine aerosols can be simulated in the laboratory using a Xe lamp equivalent to ~1 sun in intensity and synthetic *am*-FeOOH in the presence of S compounds in an aqueous solution.

Synthetic *am*-FeOOH was selected as the representative Fe reactant in simulation experiments because it is a precursor for more crystalline Fe oxides, such as goethite ( $\alpha$ -FeOOH) and hematite ( $\alpha$ -Fe<sub>2</sub>O<sub>3</sub>) (Table 3) (Schwertmann and Cornell, 1991). As crustal

particles are weathered in the atmosphere, Fe(III)(aq) released from the crystal lattice and Fe(II)(aq) formed through reductive processes are expected to immediately precipitate out of solution phase as *am*-FeOOH from the oxidation of Fe(II) and the rapid hydrolysis of Fe(III) (Schwertmann and Cornell, 1991). These newly formed *am*-FeOOH particles on the surface of marine aerosols could then interact with atmospheric S species that have crossed the gas-liquid phase boundary (Falkovich et al., 2001). These conditions are simulated in the photochemical experiments.

The reactions in the photochemical experiments are monitored over time by measuring Fe(II) and Fe(III), H<sub>2</sub>O<sub>2</sub>, and S oxidation products at selected time intervals. Fe(II) is quantified using UV-visible (UV-vis) absorbance spectrophotometry by detecting the Fe(II)-ferrozine complex (Fe(II)-(FZ)<sub>3</sub>) at 562 nm. Fe(III) can be measured in the same manner by first reducing it to Fe(II) with the reductant, hydroxylamine hydrochloride (H<sub>2</sub>NOH HCl), and subtracting the previously determined Fe(II) concentration. H<sub>2</sub>O<sub>2</sub> concentration, produced in photochemical reactions involving Fe(III) (Zuo and Hoigné, 1992), is measured directly using a probe that oxidizes H<sub>2</sub>O<sub>2</sub> to O<sub>2</sub>, resulting in an electrical (redox) current reported in pico amps (pA). Acidic S oxidation products are detected by liquid ion chromatography (IC) based on the analytes' affinity for the column.

By comparing concentrations of product formation (i.e., Fe(II), Fe(III), H<sub>2</sub>O<sub>2</sub>, or oxidized S species) and rates between photochemical experiments in the presence of different oxidized S species, mechanisms for Fe dissolution and reduction are studied.

## CHAPTER 3

### EXPERIMENTAL METHODS

#### 3.1. Photochemical Experimental Setup

Photochemical dissolution experiments were performed using synthesized 6-line *am*-FeOOH in the presence of one or a combination of various reduced S species found in the marine atmosphere. All S species used in the experiments are biogenically (i.e., DMS) derived and were chosen due to their potential to dissolve into the aqueous phase and ability to donate electrons. Henry's law constants and S-oxidation states (Table 5) are an indication for these parameters, respectively. Based on these criteria, the following S species were selected to be investigated in these photochemical experiments: DMS, DMSO, DMSO<sub>2</sub>, MSIA, and MSA. Focus was on MSIA and DMSO because atmospheric levels for DMSO are generally greater than other DMS derived compounds and both DMSO and MSIA are more water soluble (Table 5). In addition, during selected experiments, nitrate (NO<sub>3</sub><sup>-</sup>) or H<sub>2</sub>O<sub>2</sub>, were added to serve as a source of HO<sup>•</sup>. In three experiments, C<sub>2</sub>H<sub>2</sub>O<sub>4</sub> was added as a known electron donor.

Initial concentrations of these compounds in the reaction medium were derived from representative published concentrations of ambient levels found over open oceans (Table 6). Reported ambient concentrations for MSIA were not found. Therefore, the concentration for MSIA was estimated to be  $1.3 \times 10^{-10} \text{ M (m}^3\text{air)}^{-1}$  based on the relative concentrations of other atmospheric S species. This concentration is similar to the concentrations observed for DMSO in the marine atmosphere. Note that except for DMS and DMSO, all simulated values are at or slightly below observed concentrations.

The initial concentration of *am*-FeOOH in the simulation experiments was determined by assuming a total atmospheric Fe (Fe(tot)) concentration of 545 ng Fe(tot) (m<sup>3</sup>air)<sup>-1</sup> (Johansen et al., 2000). Assuming 25% of Fe(tot) in the atmosphere is of some Fe oxyhydroxide phase, the amount of *am*-FeOOH added to 100 mL of reaction medium was determined to be 0.25 g (Chen and Siefert, 2003, 2004).

All values were extrapolated to a volume of 1.0 x 10<sup>6</sup> m<sup>3</sup>air, the amount of air that would need to be collected to yield 100 mL of atmospheric liquid water, assuming a 1 x 10<sup>-10</sup> m<sup>3</sup>aq (m<sup>3</sup>air)<sup>-1</sup> liquid water content (LWC) for sea salt aerosol at 0 m (von Glasow and Sander, 2001). To simulate atmospheric water on the surface of marine aerosols, all experiments began with 100 mL of water. All water used in experiments and subsequent preparations had 18 MΩ-cm resistance using a Milli-Q water purification system.

Sunlight was simulated by a 1000 W Xenon (Xe) O<sub>3</sub> free lamp in a fan-cooled housing (Thermo Oriel, Product Number 66921). The regulated power supply (Thermo Oriel, Product Number 66920) maintained a current corresponding to 1000 W. The light was focused by a 2-inch diameter condensing lens inside the lamp housing and passed through a water-cooled circulating IR chamber to remove excess heat. The light was then passed through two sequential air mass filters, which simulate the solar spectrum found outside of the earth's atmosphere (AM 0) and at ground level when the sun is directly overhead (AM 0 + AM 1). The beam turner, attached to the filter holder, directed the simulated sunlight at a 90° angle onto the reactor vessel. Experiments were carried out in a 250-mL water-jacketed Pyrex glass vessel held at constant temperature (20.0 °C) by a recirculating water bath. The initial reaction volume was typically 100 mL with an

irradiated surface area of 20.3 cm<sup>2</sup>. All solutions were vigorously stirred with a Teflon-coated stirrer throughout the experiment (typically 6 hours duration). All equipment (Figure 19) was from Thermo Oriel (Stratford, Connecticut), including air mass filters obtained through Thermo Oriel from Spectra-Physics.

At set time intervals during the experiment, 4.5 mL of solution was withdrawn and filtered through a 0.45 μm pore size polysulfone Acrodisc® syringe filter from PALL Corp. (Ann Arbor, Michigan) to remove solid *am*-FeOOH particles. Samples were usually withdrawn at 0, 2.5, 5, 15, 30, 60, 90, 120, 150, 180, 240, and 360 min, with more samples collected near the beginning of the experiment in an effort to observe the initial rate of the reactions occurring.

The filtered solution was distributed into four separate tubes for analysis of Fe(II) and Fe(III), H<sub>2</sub>O<sub>2</sub>, and S oxidation products. A volume of 1.25 mL of sample solution was used for Fe(II), Fe(III), and H<sub>2</sub>O<sub>2</sub> measurement, while only ~500 μL was necessary for quantifying S oxidation products. Sample solutions were diluted prior to analysis in cases where analyte concentrations exceeded the range of the calibration curves. The original concentration in the reaction medium was calculated by multiplying the concentration of diluted analyte by the dilution factor. For all experiments, the pH of the solution was measured initially, prior to light exposure, and after completion of the experiment. All measurements were collected the same day the experiment was run. Control experiments were run in which one of the three factors (i.e., *am*-FeOOH, *hν*, or selected S species) was removed.

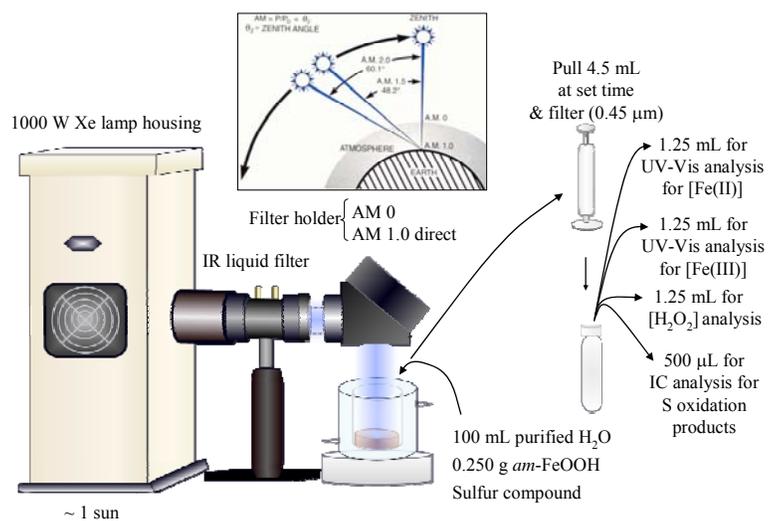


Figure 19. Photochemical simulation experiment setup.

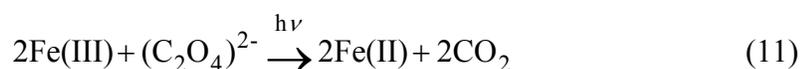
### 3.1.1. *Potassium Ferrioxalate Actinometry*

In order to ensure that natural conditions in the marine atmosphere were simulated, it was necessary to quantify the intensity of the simulated sunlight source irradiating the reaction vessel. This determination was carried out by exposing a chemical actinometer to the light source. Chemical actinometers are photochemical reactions that have been calibrated directly or indirectly with light sources of known light flux and have well-defined reaction quantum yields ( $\phi_\lambda$ ) at specific wavelengths ( $\lambda$ ) (Leifer, 1988). The reaction quantum yield expresses the relationship between the number of molecules undergoing reaction (in moles) and the number of photons absorbed (1 mole of photons = 1 einstein) (Equation 1).

$$\phi_\lambda = \frac{\text{number of moles that photoreact}}{\text{number of einsteins absorbed}} \quad (1)$$

The potassium ferrioxalate actinometer is a solution-phase actinometer that is most useful in the range of 254 to 500 nm (Leifer, 1988). This actinometer was selected because it has a large wavelength range of sensitivity in the environmentally relevant region 290 to 500 nm, where light energy is sufficient to initiate photochemical reactions. In addition, the ferrioxalate actinometer is widely used and, therefore, its  $\phi_\lambda$  are well established.

The kinetics of the ferrioxalate actinometer are followed by measuring the molar concentration of Fe(II) formed from the photoreduction of Fe(III) over time, as seen in the net photochemical reaction (Reaction 11).



The molar concentration of Fe(II) is measured spectrophotometrically through the formation of the red complex with 1,10 phenanthroline and determination of the absorbance of the complex at 510 nm. Ferric Fe forms only a weak complex with 1,10 phenanthroline that is transparent at 510 nm.

Synthesis of potassium ferrioxalate crystals ( $K_3Fe(C_2O_4)_3 \cdot 3H_2O$ ) in the dark under a red safe light, preparation of actinometer solutions, and procedures followed are described by Kuhn et al. (1989). A 0.15 M actinometer solution was prepared using synthesized potassium ferrioxalate crystals. A 10 nm narrow band pass filter (48.56% transmission, maximum at 401 nm) from Spectra Physics was placed behind the AM 0 and AM 1 filters, prior to irradiating 5 mL of 0.15 M potassium ferrioxalate solution for a period of 5 min. The actinometer solution was diluted 100-fold prior to analysis of Fe(II). Therefore, only 100  $\mu$ L of the irradiated solution was complexed with 4 mL of 0.1% 1,10 phenanthroline in a 10 mL volumetric flask containing 0.5 mL of 1.0 M sodium acetate ( $CH_3COONa$ ). The flask was diluted to the mark with water and kept in the dark for  $\sim$ 1 hour, until full color development was achieved (Kuhn et al., 1989). A blank was prepared in the same manner, except 100  $\mu$ L of non-irradiated solution actinometer solution was used.

Using the absorbance at 510 nm of the irradiated actinometer solution corrected for absorption of the blank,  $A$ , and  $\phi_{401nm}$  equal to 1.07, a measure of the incident light intensity,  $I_0$ , on the reactor vessel was calculated using Equation 2 (Murov et al., 1993).

$$I_0 \text{ (einsteins min}^{-1}\text{)} = \frac{AV_2V_3}{\epsilon d \phi_{\lambda} t V_1} \quad (2)$$

The symbol  $\epsilon$  represents the molar absorptivity extinction coefficient of the ferrous-1,10 phenanthroline complex at 510 nm ( $\sim 1.11 \times 10^4 \text{ L mol}^{-1} \text{ cm}^{-1}$ );  $d$  is the path length (in centimeters) of the absorption cell used;  $t$  is time (in minutes);  $V_1$  is the volume (in milliliters) of irradiated actinometer solution withdrawn;  $V_2$  is the volume (in liters) of actinometer irradiated; and  $V_3$  is the volume (in milliliters) of the volumetric flask used for dilution of irradiated solution.

The incident light intensity hitting the reaction vessel was determined both with and without the AM 0 and AM 1 filters in place. With the filters in place, the incident light intensity at 401 nm was determined to be  $2.5 \times 10^{-5} \text{ einsteins min}^{-1}$  or  $0.06 \text{ kW m}^{-2}$ . Extrapolating this value to the range of 300 to 500 nm yielded an  $I_0$  equal to  $1.2 \text{ kW m}^{-2}$ . This value is comparable to the value of  $\sim 1 \text{ kW m}^{-2}$ , which corresponds to the intensity of sunlight from 300 to 500 nm during summer at solar noon (Stumm and Morgan, 1996). Without the AM 0 and AM 1 filters in place, an  $I_0$  of  $2.0 \text{ kW m}^{-2}$  in the range of 300 to 500 nm was obtained. This value would be lower if only the AM 0 filter, representing solar spectrum outside Earth's atmosphere, was in place and would compare to a reported  $I_0$  equal to  $1.37 \pm 0.02 \text{ kW m}^{-2}$  outside of the earth's atmosphere when the sun is at its mean distance from the earth (Exell, 2000). Therefore, based on the values obtained from potassium ferrioxalate actinometry, the incident light intensity focused on the reactor vessel was determined to be representative of approximately the value of one sun.

### 3.1.2. *MINEQL+ Chemical Equilibrium Model*

MINEQL+ software was used as a model to predict the dominant chemical species that would be present in the reaction medium at chemical equilibrium under the

conditions of the photochemical simulation experiments (i.e., [*am*-FeOOH] and pH) (Figure 16). In the pH range of 2.3 to 4.5, which is the typical pH range of atmospheric water and the reaction medium, the photochemically active  $\text{Fe}(\text{OH})^{2+}$  is the dominant hydrolyzed form of Fe(III) and ranges from  $10^{-3.0}$  to  $10^{-7.3}$  M (i.e., 0.001 to  $5.0 \times 10^{-8}$  M). Thus, depending on the pH of the reaction medium, although  $\sim 20$  mM of *am*-FeOOH was added, only a small fraction of total Fe is dissolved and the rest is present as suspended solid *am*-FeOOH.

### 3.2. Synthesis of Ferrihydrite

Six-line *am*-FeOOH was prepared by rapid hydrolysis of an acid Fe(III) solution as described by Schwertmann and Cornell (1991), except that batches were prepared in the amount of 1 L due to a limited supply of dialysis and freeze-drying equipment. The ochreous 6-line *am*-FeOOH is often the initial precipitate that forms in the rapid hydrolysis reaction followed by the dark brown-red and almost X-ray amorphous 2-line *am*-FeOOH. It is important to note that *am*-FeOOH must be freshly synthesized because over time (i.e., several years) transformation to the more crystalline hematite will occur (Schwertmann and Cornell, 1991).

To remove ion impurities, such as  $\text{NO}_3^-$ , derived from the Fe nitrate ( $\text{Fe}(\text{NO}_3)_3 \cdot 9\text{H}_2\text{O}$ ) starting material, the rapidly cooled Fe hydroxy-polymer solution was transferred to cellulose ester dialysis tubing (membrane molecular weight cut off: 500 Daltons) from Spectrum Laboratories, Inc. (Rancho Dominguez, California). The solution was left to dialyze against water for three days, or until the conductivity of the dialysis water had stabilized and was relatively low ( $< 10 \mu\text{S cm}^{-1}$ ). The dialyzed

suspension was transferred to 600-mL freeze-drying vials (300-mL maximum capacity), then frozen and freeze dried using a VirTis Freezemobile 8SL freeze dryer equipped with a shell-freezing bath (Gardiner, New York). The freeze-drying process entailed a period of 2 to 3 days, depending on vial size, to remove all moisture through sublimation.

After freeze drying, the crystals were ground using a mortar and pestle until the finest powder was obtained and stored in the freezer until use. According to Schwertmann and Cornell (1991), this method yields around 5 g (for 2 L) with a surface area of 180 to 200 m<sup>2</sup> g<sup>-1</sup>. Our yield was lower and ranged from 1.1 to 1.8 g for a 1-L batch with an average measured surface area of 196 m<sup>2</sup> g<sup>-1</sup>. The surface area was measured using a FlowSorb III from Micromeritics (see Chapter 3.4.).

In order to increase batch sizes, another method was pursued. After rapidly cooling, the Fe hydroxy-polymer solution was distributed into six 250 mL polyethylene centrifuge bottles (Beckman Avanti Rotar JLA-16.250) and centrifuged for a minimum of 6 hours at 16,000 rpm (~39,000g). The supernatant was poured off until ~50 mL remained and water was added to a level of ~230 mL. The solution was centrifuged for an additional 6-hour period at 39,000g and again the supernatant was poured off until ~50 mL remained. To eliminate potential differences between batches, a total of six 1-L batches concentrated in this manner were combined prior to the dialysis step to form ~1-L mixture. A yield of 3.5 g was obtained (from an initial 6 L of solution, Batch 6) and was used for a large number of the photochemical experiments, except where indicated.

These centrifugation steps were not successful since a lower yield was obtained than if batches were prepared separately. Therefore, following batches were prepared in

the usual manner without the centrifugation steps. After freeze drying, these batches were combined and thoroughly crushed into the finest powder with a mortar and pestle. This produced a sufficient amount of sample for several photochemical experiment trials that would be comparable because, as it turned out, different batches displayed different behavior.

Initially, *am*-FeOOH batches were prepared from  $\text{Fe}(\text{NO}_3)_3 \cdot 9\text{H}_2\text{O}$ ; however,  $\text{NO}_3^-$  impurity trapped inside the crystal lattice during synthesis was found to affect the reaction in the photochemical experiments. The amount of  $\text{NO}_3^-$  impurity in batches of *am*-FeOOH, referred to as interstitial  $\text{NO}_3^-$ , is dependent upon the period of dialysis. In an attempt to further remove  $\text{NO}_3^-$  impurity from following *am*-FeOOH batches, the period of dialysis was extended from 3 to 11 days (Batch 3), and even 20 days (Batch 4). Later, to fully eliminate  $\text{NO}_3^-$ , *am*-FeOOH was prepared using Fe perchlorate ( $\text{Fe}(\text{ClO}_4)_3 \cdot 6\text{H}_2\text{O}$ ). The concentration of interstitial  $\text{NO}_3^-$  for *am*-FeOOH batches was determined from IC measurements of initial  $\text{NO}_3^-$  concentrations after the *am*-FeOOH batch was added to the reaction medium. Table 7 lists all *am*-FeOOH batches prepared and used for experiments, including the starting material impurity and corresponding dialysis time used to remove the impurity. Batches 1, 2, and 5 contained 350, 400, and 600  $\mu\text{M}$  of interstitial  $\text{NO}_3^-$ . Batches 3 and 4 contained 90 and 40  $\mu\text{M}$  of interstitial  $\text{NO}_3^-$ , respectively, while  $\text{Fe}(\text{ClO}_4)_3 \cdot 6\text{H}_2\text{O}$  contained no interstitial  $\text{NO}_3^-$ . In addition, parameters that varied between experiments for each batch are listed. These parameters include the selected S species, addition of an  $\text{HO}^\bullet$  source or electron donor, and whether the AM 1 filter was present.

### 3.3. X-Ray Diffraction Analysis

XRD crystallography was used to characterize the crystal structure of the *am*-FeOOH product to confirm the formation of 6-line *am*-FeOOH crystals and to establish that there were no significant differences between batches. Approximately 0.02 g (a small microspatula scoop) of *am*-FeOOH powder was spread across a glass slide with ~0.25 mL acetone and allowed to dry, forming a thin semi-translucent film, prior to analysis. A Philips X'Pert XRD system was run at 45 kV and 40 mA from 10 to 70° 2 $\theta$  (Kennedy et al., 2003).

XRD analysis was also performed on selected *am*-FeOOH samples that had undergone the photochemical experiment process to see if, in fact, its crystal and chemical structure had been altered through reactions to form a different type of Fe oxide. After a photochemical experiment was complete, the remaining solution (typically ~50 mL) was placed in a polypropylene bottle and refrigerated until it was freeze dried. The powder was thoroughly crushed with a mortar and pestle and placed in the freezer until analysis. Because only a small amount of residual *am*-FeOOH was recovered after the photochemical experiment, a surface area measurement was first performed on the sample followed by XRD analysis.

### 3.4. Surface Area Analysis

The surface area of selected powdered *am*-FeOOH samples, both prior to and after photochemical reactions in the presence of S species, was measured with the FlowSorb III (Model 2305) from Micromeritics (Norcross, Georgia) using the Brunauer, Emmett, and Teller (BET) method (Brunauer et al., 1938). By determining the quantity

of gas that adsorbs as a single layer of molecules on a solid sample, the surface area of the powdered material can be determined. For an ultra-pure N<sub>2</sub> and He mixture (30% N<sub>2</sub>), formation of a monolayer of adsorbed N<sub>2</sub> occurs under the conditions of atmospheric pressure and the temperature of liquid nitrogen. Under these conditions, the area covered by each gas molecule is known within relatively narrow limits. Thus, the surface area of the sample is directly determined from the number of adsorbed gas molecules, which is derived from the gas quantity at the prescribed conditions and the area occupied by each molecule.

The short path length of the instrument was purged with an ultra-pure N<sub>2</sub> and He mixture (30% N<sub>2</sub>) and calibrated with a 1 mL injection of N<sub>2</sub> gas according to instructions for its operation (Figure 20). The N<sub>2</sub> gas was obtained from the vapors of the liquid N<sub>2</sub> used for the cold trap in the experiment. C black (single point surface area:  $23.6 \pm 0.5 \text{ m}^2/\text{g}$ ) was initially measured as the surface area reference material to verify instrument performance and calibration. Prior to measuring surface area, the sample was degassed to remove water vapor and other gases picked up from the atmosphere. Based on trial measurements, the optimal degassing conditions for C black were 20 min of heating at 150 °C. These conditions were applied to *am*-FeOOH samples; however, the time was later reduced to 10 min of heating to prevent blackening and/or burning of the *am*-FeOOH.

After degassing, the sample was moved to the test sample position for analysis. The instrument is capable of recording an adsorption measurement when the test sample is submerged in liquid N<sub>2</sub> and desorption measurement when the sample is removed from

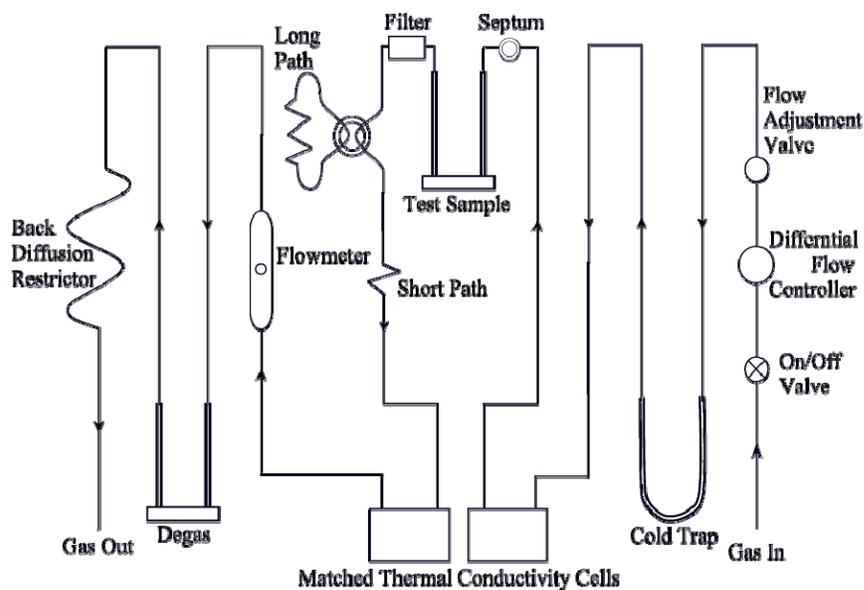


Figure 20. Diagram of the flow path of the FlowSorb III.

the liquid  $N_2$  and warmed to room temperature. Both values represent the sample surface area ( $m^2$ ). These values are then divided by the mass of the material to obtain surface area in  $m^2 g^{-1}$ . The desorption value divided by the mass of the sample after degassing yields the most accurate measurements, according to the instructions and trials on the C black reference material. Therefore, it is this value that is reported for the surface area of *am*-FeOOH.

### 3.5. UV-Visible Absorption of Iron-Sulfur Complexes

The absorbance of potential complexes between Fe(III) and DMS derived S compounds was measured using a Cary 100 BIO UV-Visible Spectrophotometer from Varian, Inc. (Sugar Land, Texas). Scans from 190 to 700 nm were collected in the Cary Win UV Scan Application.

Stock solutions of Fe(Cl)<sub>3</sub> (750 μM) and MSIA (125,000 μM) were prepared fresh. From the stock solutions, Fe, MSIA, and Fe-MSIA solutions were prepared according to Table 8. An absorbance spectrum was obtained for each of these solutions.

Table 8. Preparation of Iron and Methane Sulfinic Acid Solutions for UV-Visible Absorption Measurement

Stock Solution	Volumes of Stock Solution (mL)		
	Fe	MSIA	Fe-MSIA
750 μM Fe(Cl) <sub>3</sub>	3.25	—	3.25
125,000 μM MSIA	—	0.36	0.36
H <sub>2</sub> O	—	3.25	—
Final concentration	750 μM	13,000 μM	750/13,000 μM

Note: MSIA = methane sulfinic acid. Dash indicates solution not included.

### 3.6. Determination of Chemical Analytes

#### 3.6.1. Iron(II) and Iron(III)

Fe(II) and Fe(III) concentrations of samples collected throughout the photochemical experiment were determined spectrophotometrically through UV-vis absorption using a Teflon Z-type flow cell (SMA-Z-cell-Teflon) from FIALab Instruments, Inc. (Bellevue, Washington) with an effective optical path length of 1 cm.

Sample solution was pumped through the Z-cell using a 4-channel peristaltic pump (Peri-Star) from World Precision Instruments (WPI), Inc. (Sarasota, Florida). The incoming light was passed from the radiation source, a 5 W Xe lamp (FO-6000 Fiber Optic Light Source, WPI), to the Z-cell via a fiber optic cable with standard subminiature A adapter (SMA) terminated fittings. The outgoing signal was connected to the spectrophotometer (J&M TIDAS II, WPI) through another fiber optic cable. At each fiber optic junction in the Z-cell, fused silica windows were set in place to serve as wetting surfaces. Fluid inlet and outlet connections employed fittings and tubing from Upchurch Scientific (Oak Harbor, Washington). Data collection and system control of the spectrophotometer were performed using a laptop and TIDAS II Spectralys (version 2.0) (Figures 21 and 22).

A volume of 1.25 mL of filtered (0.45  $\mu\text{m}$  pore size filter) sample solution was transferred to a 10 mL capacity Teflon test tube containing 139  $\mu\text{L}$  of ferrozine (3-(2-pyridyl)-5,6-diphenyl-1,2,4-triazine-*p,p'*-disulfonic acid, monosodium salt hydrate, 97%) reagent, prepared as a 6 mM solution (+1 drop of concentrated hydrochloric acid (HCl) per 25 mL of ferrozine solution). Ferrozine immediately forms a stable colored complex with Fe(II), in a ratio of three ferrozine ligands to one Fe(II). Figure 23 illustrates the Fe(II)-(FZ)<sub>3</sub> complex where green, white, magenta, blue, red, and yellow represent C, H, Fe, N, O, and S, respectively. The Fe(II)-(FZ)<sub>3</sub> complex has an absorbance maximum at 562 nm ( $\epsilon = 2.79 \times 10^4 \text{ M}^{-1} \text{ cm}^{-1}$ ) (Stookey, 1970). Therefore, the concentration of Fe(II) can be determined using Beer's Law (see Chapter 3.6.1.1., Equation 3).

It is important to note that all samples analyzed were diluted by the same ratio of ferrozine to sample solution as the standards, which had a ratio of 3 mL of 6 mM

ferrozine reagent to 27 mL of standard solution. In general, the reagent should be at least 10 times higher than the reactant to ensure that all of the reactant will bind with the

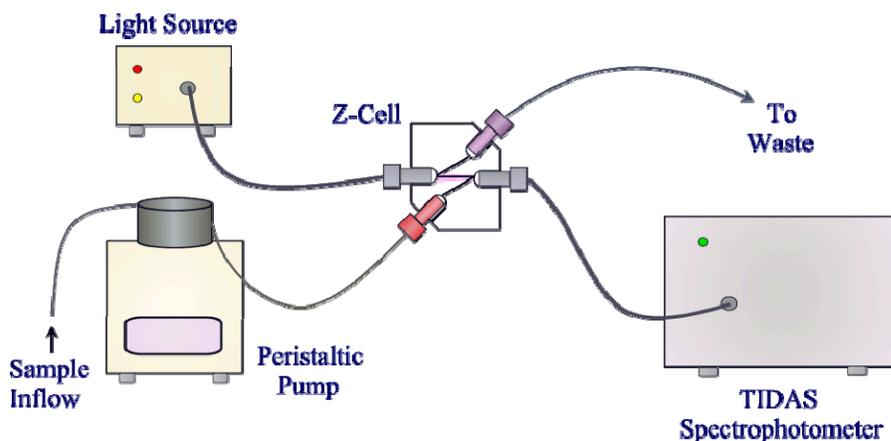


Figure 21. Diagram of the setup for iron(II) and iron(III) determination using the Z-cell (not to scale).

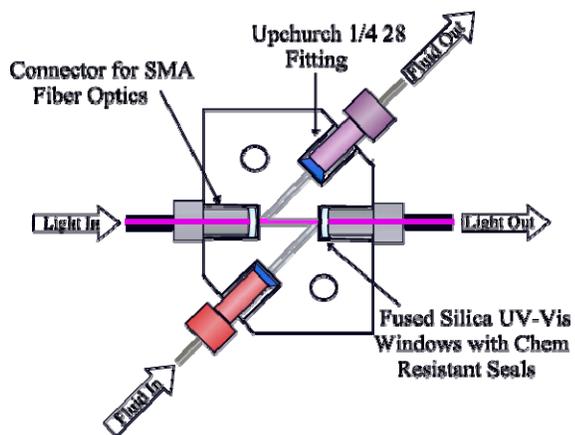


Figure 22. Diagram of the Teflon Z-type flow cell.

reagent. This dilution yields a final ferrozine concentration of  $\sim 0.6$  mM, an amount that should be more than sufficient to complex all Fe(II) present in solution at the  $\mu\text{M}$  level.

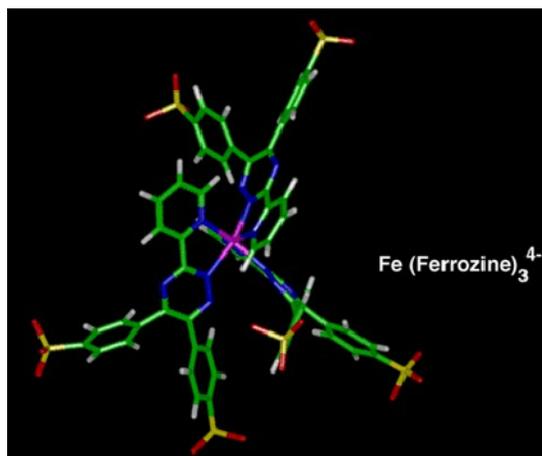


Figure 23. Chemical structure of the iron-ferrozine complex that absorbs at 562 nm. Source: Iron-Ferrozine Complex (2004).

Therefore, to maintain this ratio, 139  $\mu\text{L}$  of ferrozine was added to 1.25 mL of sample solution. In this manner, the dilution of the standards and sample solution by the addition of ferrozine solution was accounted for.

The sample solution was then pumped through the Z-cell at a typical flow rate ranging from 0.20 to 0.25 mL per minute. Three-dimensional absorbance scans from 388 to 735 nm were collected over a period of 10 seconds after a majority of the solution was flushed through the cell. Two-dimensional scans were extracted at 5 seconds in an attempt to obtain an average absorbance value. Prior to recording the absorbance at 562 nm, the baseline was set to zero by performing a baseline calculation on the absorbance scans. Fe(II) concentrations were then determined by using a calibration curve relating absorbance value to concentration of Fe(II) ( $\mu\text{M}$ ).

Analysis of the solution for total dissolved Fe ( $\text{Fe(II)(aq)} + \text{Fe(III)(aq)}$ ), in addition to Fe(II) alone, was accomplished by adding the reductant hydroxylamine hydrochloride ( $\text{H}_2\text{NOH HCl}$ ) prior to the addition of ferrozine. A volume of 1.25 mL of filtered (0.45  $\mu\text{m}$  pore size filter) sample solution was transferred to a tube containing 63  $\mu\text{L}$  of 1 mM  $\text{H}_2\text{NOH HCl}$ , which yields a final  $\text{H}_2\text{NOH HCl}$  concentration of  $\sim 50 \mu\text{M}$ . The volume and concentration of  $\text{H}_2\text{NOH HCl}$  added to 1.25 mL of sample solution was determined by assuming a dissolved concentration of Fe(III) no higher than 5  $\mu\text{M}$ . According to modeling calculations on MINEQL+ software (version 4.5), the concentration of the predominant Fe(III) species,  $\text{Fe(OH)}^{2+}$ , at a pH of 4 (the pH range of the photochemical experiments) is  $\sim 10^{-6.5}$  M or  $\sim 0.3 \mu\text{M}$  (see Figure 16). To ensure that enough  $\text{H}_2\text{NOH HCl}$  would be present to reduce all of the Fe(III), an amount 10 times  $[\text{Fe(III)}]$  was added. The solution was allowed to react for a few minutes before 146  $\mu\text{L}$  of 6 mM ferrozine reagent was added. The volume of ferrozine added was increased slightly to account for the dilution from the addition of the  $\text{H}_2\text{NOH HCl}$ . The absorbance was collected in the same manner as described above and converted to total dissolved Fe concentration. Fe(III) concentration was determined by subtracting the previously measured Fe(II) concentration from the total dissolved Fe concentration.

It is important to note that above an absorbance value of 1.8, the relationship between absorbance at 562 nm and  $[\text{Fe(II)}]$  ceases to be linear. Therefore, solutions approaching this absorbance value were diluted prior to analysis. In cases where bubbles trapped in the cell inhibited collection of an accurate scan, producing a scan that would

jump to high and low levels over the 10 second interval, the solution was pumped through the cell in the reverse direction and the scan was obtained.

#### 3.6.1.1. *Iron(II) and Iron(III) Standards*

Standard solutions of Fe(II) were prepared and analyzed immediately after preparation, although the Fe(II)-(FZ)<sub>3</sub> complex is quite stable. Several drops (~14 to 20 drops) of concentrated HCl were added to ~500 mL of water that had been purged with N<sub>2</sub> gas for 30 min. This process removes oxygen and helps to prevent oxidation of Fe(II) to Fe(III), since Fe(II) is more stable in an acidic environment. A 4 mM Fe(II) stock solution was prepared using ammonium Fe(II) sulfate (Fe(II)(NH<sub>4</sub>)<sub>2</sub>(SO<sub>4</sub>)<sub>2</sub>•6H<sub>2</sub>O) and the N<sub>2</sub> purged water. Standard solutions ranging from 0.5 to 75 μM were prepared in the amount of 27 mL with the addition of 3 mL of 6 mM ferrozine reagent. A blank was prepared in the same manner except that no Fe(II) was added.

A 5-point calibration was typically performed once every 3 months since the slope in previous calibration curves for the Z-cell was remarkably stable ( $0.02181 \pm 0.00002 \text{ M}^{-1} \text{ cm}^{-1}$ ) and the Fe(II)-(FZ)<sub>3</sub> complex is very stable. The value of the blank was subtracted from the standards and the calibration curve was forced through the origin. Since the calibration curve relates absorbance to concentration, the slope is represented by  $\epsilon b$  in Beer's Law (Equation 3).

$$A = \epsilon bc \quad (3)$$

Beer's Law represents the relationship between absorbance and concentration, where A is absorbance, b is the cell path length ( in centimeters), c is the concentration (in molarity), and  $\epsilon$  is the molar absorptivity extinction coefficient. The average  $\epsilon$

obtained for the Fe(II)-(FZ)<sub>3</sub> complex at 562 nm was  $2.18 \times 10^4 \text{ M}^{-1} \text{ cm}^{-1}$ . This value is lower compared to reported  $\epsilon$  values of  $2.79 \times 10^4 \text{ M}^{-1} \text{ cm}^{-1}$  in the literature (Kononets et al., 2002; Stookey, 1970).

Figure 24 shows a linear response in the concentration range of interest between 0.5 and 75  $\mu\text{M}$  by the spectrophotometer. Values for data points are shown in Appendix B, Table B1; an absorbance scan from a 25  $\mu\text{M}$  standard is provided in Appendix C, Figure C1.

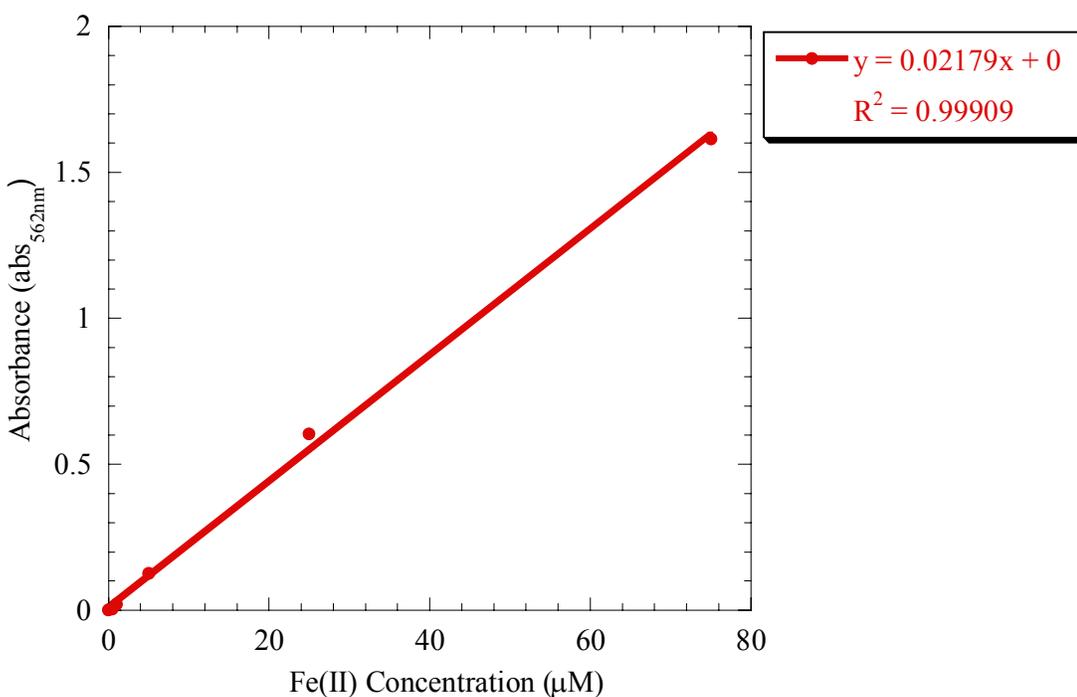


Figure 24. Standard curve data for iron(II) determination using the Z-cell. Values are determinations from standards of concentrations of 0.5 to 75  $\mu\text{M}$ .

A detection limit was determined using the method described in Harris (2003, p 727). From previous experience, the detection limit was estimated to be 0.5  $\mu\text{M}$ . A sample solution three times this concentration (1.5  $\mu\text{M}$ ) was prepared and the absorbance

at 562 nm was recorded for eight replicate samples. Eight blank solutions were prepared from 27 mL of purged N<sub>2</sub> water and 3 mL of ferrozine reagent. The values of these absorbance readings are shown in Appendix D, Table D1.

The signal detection limit ( $y_{dl}$ ) is defined as the mean of the blank measurements plus the standard deviation of the samples multiplied by a Student's  $t$  value corresponding to  $n-1$  measurements (Equation 4) (Harris, 2003, p 727).

$$y_{dl} = y_{blank} + t \cdot s \quad (4)$$

Using a Student's  $t$  value of 2.998, the  $y_{dl}$  becomes 0.013 abs. Converting this value to units of concentration yields a detection limit of 0.39  $\mu$ M (Appendix D, Table D3).

### 3.6.2. Hydrogen Peroxide

H<sub>2</sub>O<sub>2</sub> levels for each sample collected at the selected time points were directly measured using an Apollo 4000-4 Channel Free Radical Analyzer System equipped with a 100  $\mu$ m H<sub>2</sub>O<sub>2</sub> microprobe sensor (ISO-HPO-100) from WPI, Inc. The H<sub>2</sub>O<sub>2</sub> probe has a dynamic range of detection from < 10 nM to 1 mM.

Detection principles of the H<sub>2</sub>O<sub>2</sub> probe are based on the electrochemical (amperometric) response produced by the H<sub>2</sub>O<sub>2</sub> sensor. The sensor is a combination electrode, in which the sensing (working) and reference electrodes have been combined. H<sub>2</sub>O<sub>2</sub> diffuses through a selective membrane covering the sensor and is oxidized at the working electrode, resulting in an electrical (redox) current reported in pico amps (pA). The relative amount of redox current produced is linearly proportional to the amount of H<sub>2</sub>O<sub>2</sub> in the sample.

Prior to measurement, parameters in the Apollo 4000 software (version 4.1.4) were selected for operation of the H<sub>2</sub>O<sub>2</sub> microprobe. Since the dynamic range of the instrument is limited between 10 nM and 1 mM, the intrinsic noise is therefore proportional to the maximum measured value. This noise can be reduced by selecting a channel range. After preliminary calibration curves were established, a channel range of 100 nA was found to provide the most linear calibration curve. Sample rate was set at 10 samples per second. The poise voltage (+400 mV for H<sub>2</sub>O<sub>2</sub>), which is approximately the midpoint reduction potential, was set to “H<sub>2</sub>O<sub>2</sub>” and the microprobe was allowed to equilibrate for ~20 min in water at room temperature (~22 °C) until the signal was stabilized. The signal was zeroed to reduce background signal, and allowed to stabilize in air before the probe was immersed in the sample solution. Once sample signal stabilized, the probe was removed from solution and allowed to stabilize prior to immersion in the next sample solution. The relative change in pA ( $\Delta pA$ ) was recorded three times to obtain an average value that was converted to [H<sub>2</sub>O<sub>2</sub>] ( $\mu M$ ) using the calibration curve generated for each experiment prior to measuring samples.

#### 3.6.2.1. *Hydrogen Peroxide Standards*

Calibration standards were prepared from a ~10 mM solution of H<sub>2</sub>O<sub>2</sub>, which was prepared by diluting 10  $\mu L$  of 30% (w/w) H<sub>2</sub>O<sub>2</sub> stock solution in 10 mL of water. The concentration of the solution was confirmed using Beer’s Law (Equation 3) with an extinction coefficient value of  $\epsilon = 43.6 M^{-1} cm^{-1}$  at 240 nm (Clairborne, 1985, p 283).

Seven standard solutions ranging from 1  $\mu M$  to 100  $\mu M$  were prepared weekly and microprobe calibration was performed prior to each use. Standards were calibrated at

the experimental temperature (room temperature,  $\sim 22$  °C) since probe response varies with temperature. A standard curve was generated with typical correlation coefficients ( $r^2$ ) of 0.9800 or higher. The  $\Delta pA$  was recorded three times to obtain an average determination that was used to quantify  $H_2O_2$  concentration. Figure 25 shows a linear response by the microprobe over two orders of magnitude in  $H_2O_2$  concentrations. Values for data points are shown in Appendix B, Table B2 and a representation of an amperometric print out from a calibration series is provided in Appendix C, Figure C2.

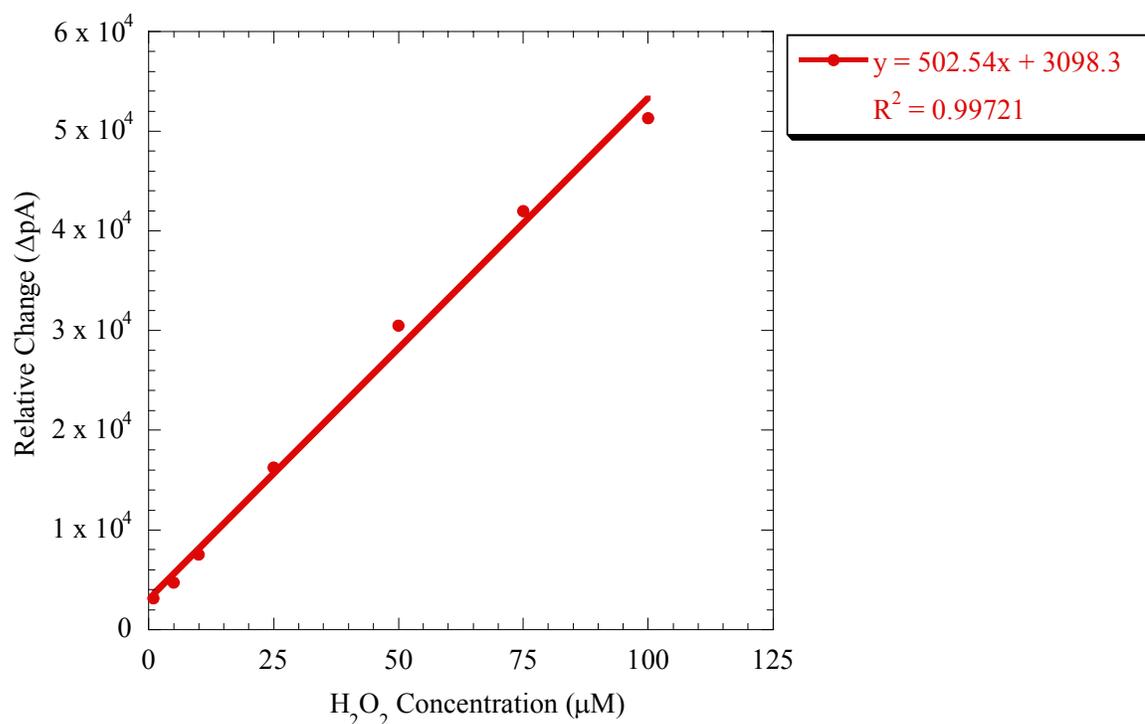


Figure 25. Standard curve data for hydrogen peroxide determination using the hydrogen peroxide probe. Values are determinations from standard concentrations of 1 to 100  $\mu M$ .

The detection limit was determined in the same manner as described for the Z-cell (Harris, 2003, p 727). A 5  $\mu M$  solution was prepared and the  $\Delta pA$  was recorded for eight replicate samples. Eight blank solutions (Milli-Q water) were also measured. The values

of these readings are shown in Appendix D, Table D2. The signal detection limit was  $\Delta pA$  of 1283, which yielded a minimal detectable concentration of 2.77  $\mu M$  (Appendix D, Table D3).

### 3.6.3. *Anions*

S oxidation products were detected and quantified using a liquid IC system with electrochemical detection. The DIONEX IC system consisted of a dual piston gradient pump (Model GP50), an electrochemical detector (Model ED40) with an anion self-regenerating suppressor (ASRS-ULTRA, 4mm), and an autosampler (Model AS40). Analytes were separated using an AS11-HC column (4 x 250 mm), specific for optimal separation of S species. All instruments and equipment were from DIONEX Corporation (Sunnyvale, California).

A method was developed in the PeakNet software (version 5.1) that allowed for optimal separation of MSIA, MSA, hydroxymethane sulfinic acid (HMSIA,  $HOCH_2SO_2H$ ),  $Cl^-$ , hydroxymethane sulfonic acid (HMSA,  $HOCH_2SO_3H$ ),  $SO_4^{2-}$ , and  $NO_3^-$  at the highest standard concentration (200  $\mu M$ ). It was not feasible to analyze for  $SO_3^{2-}$  because it was found to undergo rapid oxidation to  $SO_4^{2-}$ . First, analyte retention times were established by running each analyte individually. Because many of these oxidized S species are acids, a proton is donated to the solution phase, which allows for detection of the anion counter part at characteristic retention times as it is eluted from the column. Once peaks were identified, the 200  $\mu M$  mixed analyte standard was run at various eluent concentrations until optimal separation and resolution was achieved. A volume of 1 L of 100 mM sodium hydroxide (NaOH) eluent was prepared as needed

from a 50% (w/w) NaOH stock, being careful to avoid introduction of CO<sub>2</sub>. Eluent concentration was set at 15% 100 mM NaOH and 85% water with a 1.50 mL per minute flow rate and was ramped to 20% NaOH from 4 to 8 min to allow for separation of SO<sub>4</sub><sup>2-</sup> and NO<sub>3</sub><sup>-</sup>, while maintaining a relatively short runtime of 11 min.

A volume of 500 µL was transferred into a 500 µL Dionex vial, capped with a 0.2 µm pore size filter, and placed in the autosampler for analysis. Sample injection occurred at 1 min, after initiation of the sample run. Blanks consisting of 18 MΩ Milli-Q water were run before analysis of the first sample to ensure complete elution of remaining components from the column and a stable baseline.

#### 3.6.3.1. *Anion Standards*

A mixed stock solution containing 0.01 M of MSIA, HMSIA, MSA, HMSA, and Na<sub>2</sub>SO<sub>4</sub> was prepared fresh monthly (Arsene et al., 2002). In addition, NaCl and NaNO<sub>3</sub> were added to the stock solution to monitor the amount of these impurities trapped inside the crystal lattice of *am*-FeOOH during the synthesis process. A couple drops of formaldehyde (CH<sub>2</sub>O) were added as a preservative against microorganisms that may process and degrade these S compounds.

Standard solutions ranging from 5 to 200 µM were prepared fresh weekly and analyzed immediately after preparation to yield a to five-point calibration curve for each species of interest. On the rare occasion a calibration point significantly skewed the calibration curve, it was left out. During each week, a 150 µM check standard was run with each set of experimental samples to ensure consistency in instrumentation

performance. If peak areas for analytes were outside  $\pm 10\%$ , fresh standards were used to construct a new calibration curve.

When analyzed individually, HMSA was found to contain a small amount of  $\text{SO}_4^{2-}$ , most likely produced from oxidation. To correct for this impurity,  $\text{SO}_4^{2-}$  peak areas from HMSA standards and the mixed analyte standard calibration curve were used to calculate  $\text{SO}_4^{2-}$  concentrations. It was estimated that the  $\text{SO}_4^{2-}$  impurity from HMSA accounted for approximately 1.5% of the  $\text{SO}_4^{2-}$  observed. Therefore, the concentrations of the standards for the  $\text{SO}_4^{2-}$  calibration curve were corrected for this amount. Once standard calibration curves for MSIA, HMSIA,  $\text{Cl}^-$ , MSA, HMSA,  $\text{SO}_4^{2-}$ , and  $\text{NO}_3^-$  were generated, analyte concentration ( $\mu\text{M}$ ) in samples could be determined by using the integrated areas of peaks corresponding to analyte retention times.

Figure 26 shows a linear response forced through the origin by the electrochemical detector over two orders of magnitude in MSIA concentrations. The values for this graph and MSA, HMSIA, and HMSA are shown in Appendix B, Table B3. Graphs of the linear responses for these species are shown in Figures B1 through B3. Values and linear response for  $\text{SO}_4^{2-}$  are not shown because  $\text{SO}_4^{2-}$  values detected in experiments were consistently below detection limits (BDL). An example chromatogram showing column retention times is provided in Appendix C, Figure C3. Detection limits for each analyte were determined using the method described above (Harris, 2003, p 727) and are listed in Appendix D, Table D3.

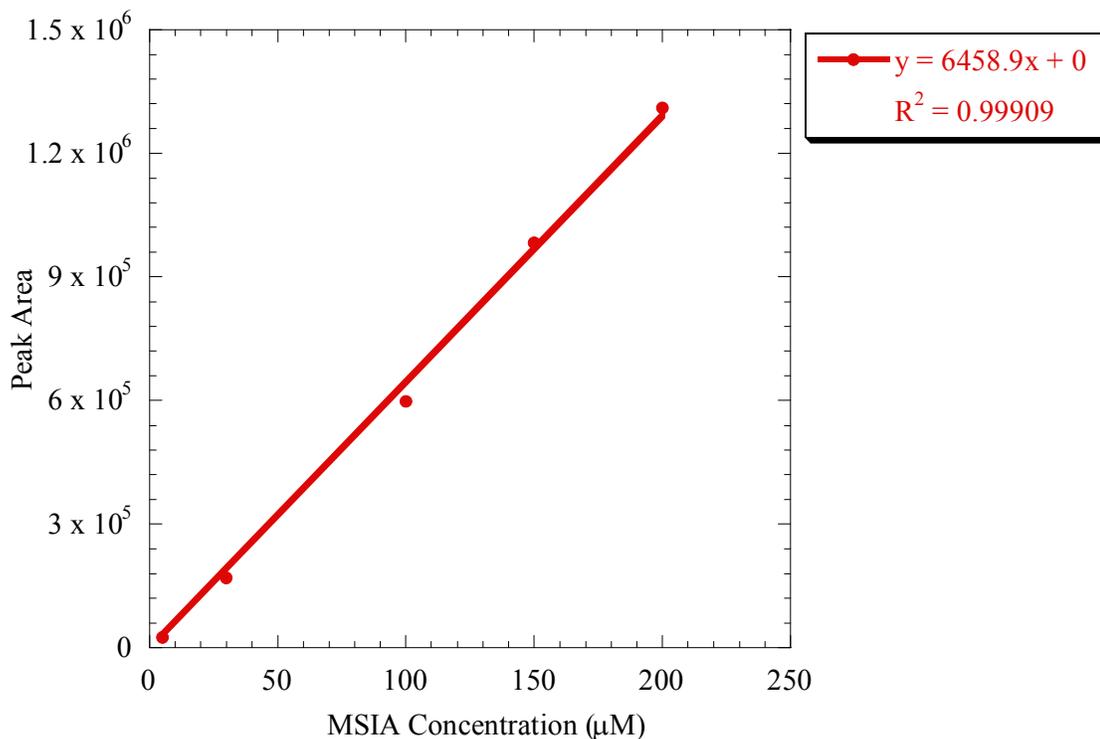


Figure 26. Standard curve data for methane sulfinic acid determination using the ion chromatograph. Values are determinations from standard concentrations of 5 to 200 μM.

### 3.7. Statistics

To obtain statistical parameters for an experiment, it would need to be run at least in triplicate. In general, this was not feasible due to limited supply of *am*-FeOOH from the same batch, especially from initial batches. Therefore, to get an estimate of the reproducibility of results from the photochemical experiments, one experiment was selected (i.e., *am*-FeOOH-hv-MSIA, Batch 7 prepared from FeClO<sub>4</sub><sup>-</sup>) and conducted three times in the same manner under identical conditions.

## CHAPTER 4

### RESULTS

#### 4.1. Characterization of Reaction Medium

##### 4.1.1. *Ferrihydrite Characterization*

Batches of *am*-FeOOH were initially synthesized from  $\text{Fe}(\text{NO}_3)_3 \cdot 9\text{H}_2\text{O}$  and later from  $\text{Fe}(\text{ClO}_4)_3 \cdot 6\text{H}_2\text{O}$ . To ensure that there was no crystallographic difference between batches prepared from either starting material, XRD scans were collected before photochemical experiments (with the exception of Batch 1). Scans were also collected for selected batches (Batches 2 and 6) after photochemical reaction. Despite the fact that the synthesis technique used was specific for 6-line *am*-FeOOH, all XRD scans, both before and after photochemical reaction, show a similar characteristic scan typical for amorphous 2-line *am*-FeOOH consisting of two broad peaks between  $30$  to  $35^\circ$  and  $60$  to  $65^\circ$   $2\theta$  (Schwertmann and Cornell, 1991) (see Appendix E). Some of the scans show an indication of being less amorphous *am*-FeOOH (e.g., Batches 2 and 4), while, on the other end of the spectrum, Batch 5 appears more amorphous (smoother, more subdued peaks). The scan of Batch 6 after reaction in the presence of MSIA was the only scan to show a sharp peak at  $25^\circ$   $2\theta$ . It is unusual to observe one peak and, thus, this peak could not be identified by the X'Pert software.

In addition, surface area analyses were also performed on selected batches before and after photochemical reaction. Ferrihydrite surface areas on Batches 4, 5, and 6 before photochemical experiments show consistent values of  $\sim 200 \text{ m}^2 \text{ g}^{-1}$  as expected from Schwertmann and Cornell (1991) and are independent of the starting material

(Appendix E, Table E1). Throughout the experiment the reaction medium seemed to become increasingly cloudy, thus indicating smaller particles and larger surface areas. However, surface areas after reaction in photochemical experiments were smaller,  $\sim 100 \text{ m}^2 \text{ g}^{-1}$ , and similar surface areas were observed for *am*-FeOOH samples exposed to light and MSIA, light and DMSO, and light alone. These results are suspect because surface area determinations after experiments involve a second freeze drying process to recover *am*-FeOOH particles in powder form. However, during this process, particles agglomerate and grow, thus rendering values that are not representative of the surface area of the colloidal particles in suspension. A better method for tracking a possible decrease in particle size is by an in situ particle counter that delivers a histogram of the number of particles in a certain size range.

#### 4.2. Photochemical Experiments

Over the course of 2 years, 48 photochemical experiments including *am*-FeOOH and one or a combination of selected atmospheric S species were conducted (Appendix F, Table F1). Results of experiments are presented in the following sections in order of increasing S oxidation state, preceded by the statistics section. As S oxidation state increases, the S species becomes more soluble in solution and is more available for reaction in the aqueous medium. On the other hand, more reduced S species (i.e., DMS) have the potential for a greater number of oxidation steps, and therefore, more Fe(III)(aq) reduction. Most experiments were carried out with DMSO, due to its dissolution into the aqueous phase, and MSIA, because of its strong effect on enhancing the photoreductive dissolution of Fe(II). This effect was also observed with DMSO, but to a lesser degree.

It is important to note that although HMSIA, HMSA, and  $\text{SO}_4^{2-}$  were analyzed in aliquots removed at selected time intervals, no detectable amounts were observed in any of the experiments and thus no results are presented for these potential products. In addition, measured Fe(III) levels were generally not present at detectable limits. Therefore, results are considered to be BDL of  $0.39 \mu\text{M}$ , unless otherwise noted, and are not presented. In terms of graphs, analytes that indicated results of zero are mentioned in the text, but not plotted on graphs for simplicity. In general, only one repetition is plotted; however, experiments that were run in triplicate are plotted with error bars when the data was available.

The pH of the reaction medium was measured before and after photochemical reaction. As Fe(II) is formed, S oxidation products are also formed. These oxidized species are acids, and therefore lower the pH of the reaction medium. The average change in pH for experiments is presented in the following sections for each selected S species and is derived from pH measurements in Appendix F, Table F1.

#### 4.2.1. *Statistics*

Results are presented in Figures 27, 28, 29, and 30, where error bars represent reproducibility within one standard deviation. Reproducibility is represented by error bars of the standard deviation. Standard deviations obtained from this set of experiments were assumed representative and transferable to the other experiments. In Table 9, the average relative standard deviation for each parameter is presented.

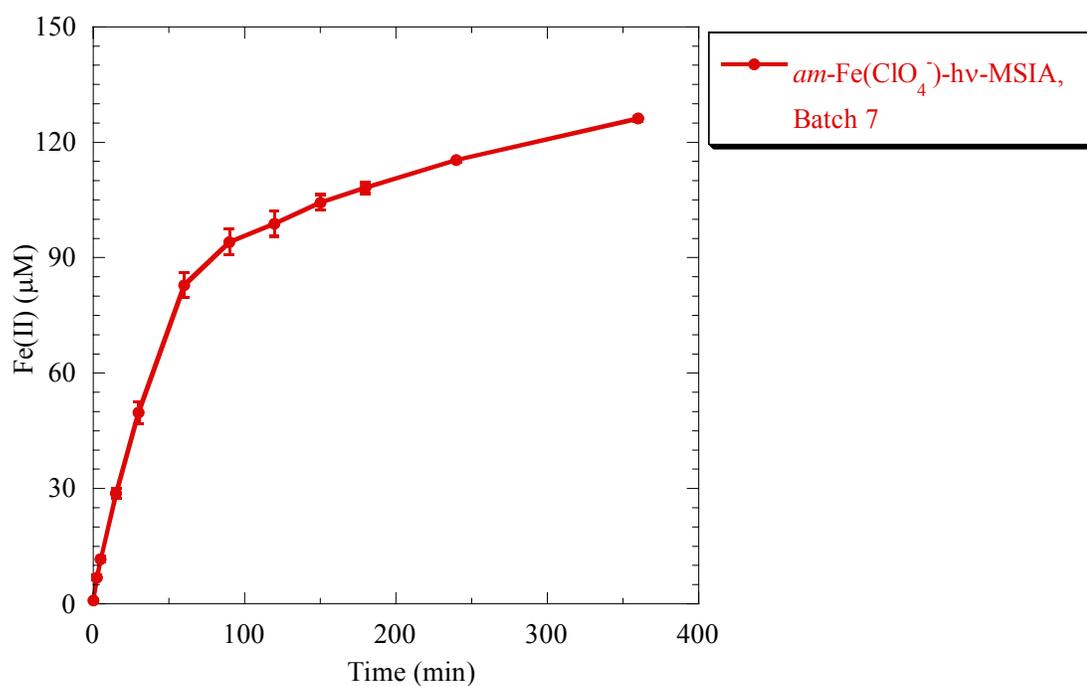


Figure 27. Reproducibility of iron(II) results for the ferrihydrite-light-methane sulfonic acid run in triplicate.

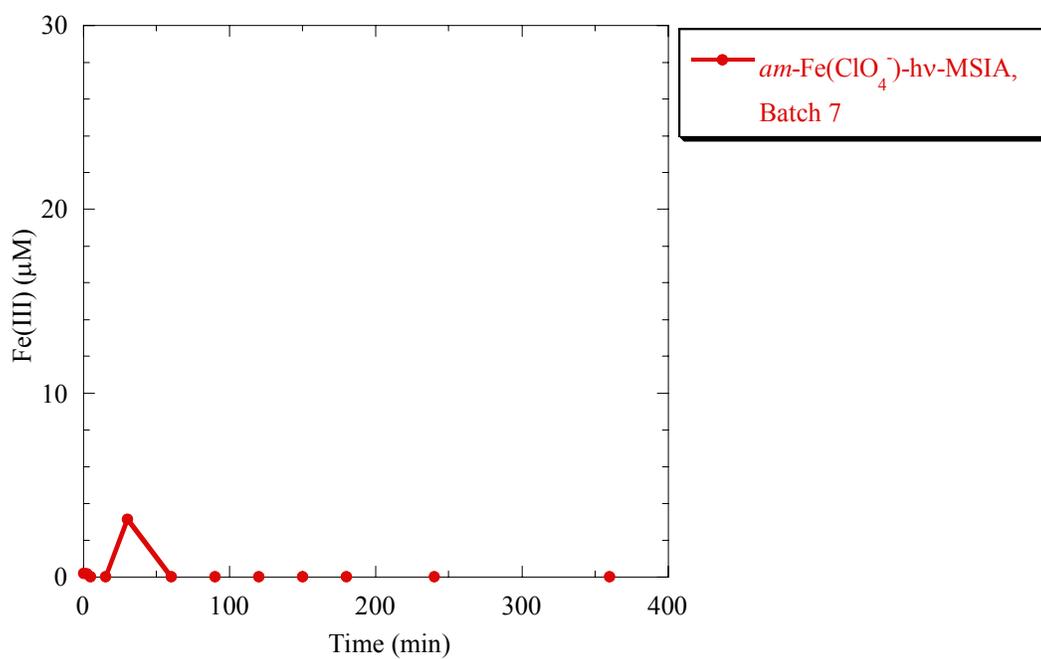


Figure 28. Reproducibility of iron(III) results for ferrihydrite-light-methane sulfonic acid run in triplicate. Iron(III) was typically zero, thus, a standard deviation could not be obtained.

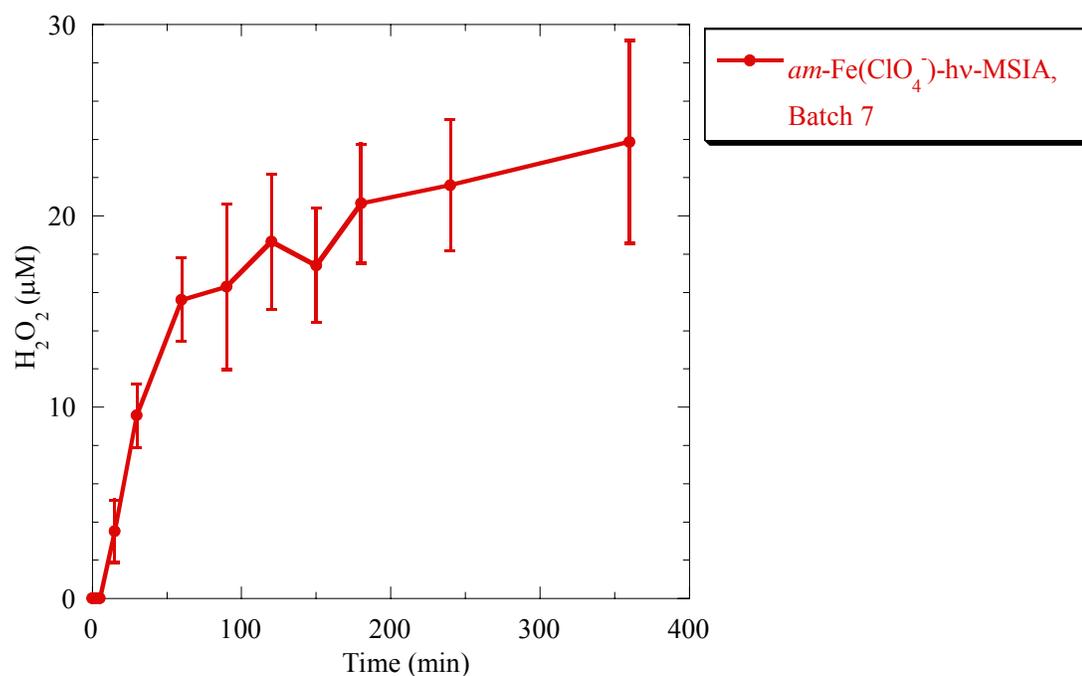


Figure 29. Reproducibility of hydrogen peroxide results for ferrihydrite-light-methane sulfinic acid run in triplicate.

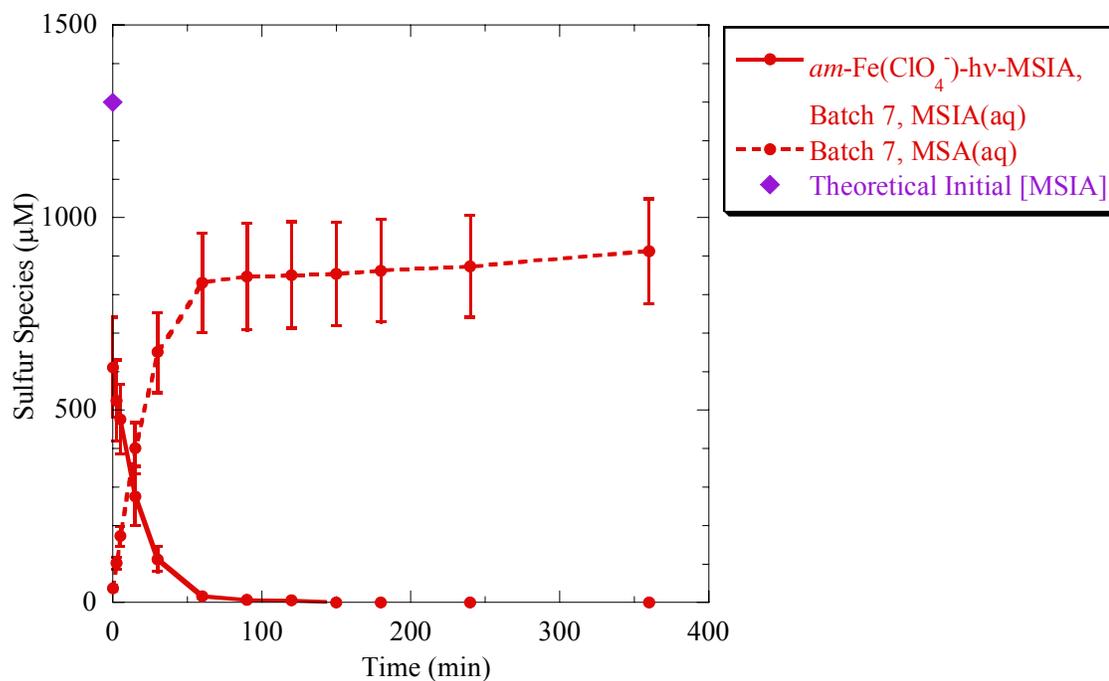


Figure 30. Reproducibility of methane sulfinic acid and methane sulfonic acid results for ferrihydrite-light-methane sulfinic acid run in triplicate.

Table 9. Relative Standard Deviation for Parameter Plots

Species	Typical Relative Standard Deviation (%)
Fe(II)(aq)	3.8
Fe(III)(aq)	0.0 <sup>a</sup>
H <sub>2</sub> O <sub>2</sub>	18.4
MSIA	20.7
MSA	15.7
pH	1.8

Note: MSIA = methane sulfinic acid; MSA = methane sulfonic acid.

<sup>a</sup>Values were typically zero and a relative standard deviation could not be obtained.

#### 4.2.2. Dimethyl Sulfide

Results from Fe(II), H<sub>2</sub>O<sub>2</sub>, and S oxidation product measurement in photochemical experiments including *am*-FeOOH and DMS are shown in Figures 31, 32, and 33, respectively. The concentration of Fe(II)(aq) in the presence of DMS (red, Figure 31) is only slightly higher than the light control without DMS (orange). To test the effect of DMS further, the reaction medium was spiked with an additional 850  $\mu$ L of DMS after 90 min, which appears to further increase Fe(II) concentration slightly.

H<sub>2</sub>O<sub>2</sub> levels are essentially zero until after the DMS spike, where levels jump from zero to  $\sim$ 15  $\mu$ M at the end of the Fe-hv-DMS experiment (red, Figure 32). With the exception of low levels of MSA, no detectable amounts of S anions are observed (Figure 33). Initial MSA(aq) levels drop from  $\sim$ 2  $\mu$ M immediately after the reaction is initiated. A slight increase in MSA concentration to  $\sim$ 1.5  $\mu$ M is observed after the DMS spike,

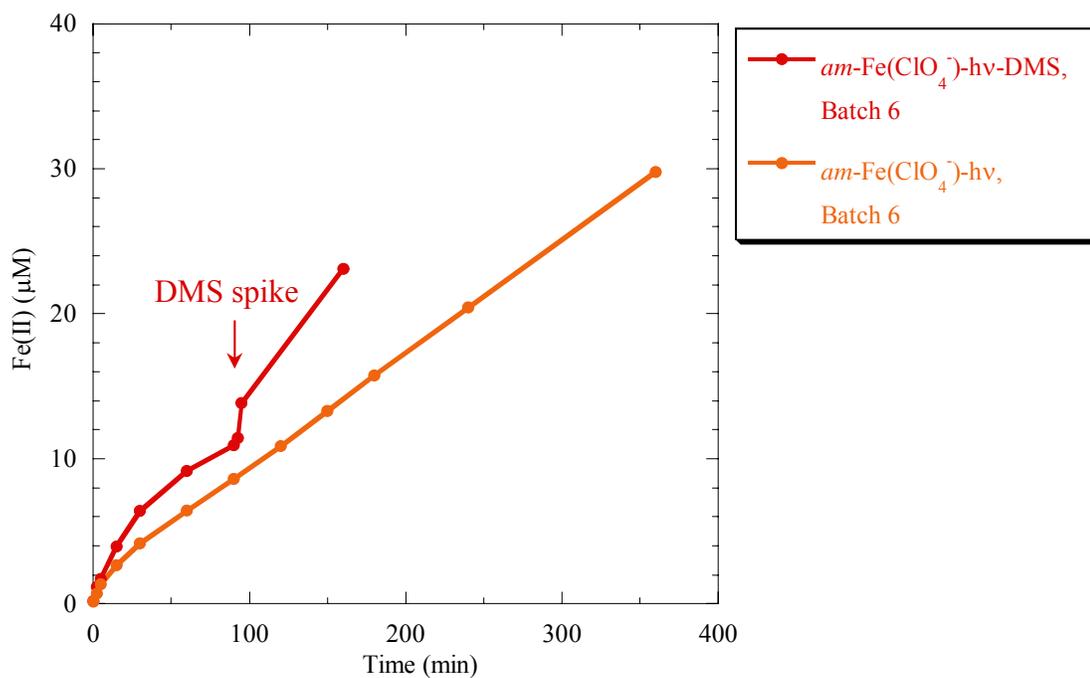


Figure 31. Photoreductive dissolution of ferrihydrite in the presence of light and dimethyl sulfide.

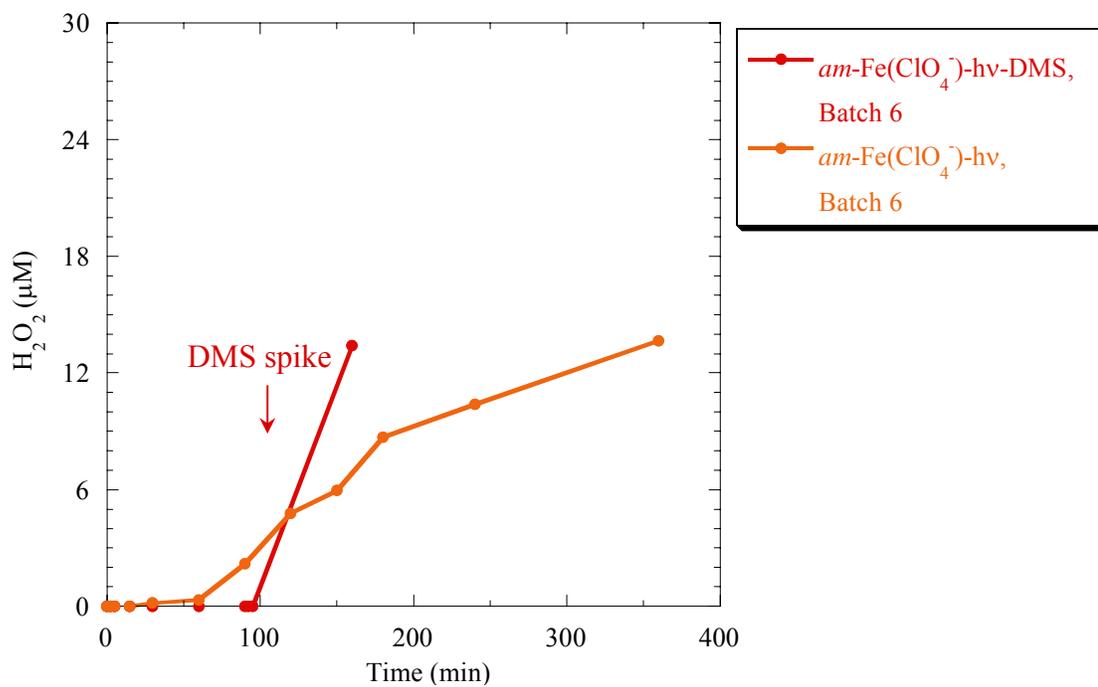


Figure 32. Hydrogen peroxide formation for ferrihydrite, light, and dimethyl sulfide with light control.

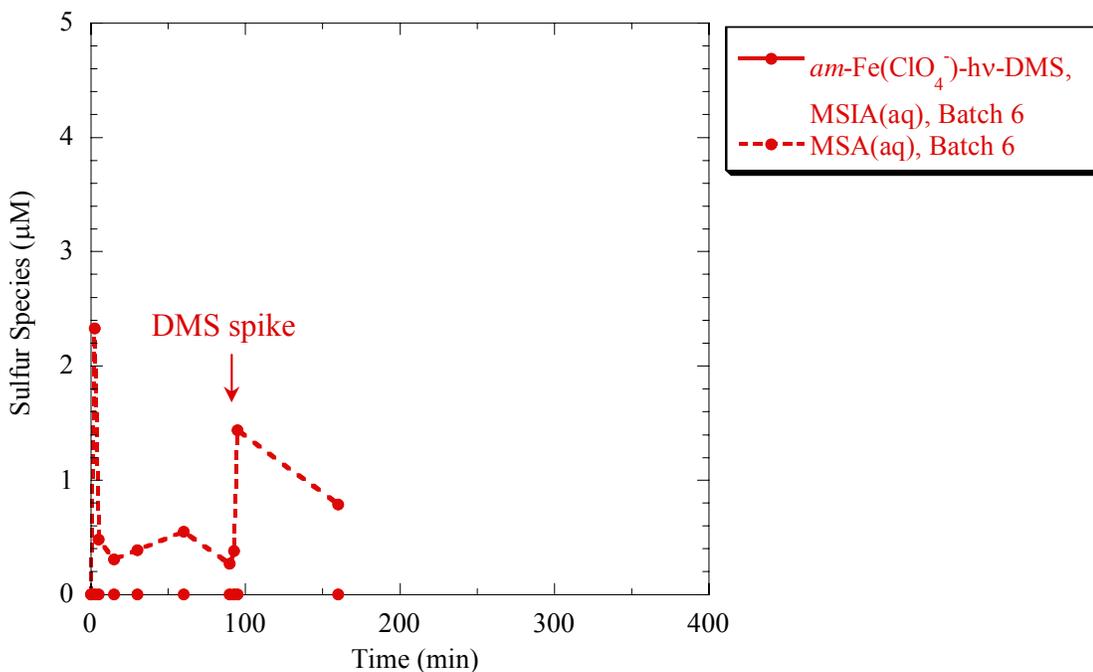


Figure 33. Sulfur oxidation product formation in the presence of ferrihydrite and light, with and without dimethyl sulfide.

which drops below detection limits ( $0.82 \mu\text{M}$ ) prior to the end of the experiment. The pH drops for the experiment and control were 0.22 and 0.52 pH units, respectively.

#### 4.2.3. Dimethyl Sulfoxide

Results from Fe(II),  $\text{H}_2\text{O}_2$ , and S oxidation product measurements in photochemical experiments including *am*-FeOOH and DMSO (run in triplicate) are shown in Figures 34, 35, and 36, respectively. A statistically significant difference in Fe(II) concentration after 6 hours compared to the light control is observed in the presence of DMSO. With DMSO, the Fe(II) concentration in solution increases linearly, dropping only slightly after 90 min (red in Figure 34) compared to the linear increase of the control (orange). This experiment was run in triplicate and error bars of one standard deviation are shown. Error bars are not shown for  $\text{H}_2\text{O}_2$  concentrations, which are an

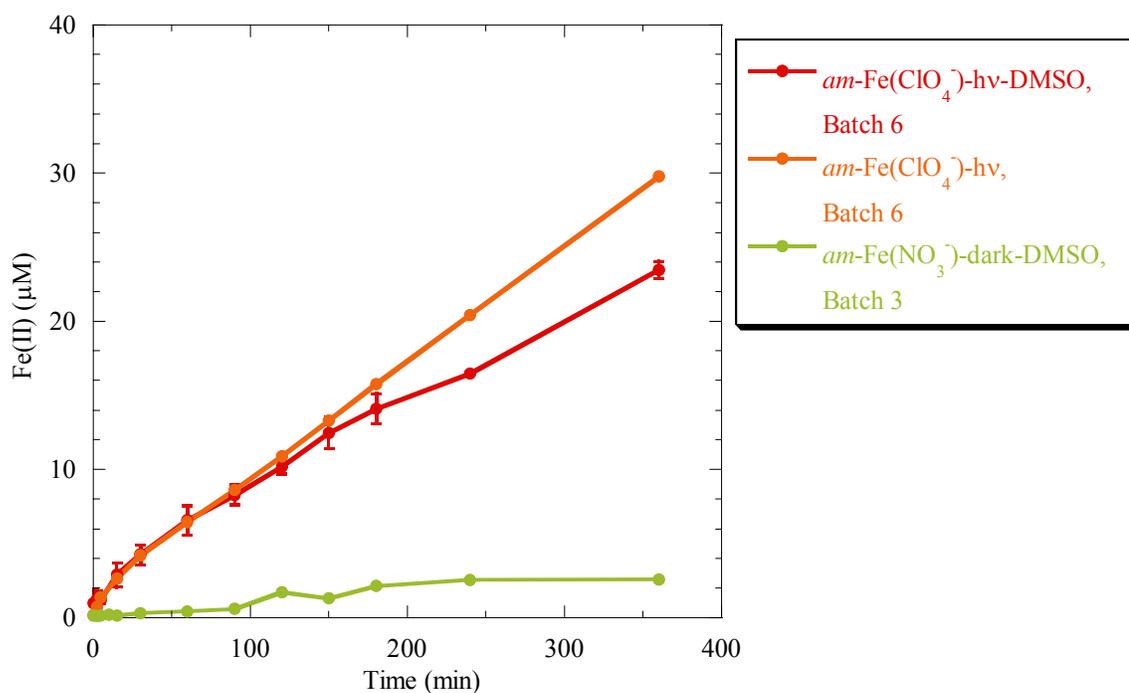


Figure 34. Photoreductive dissolution of ferrihydrite in the presence of light and dimethyl sulfoxide.

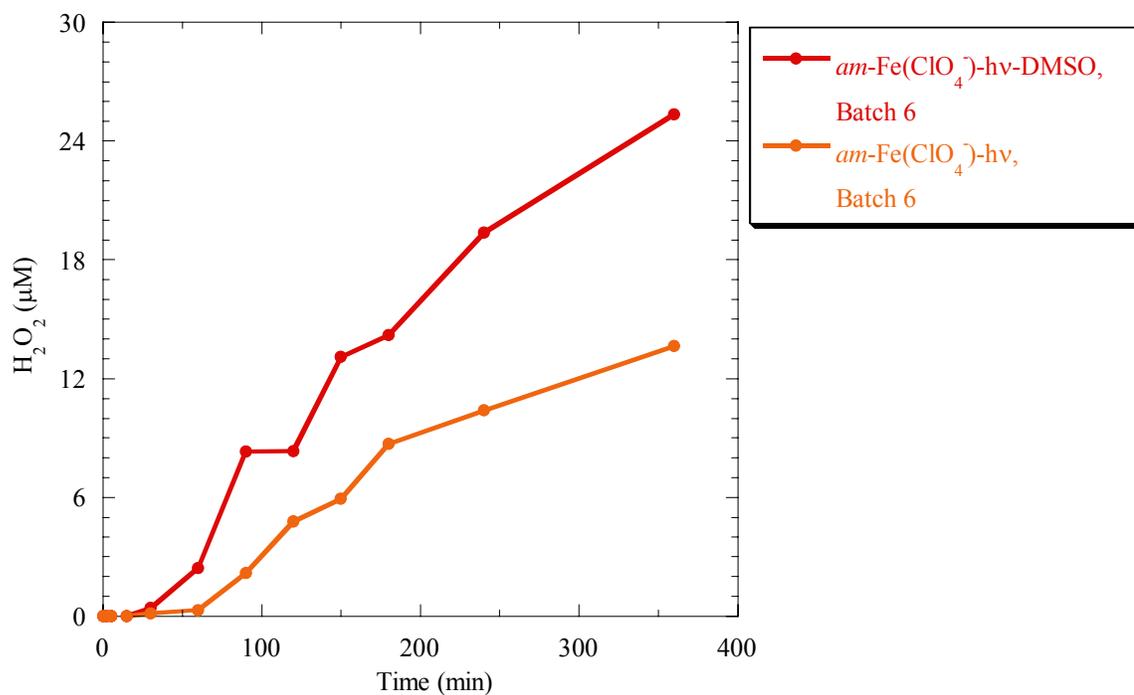


Figure 35. Hydrogen peroxide concentration of ferrihydrite and light, with and without dimethyl sulfoxide.

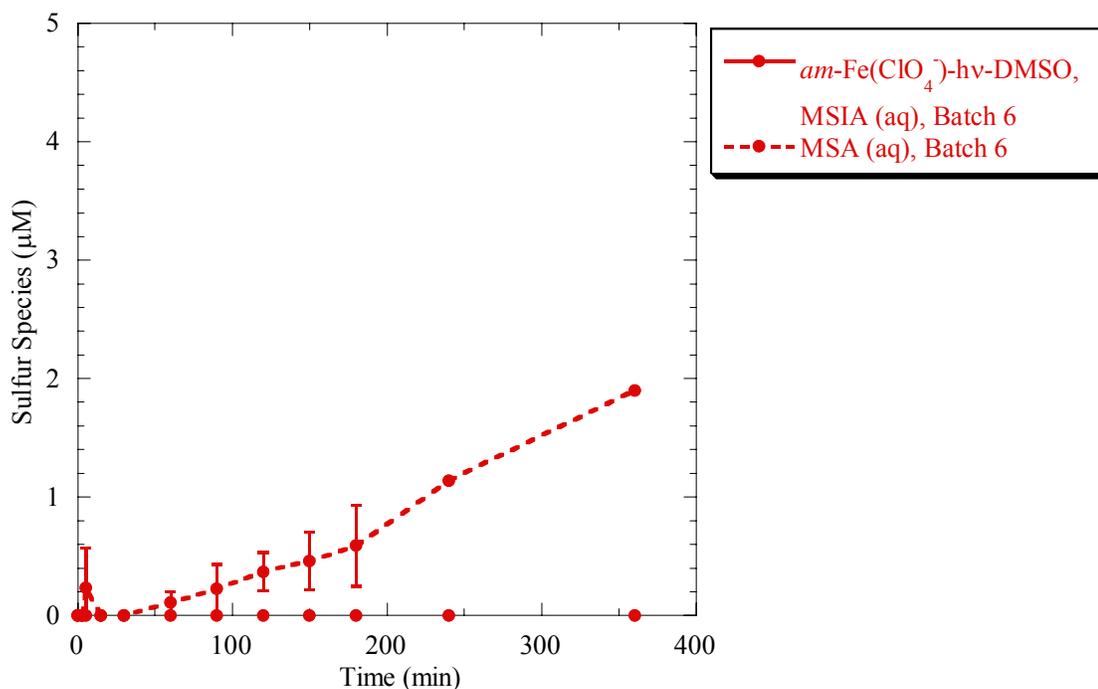


Figure 36. Sulfur oxidation product formation in the presence of ferrihydrite, light, and dimethyl sulfoxide.

average of only two experiments. In comparison, little change was observed in the dark control (green). A dark control using a different batch of *am*-FeOOH (Batch 3) was used for comparison, since a dark control was not collected for these experiments with *am*-FeOOH (Batch 6) and DMSO. This difference between *am*-FeOOH for the dark control is assumed to be insignificant, since reactions were typically not observed in dark controls, other than minor amounts of thermal reactions.

H<sub>2</sub>O<sub>2</sub> steadily increased over time to 24 µM in the experiment with DMSO and 14 µM in the experiment without DMSO (Figure 35). MSA concentrations steadily increase in a similar fashion and reach 2 µM at the end of the *am*-FeOOH-hv-DMSO experiment (Figure 36). This concentration of MSA is above the detection limit of 0.82 µM;

however, it is very low. Values for the light and dark controls remained at zero. The pH drop for the experiment and control was  $0.09 \pm 0.13$  and 0.52 pH units, respectively.

In addition, the effect of an electron donor ( $C_2H_2O_4$ ) and  $HO^\bullet$  source ( $H_2O_2$ ) were investigated for experiments with DMSO. An experiment of *am*-FeOOH with DMSO in the presence of 8  $\mu M$  of  $C_2H_2O_4$  was conducted to confirm the formation of Fe(II) from the photochemical reduction of *am*-FeOOH, as reported by many groups (Emmenegger et al., 2001; Pehkonen et al., 1993). Results indicate a significant rise in Fe(II) levels to a maximum of 270  $\mu M$  followed by a rapid drop after  $C_2H_2O_4$  levels were depleted (Appendix G, Figure G1). No significant difference is observed in the *am*-FeOOH-hv-DMSO experiment with and without added  $H_2O_2$  (1.3 mM). Since these experiments were carried out to test the experimental set up against known reactions, results are presented in Appendix G and will not be discussed in detail.

#### 4.2.3.1. *Effect of Dimethyl Sulfoxide on Different Amorphous Ferrihydrite Batches*

The behavior of different batches varied considerably and is presented as a function of  $NO_3^-$ . However, other parameters (e.g., the degree of crystallinity) may be affecting outcomes, but are hard to quantify.  $NO_3^-$  trapped inside the crystal lattice of *am*-FeOOH during the synthesis process was found to have an effect on the photo-reductive dissolution of *am*-FeOOH and formation of S oxidation products. This  $NO_3^-$ , referred to as interstitial  $NO_3^-$ , exhibits a different effect from  $NO_3^-$  added to experiments.

Results comparing the effect of the amount of interstitial  $NO_3^-$  present between batches of *am*-FeOOH in the presence of light and DMSO are shown for Fe(II),  $H_2O_2$ , and S oxidation products in Figures 37, 38, and 39. For the following figures, Batch 5, 2,

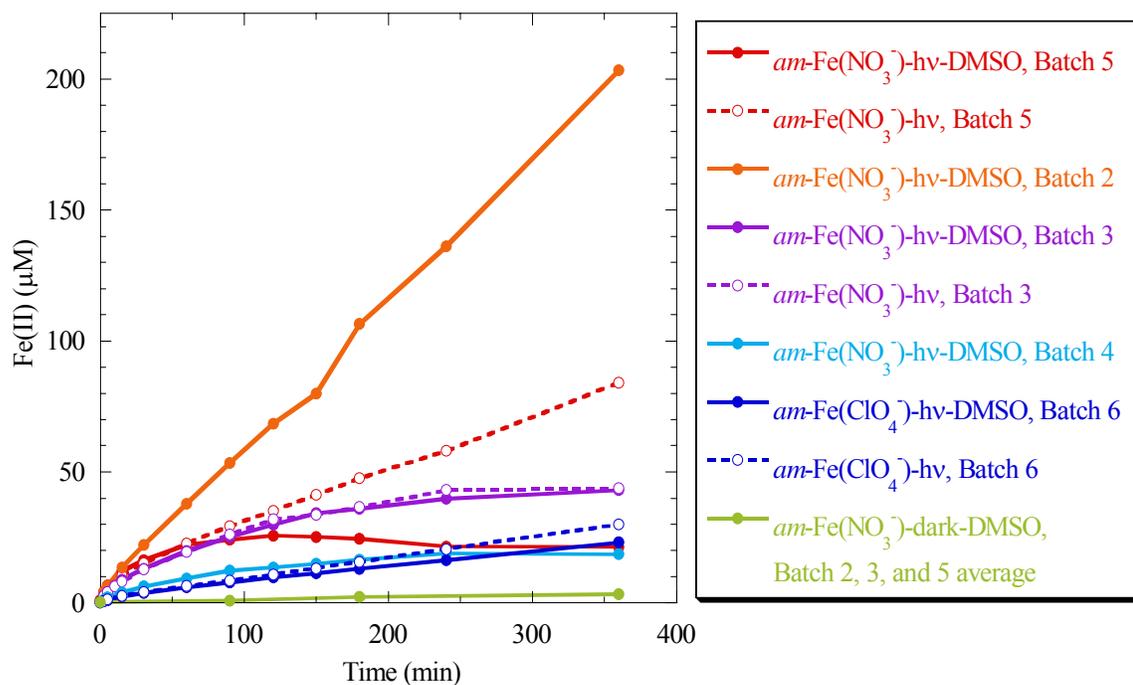


Figure 37. Comparison of iron(II) production for varying amounts of interstitial nitrate in experiments with ferrihydrite, light, and dimethyl sulfoxide.

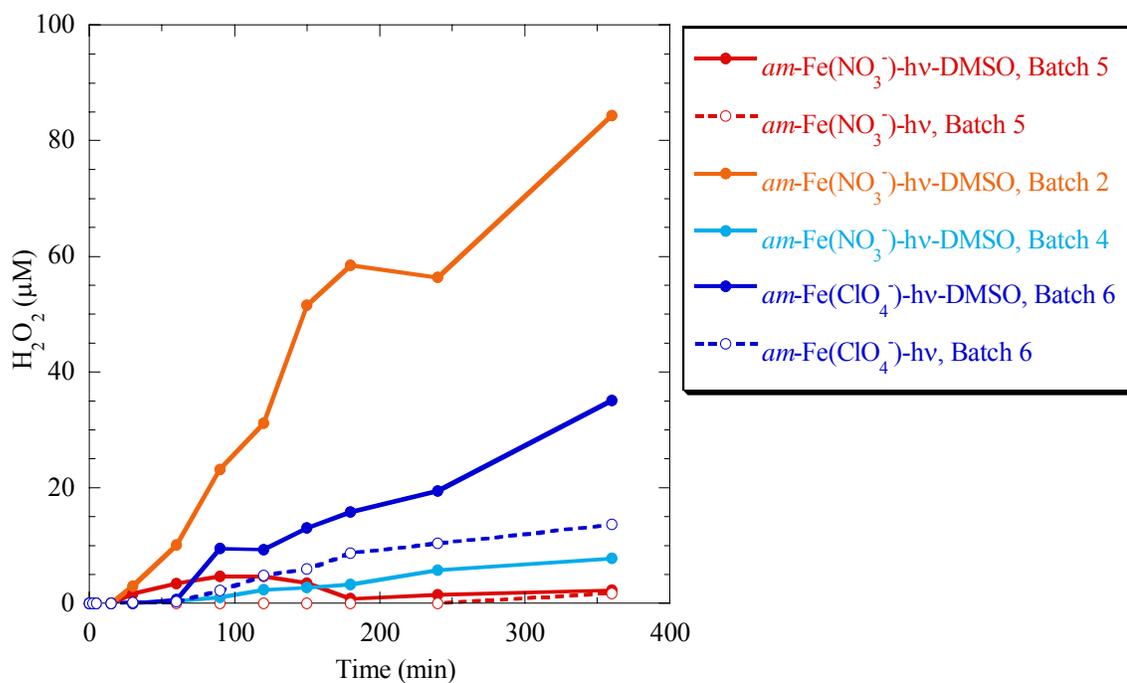


Figure 38. Comparison of hydrogen peroxide production for varying amounts of interstitial nitrate in experiments with ferrihydrite, light, and dimethyl sulfoxide.

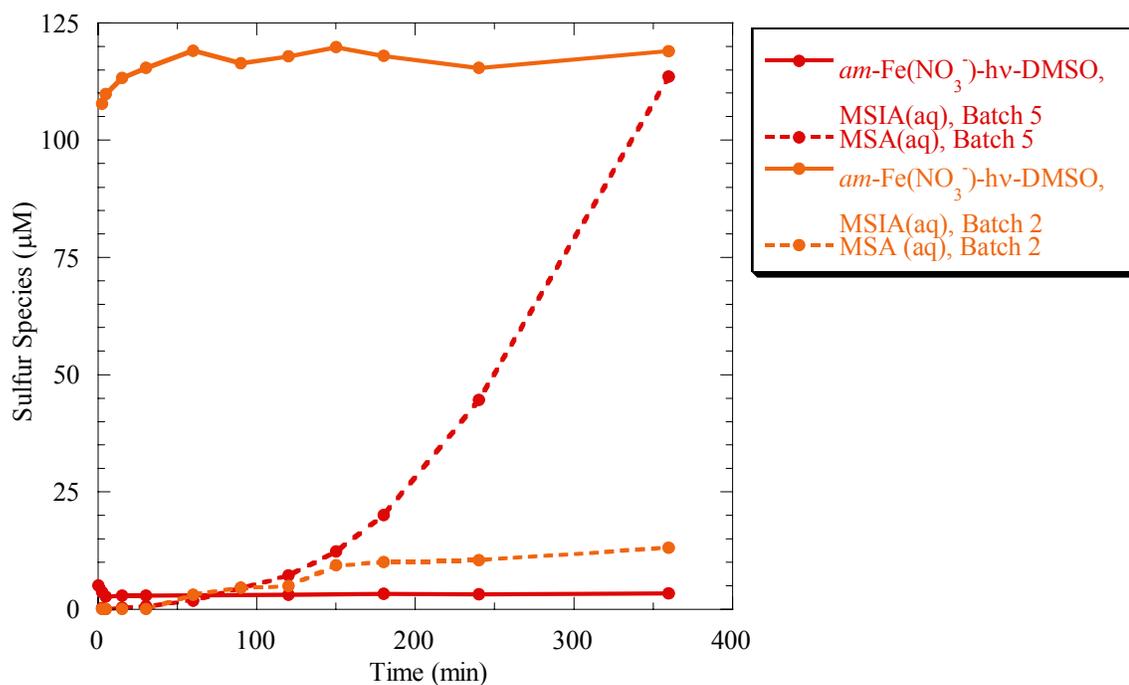


Figure 39. Sulfur oxidation product formation for varying amounts of interstitial nitrate in experiments with ferrihydrite, light, and dimethyl sulfoxide.

3, 4, and 6 (in order of increasing  $\text{NO}_3^-$ ) are shown in red, orange, purple, light blue, and dark blue, respectively. The dark controls are an average of Batches 2, 5, and 3 (green). Batch 1 and its respective light control fall slightly above the Batch 5 light control and is not plotted for simplicity.

The formation of Fe(II) for Batch 2 (orange) in Figure 37 increases most rapidly and in a linear fashion when compared to other batches of *am*-FeOOH, with equivalent and lesser amounts of interstitial  $\text{NO}_3^-$ ; however, a light control for comparison was not collected for Batch 2 (or Batch 4) due to a lack in supply of sample. In general, within the precision of these measurements, lower levels of interstitial  $\text{NO}_3^-$  yielded lower production rates and magnitudes of Fe(II) concentrations in both the light controls and experiments with DMSO. Batch 5 does not follow this pattern.

H<sub>2</sub>O<sub>2</sub> levels (Figure 38) are highest in Batch 2 (~400 μM interstitial NO<sub>3</sub><sup>-</sup>) and increase from 0 to 85 μM by the end of the experiment. Batch 6, which had no interstitial NO<sub>3</sub><sup>-</sup> present, reached H<sub>2</sub>O<sub>2</sub> levels of 35 μM in the presence of DMSO and 15 μM in the light control. Batch 4, which had very low levels of interstitial NO<sub>3</sub><sup>-</sup>, follows a similar trend as the Batch 6 light control and reaches a level of 10 μM. H<sub>2</sub>O<sub>2</sub> data was not collected for Batch 3 (purple) and is, therefore, not available for comparison. Based on these results, H<sub>2</sub>O<sub>2</sub> does not present a simple NO<sub>3</sub><sup>-</sup> dependency.

In terms of S oxidation product formation (Figure 39), Batch 5 and 2, which contain some of the higher levels of interstitial NO<sub>3</sub><sup>-</sup> (600 and 400 μM, respectively), show striking results. For Batch 2, MSIA(aq) remains between 107 and 120 μM throughout the experiment, while MSA(aq) increases from 0 to 15 μM by the end of the experiment. For Batch 5, MSA increases from 0 to 114 μM and MSIA remains at ~4 μM. MSIA(aq) and MSA(aq) concentrations were BDL for the Batch 5 light control, Batch 3 experiment and light control, Batch 4 experiment, Batch 6 experiment and light control, and the dark control. The average pH drop for NO<sub>3</sub><sup>-</sup> batches in the presence of DMSO is  $0.63 \pm 0.89$  pH units. The average pH increases for both light ( $0.53 \pm 0.32$ ) and dark controls ( $0.28 \pm 0.33$ ) for NO<sub>3</sub><sup>-</sup> batches.

In addition, results from Fe(II), H<sub>2</sub>O<sub>2</sub>, and S oxidation product measurement in photochemical experiments including *am*-FeOOH, comparing interstitial NO<sub>3</sub><sup>-</sup> with added NO<sub>3</sub><sup>-</sup> in the presence of DMSO, are shown in Figures 40, 41, and 42, respectively. The experiments in these figures without interstitial NO<sub>3</sub><sup>-</sup> (perchlorate batches) had NO<sub>3</sub><sup>-</sup>

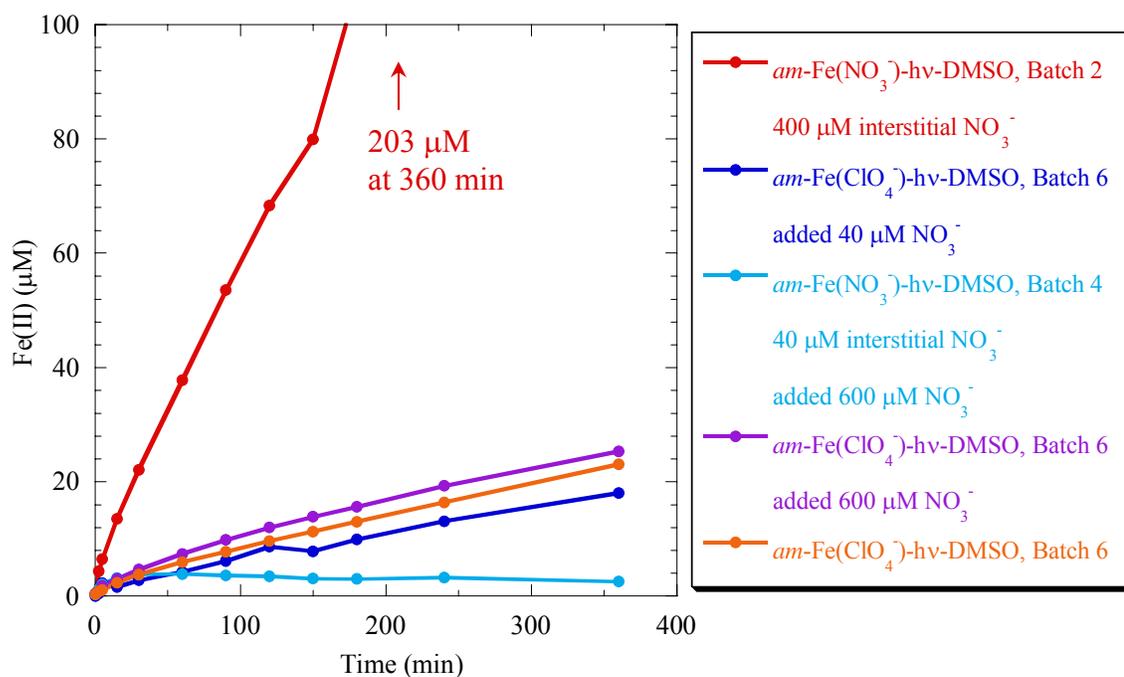


Figure 40. Effect of interstitial versus added nitrate on iron(II) production in experiments with ferrihydrite, light, and dimethyl sulfoxide.

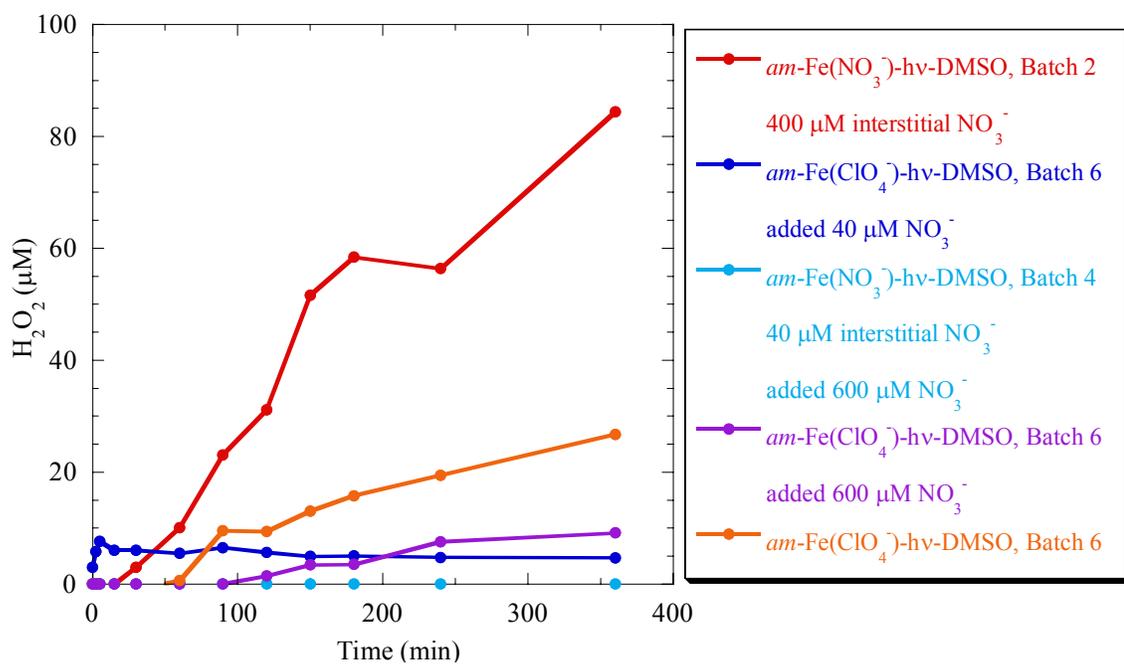


Figure 41. Effect of interstitial versus added nitrate on hydrogen peroxide production in experiments with ferrihydrite, light, and dimethyl sulfoxide.

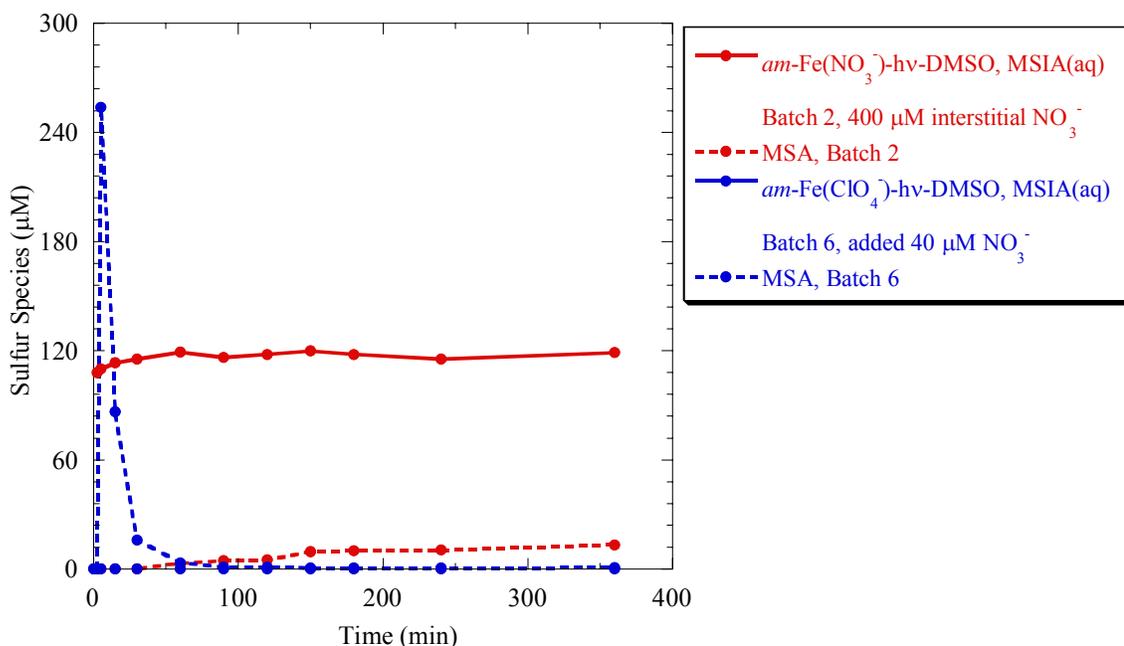


Figure 42. Effect of interstitial versus added nitrate on methane sulfinic acid and methane sulfonic acid concentration in experiments with ferrihydrite, light, and dimethyl sulfoxide.

added to the reaction medium prior to light exposure in both an amount equivalent to the lowest interstitial  $\text{NO}_3^-$  (40  $\mu\text{M}$ , Batch 4) and highest (600  $\mu\text{M}$ , Batch 5).

Levels of Fe(II) production (Figure 40) increase at the fastest rate and are highest (200  $\mu\text{M}$ ) in the experiment with interstitial  $\text{NO}_3^-$  representative of 400  $\mu\text{M}$  of  $\text{NO}_3^-$  in solution (Batch 2). This effect is not observed in the experiments using batches prepared from Fe perchlorate with 600  $\mu\text{M}$   $\text{NO}_3^-$  added, which reach Fe(II) levels of 26  $\mu\text{M}$ . The experiment involving Batch 4, which contained 40  $\mu\text{M}$  of interstitial  $\text{NO}_3^-$ , and an additional 600  $\mu\text{M}$   $\text{NO}_3^-$  yields the lowest levels of Fe(II).

$\text{H}_2\text{O}_2$  levels (Figure 41) follow a similar trend, with the interstitial  $\text{NO}_3^-$  batch (red) yielding the fastest  $\text{H}_2\text{O}_2$  production rate and highest level by the end of the experiment (85  $\mu\text{M}$ ). This level is significantly higher when compared with 10  $\mu\text{M}$  and

15  $\mu\text{M}$   $\text{H}_2\text{O}_2$  observed in the experiments with 40  $\mu\text{M}$  and 600  $\mu\text{M}$  of added  $\text{NO}_3^-$  to perchlorate *am*-FeOOH batches, respectively, and levels near zero for the experiment with Batch 4 (with 40  $\mu\text{M}$  interstitial and 600  $\mu\text{M}$   $\text{NO}_3^-$  added).

S oxidation products remain near zero with some exceptions (Figure 42). In the experiment with 40  $\mu\text{M}$  of  $\text{NO}_3^-$  added (dark blue), an initial sharp jump in MSA levels from zero to 250  $\mu\text{M}$  is observed. These levels immediately drop to zero after the first hour of radiation. Interestingly, MSIA(aq) levels for the experiment with interstitial  $\text{NO}_3^-$  (red) start at 120  $\mu\text{M}$ , while MSA(aq) levels slowly increase to 12  $\mu\text{M}$ . Batch 4, Batch 6 (with 600  $\mu\text{M}$   $\text{NO}_3^-$  added), and the Batch 6 light control were not plotted for simplicity. In experiments with added  $\text{NO}_3^-$  the pH increases an average of  $0.30 \pm 0.24$  pH units.

#### 4.2.3.2. Dimethyl Sulfoxide and the Air Mass 1 Filter Effect

For selected photochemical experiments with DMSO, the AM 1 filter was removed prior to light exposure, resulting in an increased dose of UV radiation during the experiment. This increase in UV radiation seems to lead to enhanced Fe(II) and S oxidation product formation in experiments with *am*-FeOOH containing  $\text{NO}_3^-$  impurities in the presence of DMSO.

Results comparing the effect of the presence and absence of the AM 1 filter for Batch 1, 3, 5, and 6 of *am*-FeOOH in the presence of light and DMSO are shown for Fe(II) and S oxidation products in the following figures. Fe(III) and  $\text{H}_2\text{O}_2$  results are shown only when the data is available. Results of the AM 1 filter effect for Batch 2 of *am*-FeOOH in the presence of light and DMSO are not shown for the following reasons: the *am*-Fe( $\text{NO}_3^-$ )-hv-DMSO experiment with the AM 1 filter was not run until several

months after the experiments without the filter and there was no light control (with the AM 1) for this experiment. These factors make comparison of the AM 1 effect for Batch 2 experiments difficult.

Results from Batch 1 are shown in Figures 43 and 44. In Figure 43, the experiment with DMSO and no AM 1 filter (red) was run in triplicate and standard error bars are plotted. Fe(II) formation in both the light controls and experiment with DMSO added is much higher in the absence of the AM 1 filter (dark and light blue) compared with experiments when it was in place (red and orange). In the presence of DMSO (dark blue), Fe(II) levels slowly increase, followed by a sharp increase from 10 to 185  $\mu\text{M}$  after an hour of radiation. These levels begin to level off and reach 200  $\mu\text{M}$  by the end of the experiment. Levels in the light control are initially higher than the experiment with

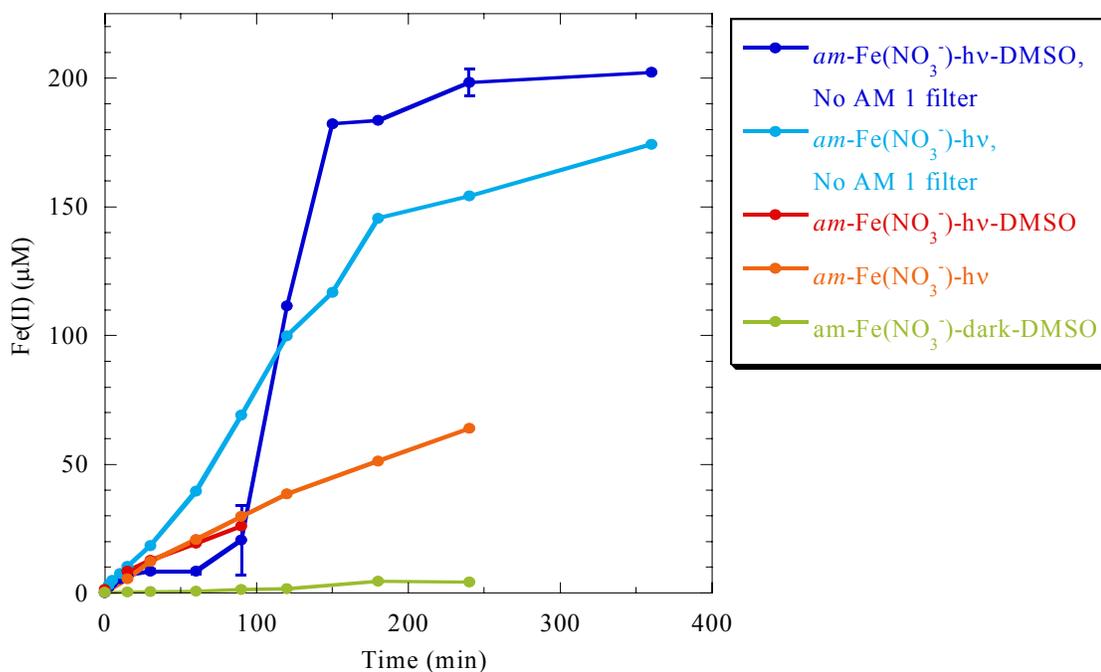


Figure 43. Effect of removal of the Air Mass 1 filter in experiments with ferrihydrite (Batch 1), light, and dimethyl sulfoxide on iron(II) production.

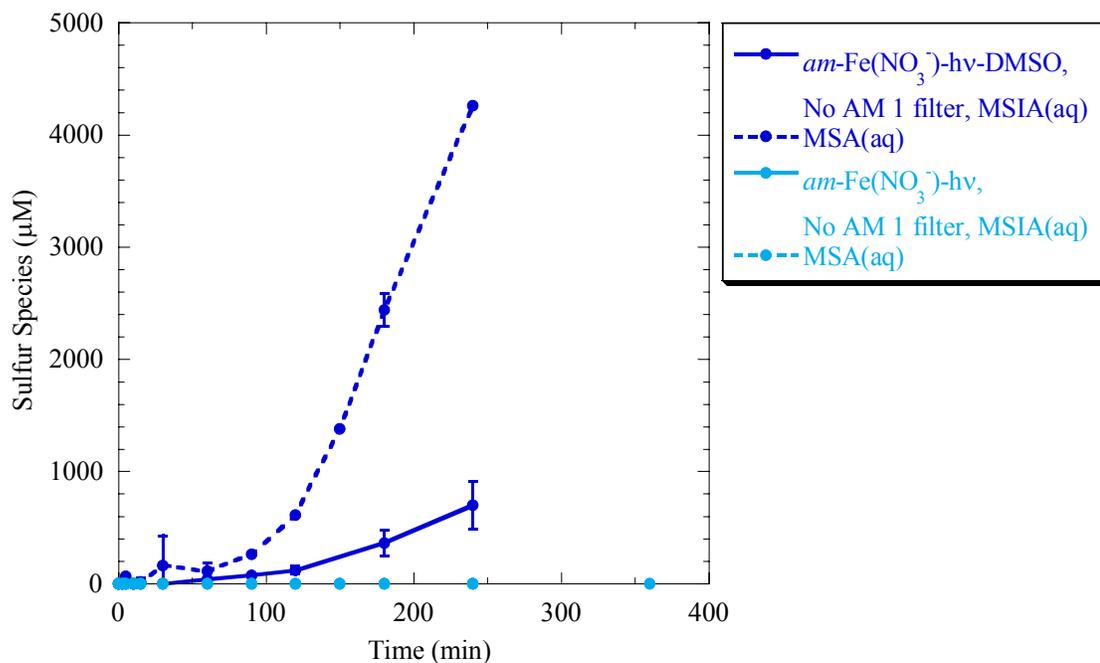


Figure 44. Effect of removal of the Air Mass 1 filter in experiments with ferrihydrite (Batch 1), light, and dimethyl sulfoxide on methane sulfinic acid and methane sulfonic acid formation.

DMSO present; however, by the end of the experiment these levels are lower, though they steadily increase throughout the experiment to 175  $\mu\text{M}$ . The experiment with DMSO and the AM 1 filter in place follows a similar trend as the light control, which steadily increases up to 65  $\mu\text{M}$ . Because these were initial photochemical experiments, data was only collected up to 90 and 240 min for the experiments with the AM 1 filter and the dark control. Fe(II) levels in the dark control remain near zero.

In Figure 44, MSIA(aq) and MSA(aq) levels increase in an exponential manner for the experiment with DMSO and no AM 1 filter, reaching 800 and 4400  $\mu\text{M}$ , respectively, by the end of the experiment at 240 min. Though these concentrations appear to be high, they represent only 2.3% and 12.6%, respectively, of total DMSO

added ( $35,000 \mu\text{M}$ ). S product levels remain near zero for the experiment, light, and dark control (all with the AM 1 filter present) and are not shown for simplicity.

Results comparing the effect of the presence and absence of the AM 1 filter for Batch 3 of *am*-FeOOH in the presence of light and DMSO are shown for Fe(II) and S oxidation products in Figures 45 and 46. It is important to note that Batch 3 underwent longer dialysis and has less than  $\sim 1/4$  the  $\text{NO}_3^-$  impurity ( $90 \mu\text{M}$ ) than Batch 1.

In Figure 45, Fe(II) levels from the experiment in the presence of DMSO and the light control slowly increase and appear to start leveling off after 240 min to  $\sim 45 \mu\text{M}$ . Similar levels are observed in the experiment without the AM 1 filter, but at the beginning Fe(II) production is slightly less while after 180 min the Fe(II) surpasses

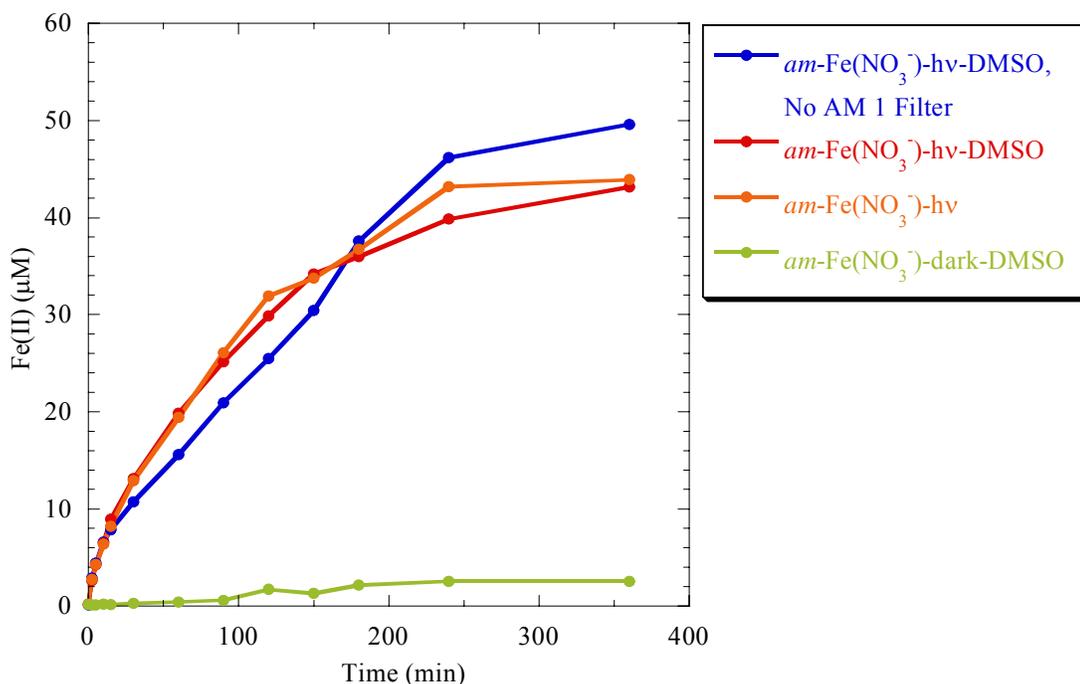


Figure 45. Effect of removal of the Air Mass 1 filter in experiments with ferrihydrite (Batch 3), light, and dimethyl sulfoxide on iron(II) production.

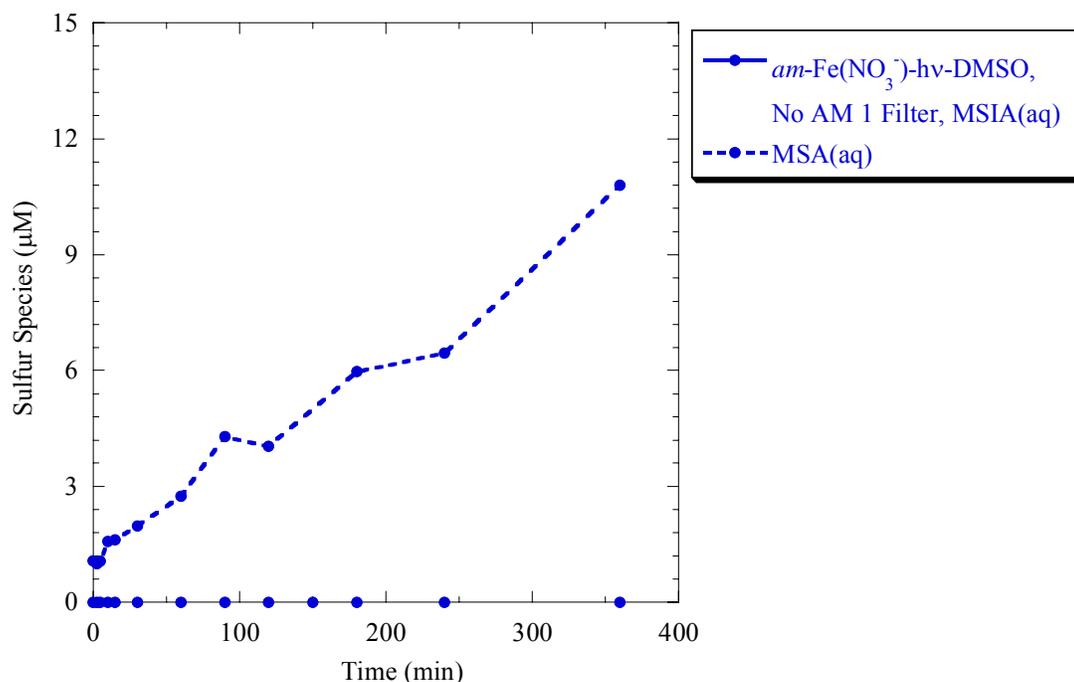


Figure 46. Effect of removal of the Air Mass 1 filter in experiments with ferrihydrite (Batch 3), light, and dimethyl sulfoxide on methane sulfinic acid and methane sulfonic acid formation.

that in the experiment with the AM 1 filter. A light control without the AM 1 filter is not available for comparison.

Of S products, only MSA(aq) displays values above detection limits in the DMSO experiment without the AM 1 filter (Figure 46). MSA(aq) concentration slowly increases to 10  $\mu\text{M}$  at 180 min. By the end of the experiment, the MSA(aq) concentration reaches 12  $\mu\text{M}$ . This is substantially lower than what is observed for Batch 1 and no MSIA is observed. Again, the experiment, light, and dark control (all with AM 1 filter present) are BDL and not shown for simplicity.

Results for Batch 5, including Fe(III) and  $\text{H}_2\text{O}_2$  data, are presented in Figures 47 to 51. In terms of interstitial  $\text{NO}_3^-$ , Batch 5 contains about double the  $\text{NO}_3^-$  of Batch 1

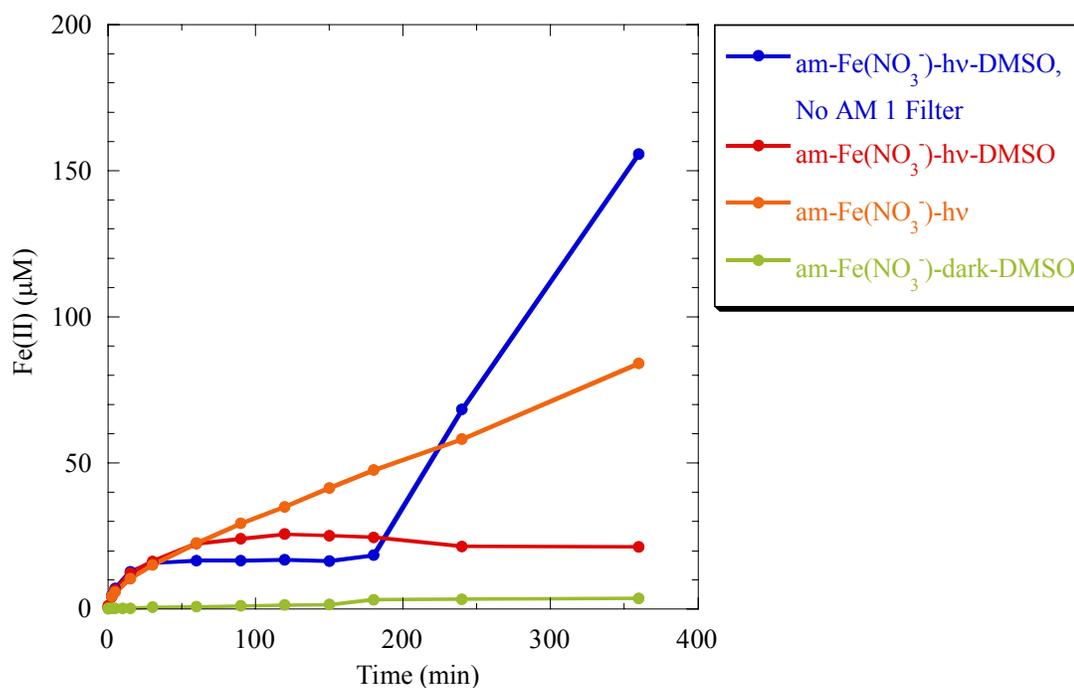


Figure 47. Effect of removal of the Air Mass 1 filter in experiments with ferrihydrite (Batch 5), light, and dimethyl sulfoxide on iron(II) production.

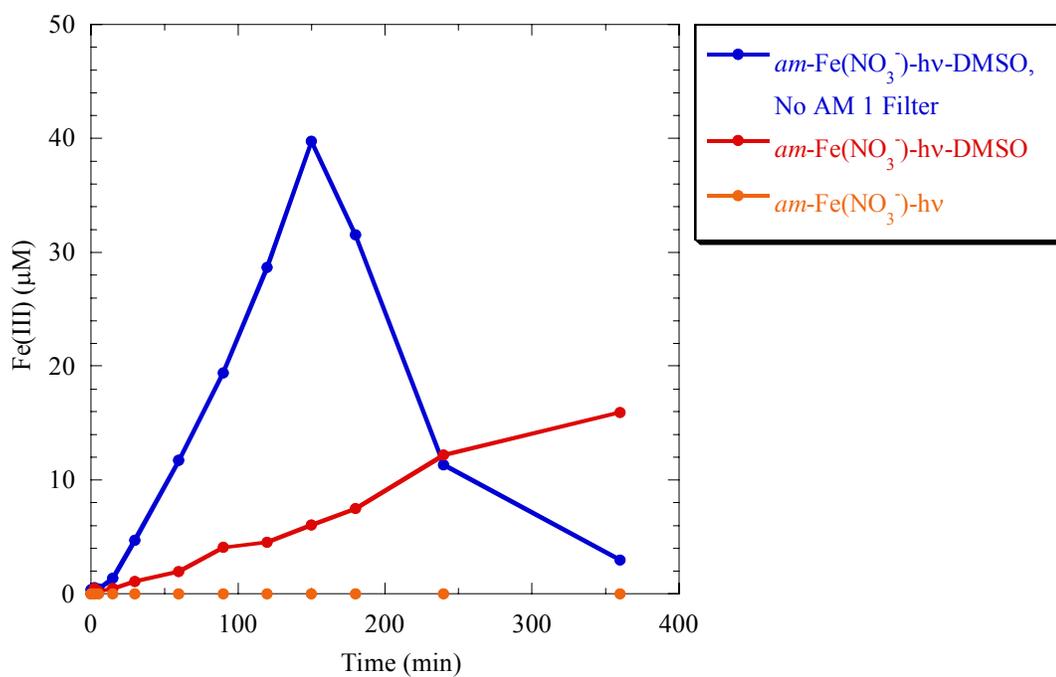


Figure 48. Effect of removal of the Air Mass 1 filter in experiments with ferrihydrite (Batch 5), light, and dimethyl sulfoxide on iron(III) formation.

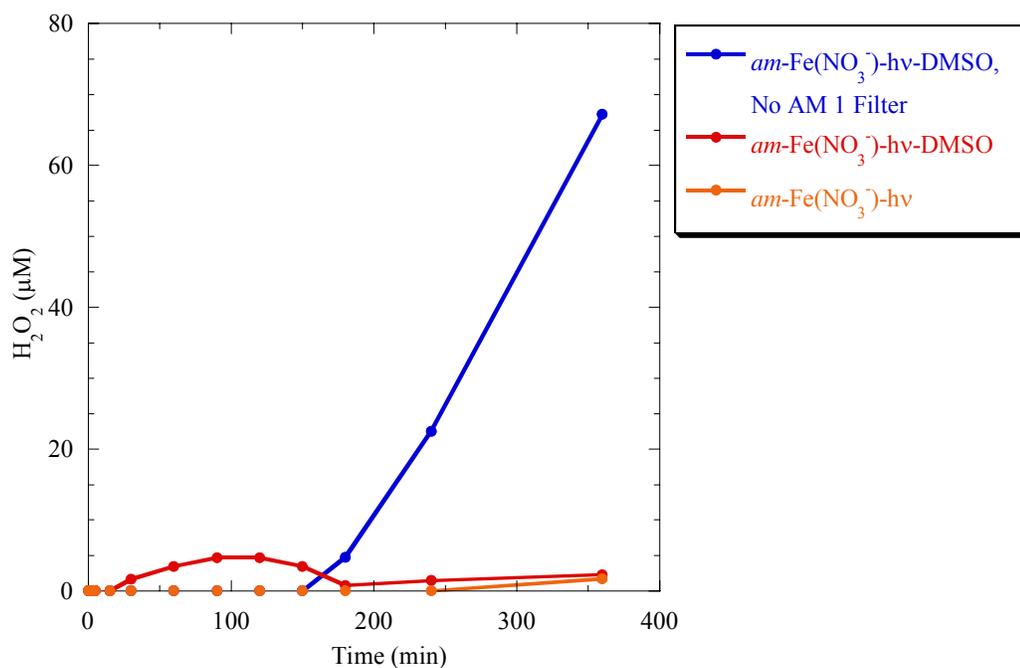


Figure 49. Effect of removal of the Air Mass 1 filter in experiments with ferrihydrite (Batch 5), light, and dimethyl sulfoxide on hydrogen peroxide formation.

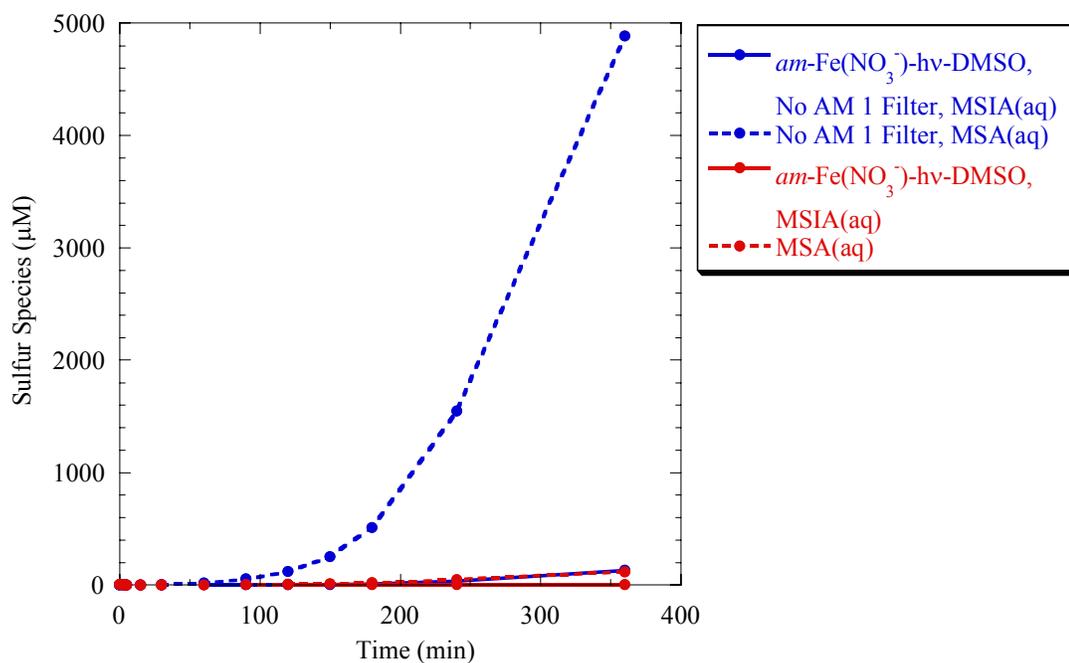


Figure 50. Effect of removal of the Air Mass 1 filter in experiments with ferrihydrite (Batch 5), light, and dimethyl sulfoxide on methane sulfinic acid and methane sulfonic acid formation.

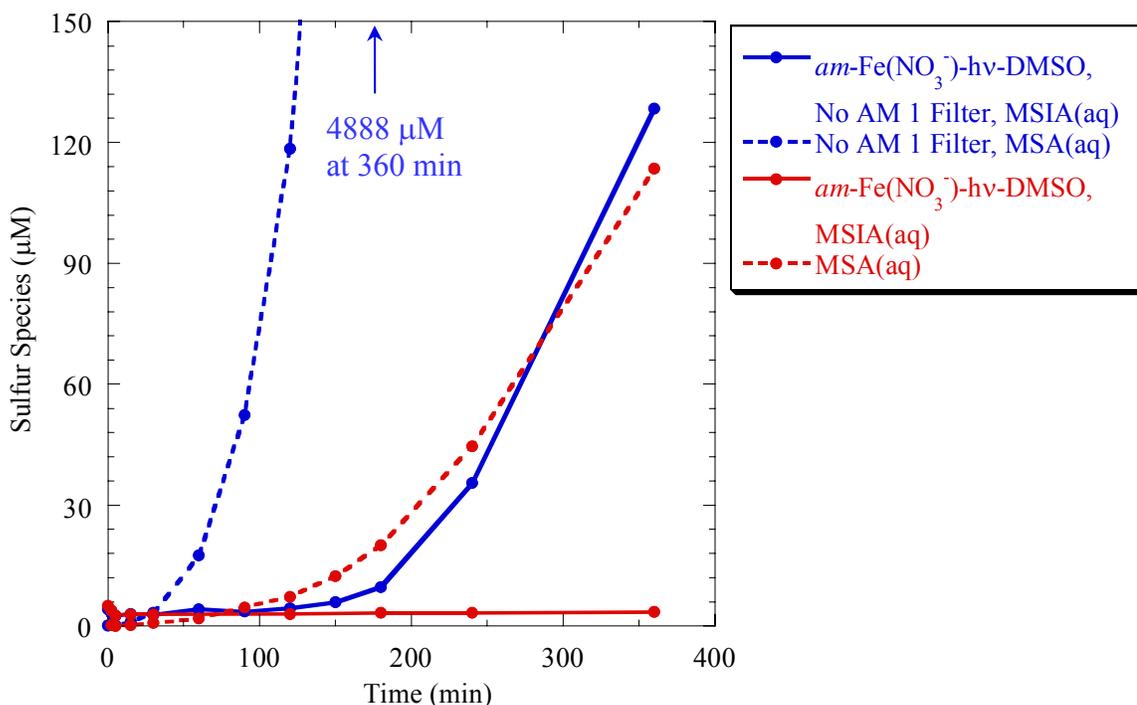


Figure 51. Enlargement of Figure 50 (Batch 5).

(600  $\mu\text{M}$  vs. 350  $\mu\text{M}$ ). There is no light control for the experiment without the AM 1 filter. Similar to what is observed for Batch 1, Fe(II) concentrations in the presence of DMSO and no AM 1 filter are suppressed until 180 min into the experiment, when Fe(II) increases drastically in conjunction with  $\text{H}_2\text{O}_2$  (Figure 49) and MSA (Figures 50 and 51). Interestingly, in the DMSO experiment without the AM 1 filter, Fe(III) levels reach 40  $\mu\text{M}$  after 150 min and then drop to 2  $\mu\text{M}$  by the end of the experiment (Figure 48), while in the same experiment with the filter, Fe(III) levels steadily increase up to 16  $\mu\text{M}$ .

In terms of S oxidation products (Figure 50 and 51), MSA(aq) rises exponentially to levels near 5000  $\mu\text{M}$  by 360 min in the DMSO experiment without the AM 1 filter, while MSIA(aq) concentrations increase to 200  $\mu\text{M}$ . The pattern is similar to what was seen for Batch 1; however, by the end of the experiment for Batch 5, concentrations are

lower by factors of 4 and 17 for MSA and MSIA, respectively. The light and dark controls remained at zero and are not shown for simplicity. The pH was averaged for Batches 1 and 5 and was found to have dropped  $1.10 \pm 0.36$  without the AM 1 filter versus an average of  $0.01 \pm 0.52$  with the filter.

Results for Batch 6 are shown in Figures 52, 53, and 54. Batch 6 has no  $\text{NO}_3^-$  impurities as it is made from Fe perchlorate; however,  $\text{NO}_3^-$  was added in both an experiment with and without the AM 1 filter to observe its effect. There is no light control for the experiment without the AM 1 filter. Both DMSO experiments, with and without the filter, and the light control with the filter follow a similar trend for Fe(II) production with final Fe(II) concentrations lower than for Batches 1, 3, and 5 presented above. In Figure 53,  $\text{H}_2\text{O}_2$  levels are lowest for the DMSO experiment without the filter,

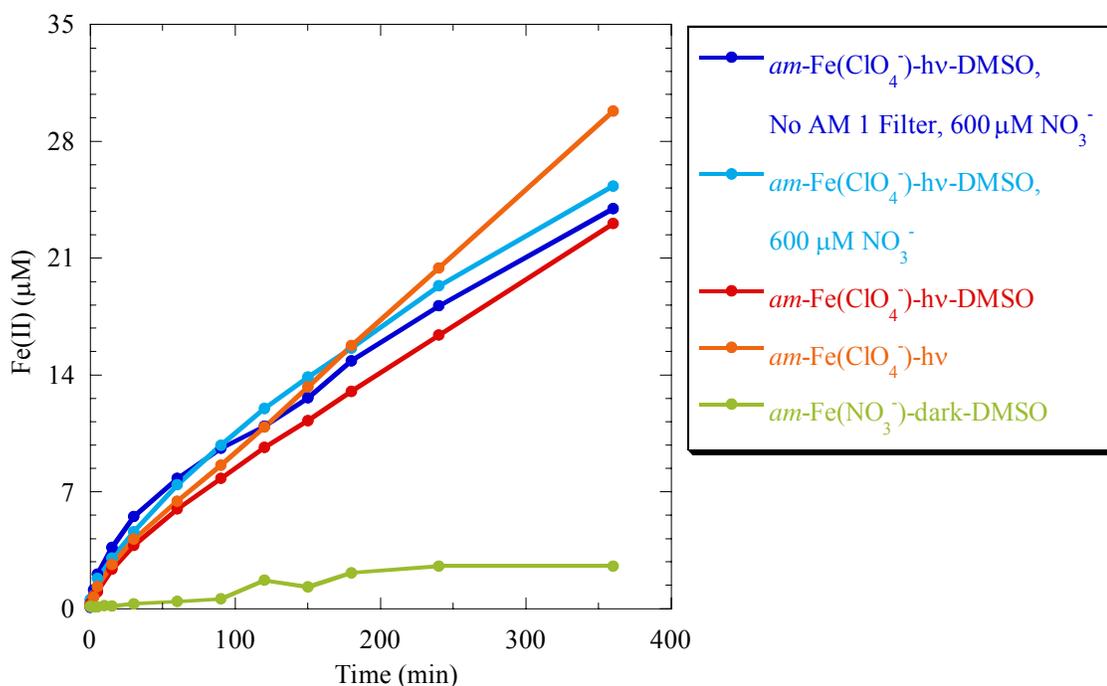


Figure 52. Effect of removal of the Air Mass 1 filter in experiments with ferrihydrite (Batch 6), light, and dimethyl sulfoxide on iron(II) production.

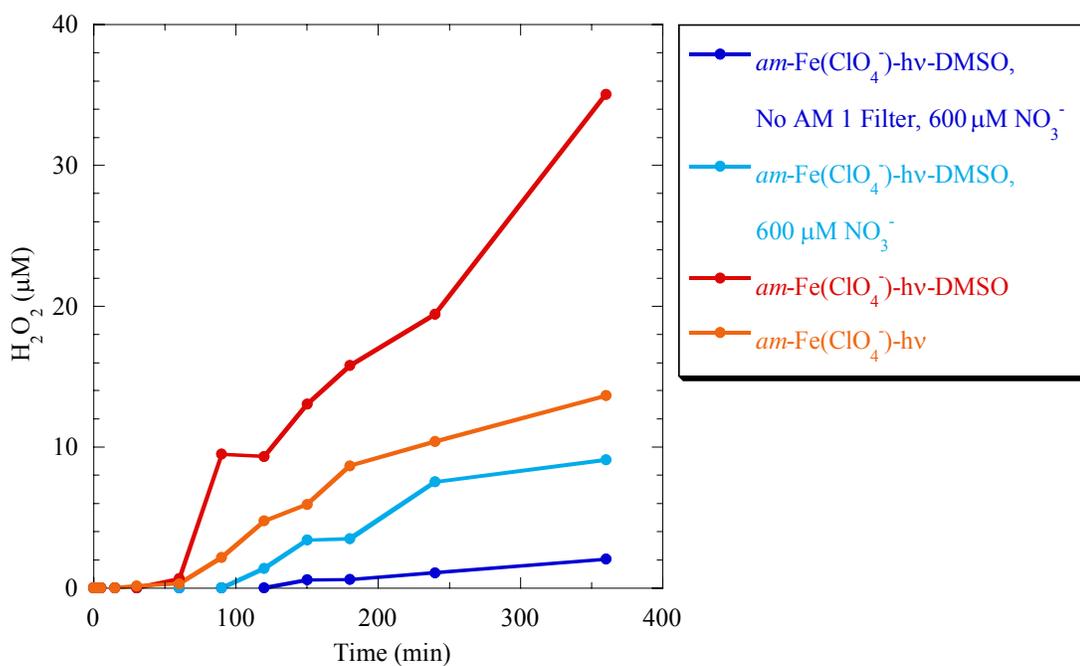


Figure 53. Effect of removal of the Air Mass 1 filter in experiments with ferrihydrite (Batch 6), light, and dimethyl sulfoxide on hydrogen peroxide formation.

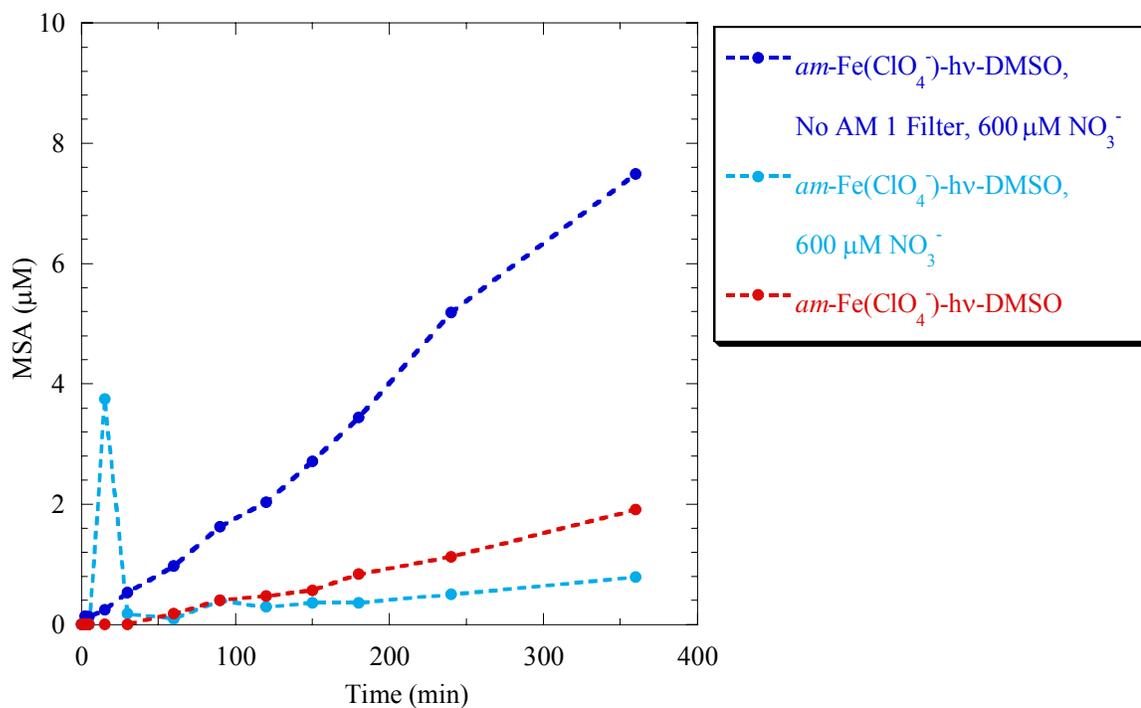


Figure 54. Effect of removal of the Air Mass 1 filter in experiments with ferrihydrite (Batch 6), light, and dimethyl sulfoxide on methane sulfonic acid formation.

reaching 2  $\mu\text{M}$ . With the filter,  $\text{H}_2\text{O}_2$  concentrations reach 9  $\mu\text{M}$  with DMSO and  $\text{NO}_3^-$  and 14  $\mu\text{M}$  in the control without DMSO. The largest  $\text{H}_2\text{O}_2$  concentrations are observed for DMSO with the AM 1 filter. MSA(aq) levels (Figure 54) are very low and steadily increase up to 8  $\mu\text{M}$  in the absence of the filter. With the filter, MSA levels increase to only 1  $\mu\text{M}$  and are lower than the experiment without  $\text{NO}_3^-$ . All MSIA(aq) and MSA(aq) concentrations for the light and dark control remained at zero and are not plotted for simplicity. The pH is averaged for Batches 3 and 6 and increases to 0.58 without the AM 1 filter versus an average drop of  $0.09 \pm 0.13$  with the filter.

#### 4.2.4. *Dimethyl Sulfone*

Results from Fe(II),  $\text{H}_2\text{O}_2$ , and S oxidation product measurement in photochemical experiments including *am*-FeOOH and  $\text{DMSO}_2$  are shown in Figures 55, 56, and 57, respectively. Dark controls were not collected. The photoreductive dissolution of Fe in the presence of  $\text{DMSO}_2$  (red in Figure 55) shows almost an identical trend to the light control without  $\text{DMSO}_2$ . However,  $\text{H}_2\text{O}_2$  levels steadily increase until nearing 100  $\mu\text{M}$  at the end of the experiment with  $\text{DMSO}_2$  (red in Figure 56) while levels in the light control increase at a slower rate to  $\sim 24$   $\mu\text{M}$  by the end of the experiment.

Only MSA was detected and only in the Fe-hv- $\text{DMSO}_2$  experiment, where it started at about 4 and increased to 6.7  $\mu\text{M}$  during the experiment (Figure 57). The pH in the experiment dropped 0.47 pH units, while the light control dropped 0.52 pH units.

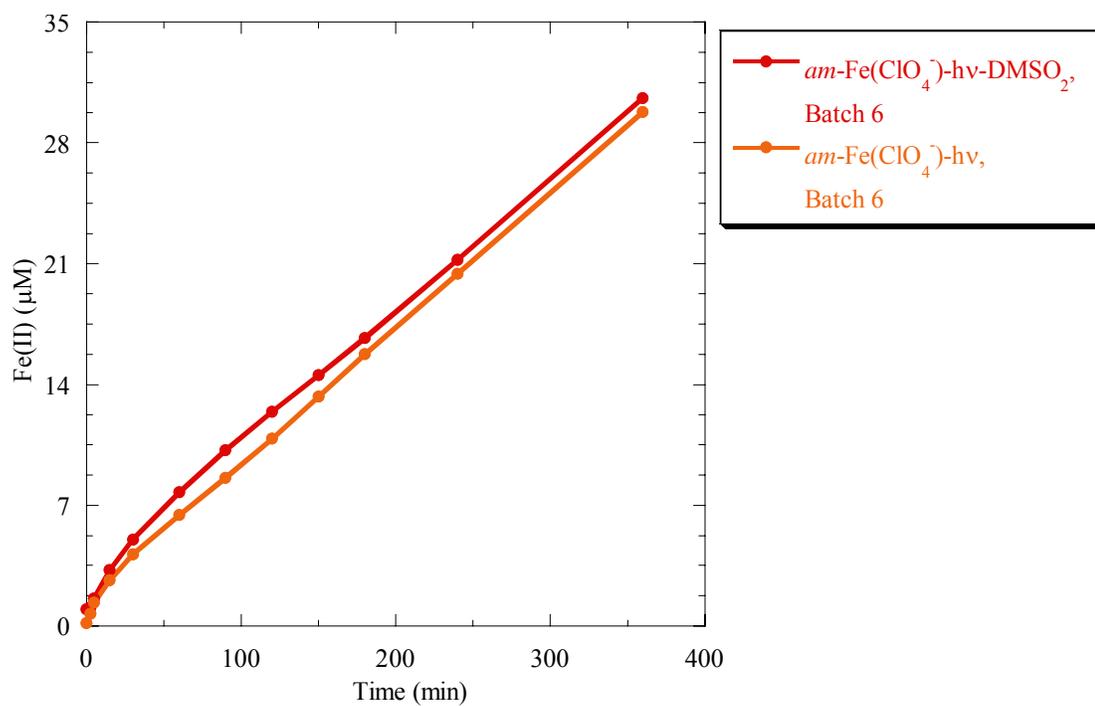


Figure 55. Photoreductive dissolution of ferrihydrite in the presence of light and dimethyl sulfone.

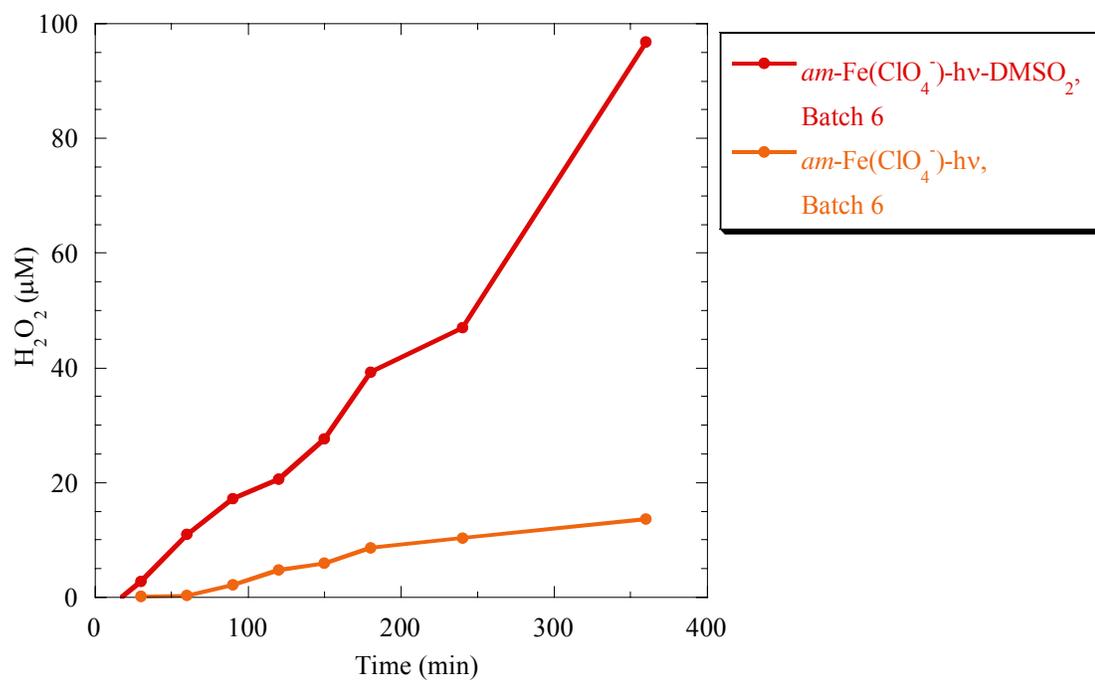


Figure 56. Hydrogen peroxide concentration of ferrihydrite in the presence of light and dimethyl sulfone.

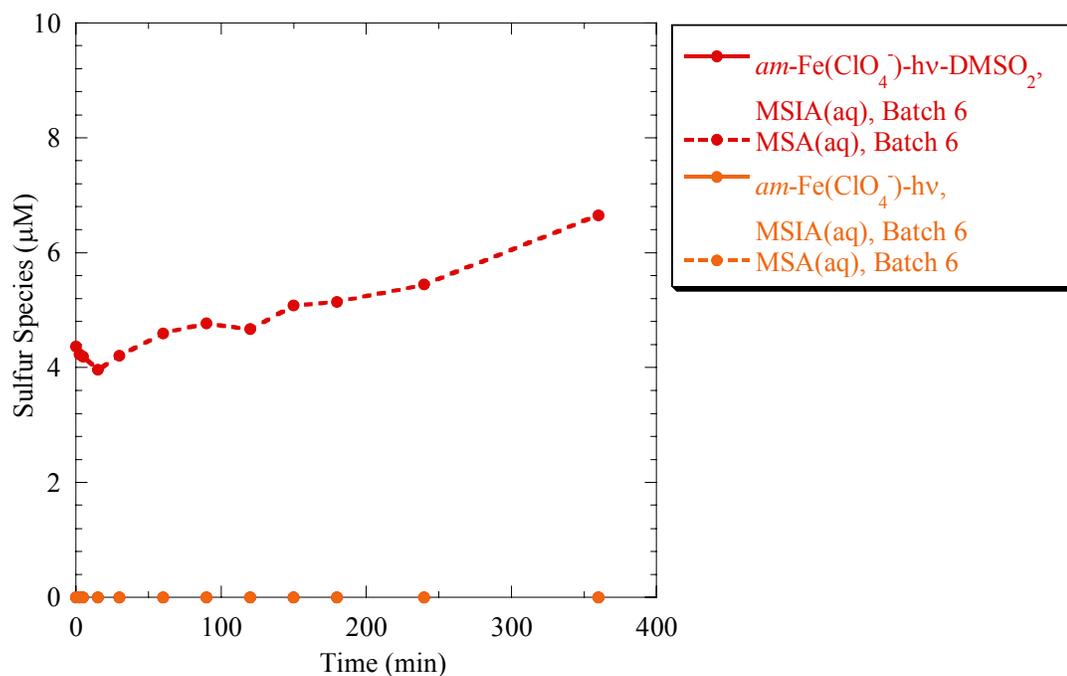


Figure 57. Sulfur oxidation product formation in the presence of ferrihydrite, light, and dimethyl sulfone.

#### 4.2.5. Methane Sulfinic Acid

Results from Fe(II), H<sub>2</sub>O<sub>2</sub>, and S oxidation product measurement during photochemical experiments including *am*-FeOOH and MSIA are shown in Figures 58, 59, and 60, respectively. The Fe(II) concentration in solution rapidly increases in the presence of MSIA and begins to level off after 90 min (red in Figure 58). The concentration of Fe(II) steadily increases in a linear fashion in the light control (orange); however, this increase is not as rapid or of the magnitude that is observed in the presence of MSIA by the end of the experiment. In comparison, little change is observed in the dark control (green).

H<sub>2</sub>O<sub>2</sub> levels are higher when *am*-FeOOH is in the presence of MSIA; however, H<sub>2</sub>O<sub>2</sub> levels began dropping after ~1 hour down to 24 µM by the end of the experiment

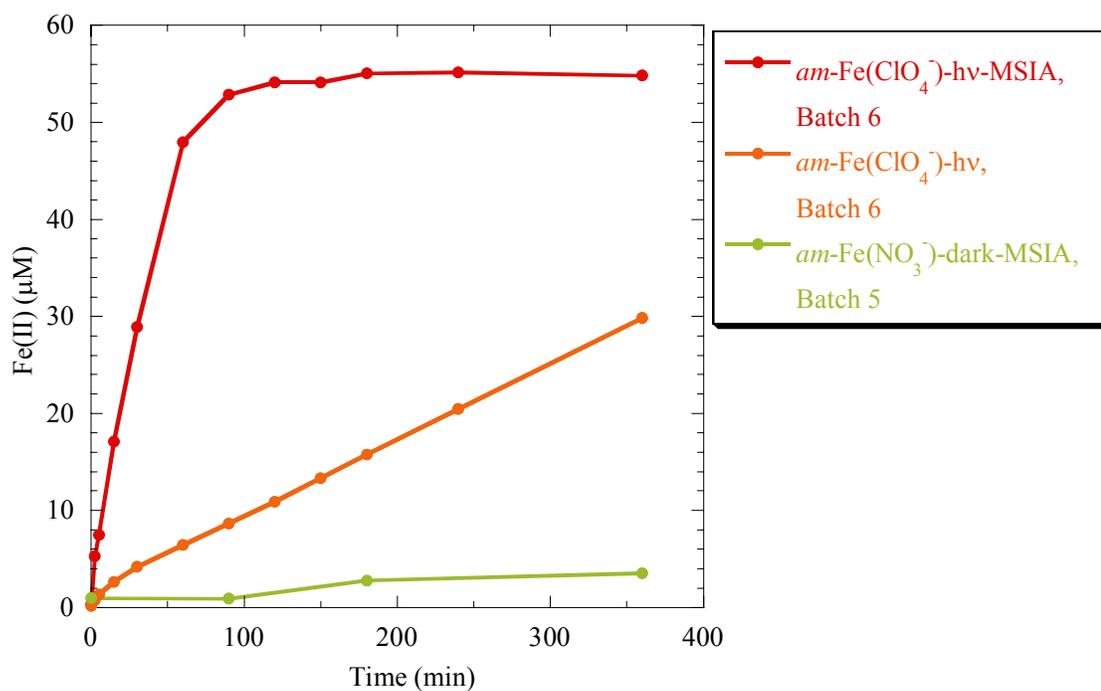


Figure 58. Photoreductive dissolution of ferrihydrite in the presence of light and methane sulfinic acid.

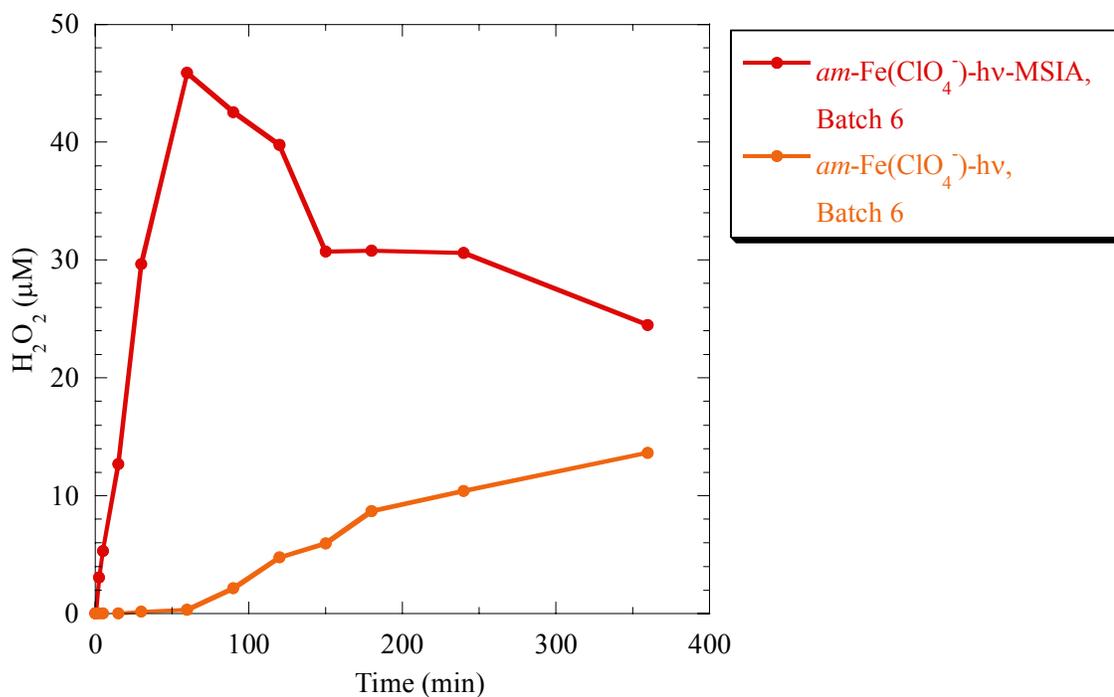


Figure 59. Hydrogen peroxide concentration of ferrihydrite, light, and methane sulfinic acid with light control.

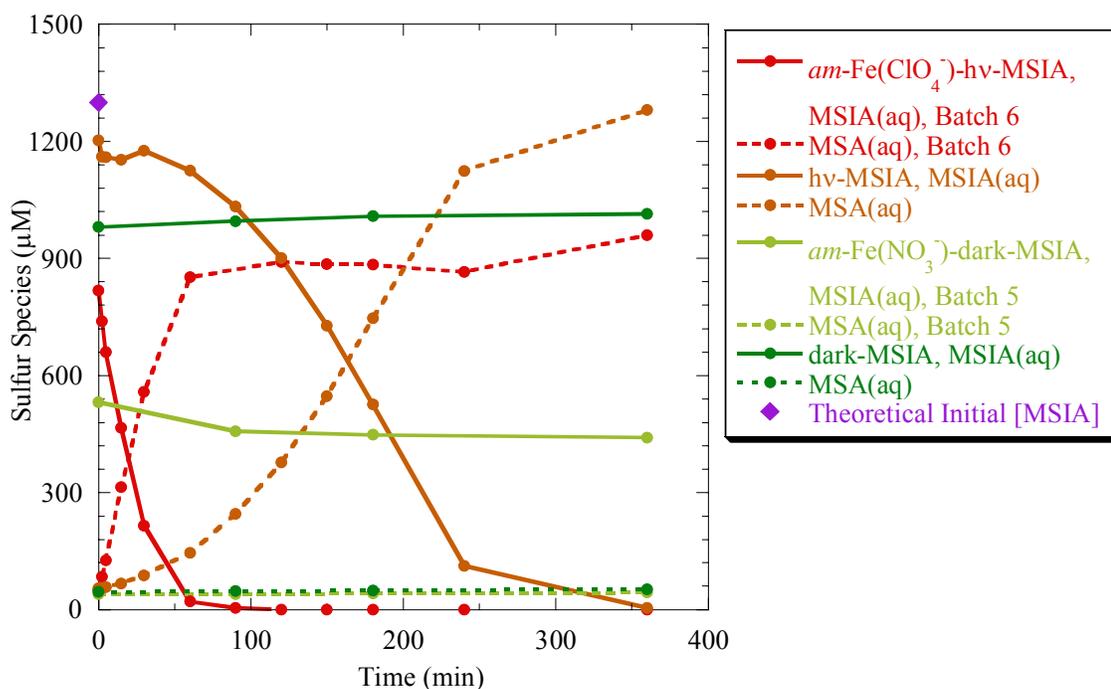


Figure 60. Sulfur oxidation product formation in the presence of ferrihydrite, light, and methane sulfonic acid with respective light and dark controls.

(Figure 59).  $\text{H}_2\text{O}_2$  levels in the light control steadily increase over time, but the rate of increase is slower with a concentration of  $14 \mu\text{M}$  by the end of the experiment.  $\text{H}_2\text{O}_2$  is not observed in the dark control with *am*-FeOOH and MSIA or the MSIA-light and MSIA-dark controls, which are not plotted for simplicity.

In addition, the concentration of MSIA in solution rapidly decreases as the concentration of MSA(aq) increases (red in Figure 60) in an almost perfect mass balance when *am*-FeOOH is in the presence of light and MSIA. A similar trend, however slower, is observed in the absence of *am*-FeOOH (ochre). Initial MSIA(aq) and final MSA(aq) concentrations are more comparable to the theoretical initial MSIA(aq) concentration of  $1300 \mu\text{M}$  (shown in purple) in the latter experiment. In comparison, levels of MSIA(aq) remain relatively steady throughout the dark control experiment with *am*-FeOOH (green),

but at considerably lower concentrations than the initial theoretical concentration, possibly due to the fact that the dark control was a different a different *am*-FeOOH batch (Batch 5). Also the MSIA dark control shows a lower concentration than expected. The pH drop is  $0.12 \pm 0.21$  pH units compared to 0.52 in the light control.

#### 4.2.5.1. Methane Sulfinic Acid and the Nitrate Effect

Interstitial  $\text{NO}_3^-$  is also found to have an appreciable effect on the photoreductive dissolution of *am*-FeOOH in the presence of MSIA. Results from Fe(II),  $\text{H}_2\text{O}_2$ , and S oxidation product measurement in photochemical experiments including *am*-FeOOH, with and without interstitial  $\text{NO}_3^-$ , and MSIA are shown in Figures 61, 62, and 63.

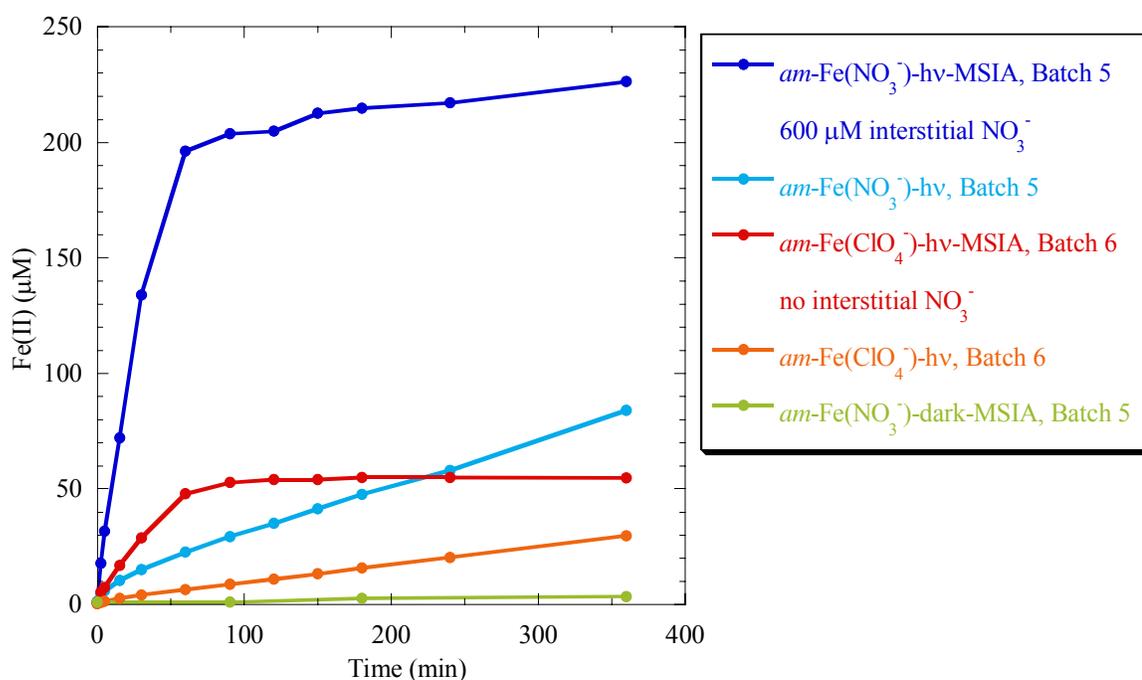


Figure 61. Effect of interstitial nitrate on the photoreductive dissolution of ferrihydrite in the presence of light and methane sulfinic acid.

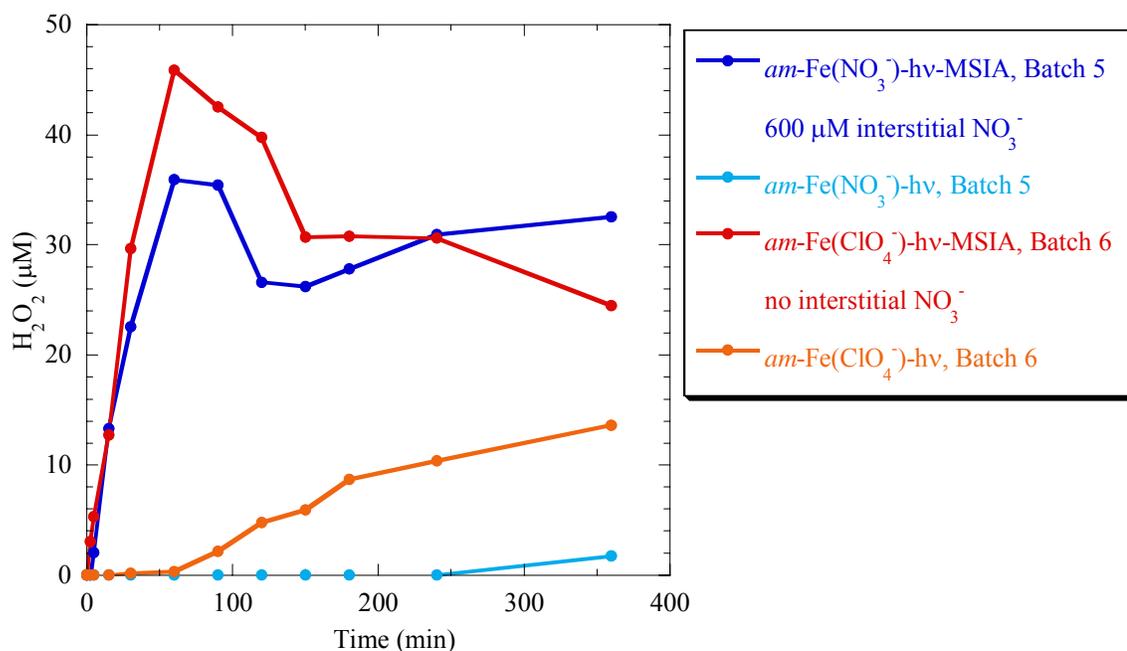


Figure 62. Effect of interstitial nitrate on hydrogen peroxide concentration with ferrihydrite, light, and methane sulfinic acid present.

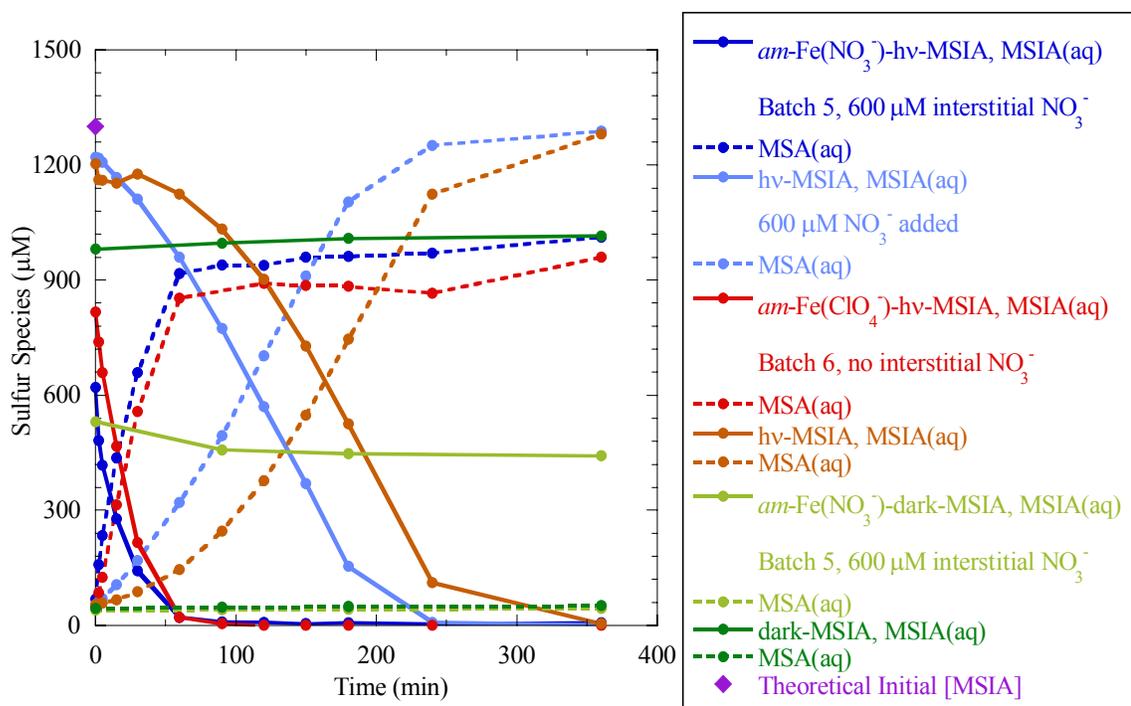


Figure 63. Effect of interstitial nitrate on methane sulfinic acid and methane sulfonic acid concentration with ferrihydrite, light, and methane sulfinic acid present.

The initial rate of Fe(II) formation is much faster for the *am*-FeOOH experiment with interstitial NO<sub>3</sub><sup>-</sup> in the presence of MSIA (dark blue in Figure 61) than the experiment with *am*-FeOOH synthesized from Fe perchlorate (no interstitial NO<sub>3</sub><sup>-</sup>) in the presence of MSIA (red). In addition, a significantly larger magnitude of ~230 μM of Fe(II) is observed by the end of the experiment with interstitial NO<sub>3</sub><sup>-</sup> and MSIA when compared to 50 μM of Fe(II) in the experiment without interstitial NO<sub>3</sub><sup>-</sup>. The light control with interstitial NO<sub>3</sub><sup>-</sup> is higher in Fe(II) concentration compared to the light control with *am*-FeOOH synthesized from Fe(ClO<sub>4</sub>)<sub>3</sub>•6H<sub>2</sub>O. For both of the light controls, Fe(II) steadily increases in a linear fashion throughout the experiments; however, the difference in concentration between the control with interstitial NO<sub>3</sub><sup>-</sup> and without increases over time. No significant change in Fe(II) concentration is observed in the dark control.

H<sub>2</sub>O<sub>2</sub> levels initially increase rapidly in both experiments with MSIA (Figure 62). Levels begin to drop after half an hour. The experiment with interstitial NO<sub>3</sub><sup>-</sup> begins to rise again after 150 min, and surpasses the experiment without interstitial NO<sub>3</sub><sup>-</sup> after 240 min. In the light control without interstitial NO<sub>3</sub><sup>-</sup>, H<sub>2</sub>O<sub>2</sub> levels are higher than that observed in the experiment with interstitial NO<sub>3</sub><sup>-</sup>. H<sub>2</sub>O<sub>2</sub> concentrations in the light controls with MSIA alone and with 600 μM NO<sub>3</sub><sup>-</sup> added remained at zero. H<sub>2</sub>O<sub>2</sub> is not observed in the dark controls with and without *am*-FeOOH. These four experiments are not shown.

MSIA concentrations show similar trends of an initial increase in Fe(II) followed by a leveling off in concentration after an hour of reaction. MSIA(aq) levels in the

experiments with *am*-FeOOH-hv-MSIA quickly drop near zero within the first hour and a half of reaction (Figure 63). In the light controls with MSIA alone and MSIA with  $\text{NO}_3^-$  added, MISA(aq) levels also drop near zero by the end of the experiment, but at a much slower rate. Experiments with  $\text{NO}_3^-$ , whether interstitial or added in the light control, react at faster rates. Levels of MSIA(aq) even drop slightly from 540 to 480  $\mu\text{M}$  in the dark control with interstitial  $\text{NO}_3^-$  when compared to the dark control with only MSIA, which remains at levels exceeding 960  $\mu\text{M}$  throughout the experiment. Initial MSIA(aq) levels are much lower in experiments with *am*-FeOOH than experiments and controls without *am*-FeOOH, which are more comparable to the theoretical level of 1300  $\mu\text{M}$  MSIA(aq).

It is important to note that a different reaction vessel was used for the dark controls, which may explain the observed discrepancy in initial MSIA concentrations between the dark controls and experiments and light controls (Figure 63). In addition to having different surface properties, the glass vessel differed in shape, thus more of the reaction medium was in contact with the surface of the glass vessel and more MSIA may have been bound to the glass surface versus remaining in solution. This may explain why both dark controls (with and without *am*-FeOOH) exhibited lower initial MSIA concentrations when compared to the corresponding experiment and light control.

MSA(aq) levels conversely rise in a similar trend (Figure 63). MSA(aq) levels in the experiments with *am*-FeOOH-hv-MSIA quickly rise to 900  $\mu\text{M}$  within the first hour of reaction. In the light controls with MSIA alone and MSIA with  $\text{NO}_3^-$  added, MSA(aq) levels reach 1290  $\mu\text{M}$  by the end of the experiments, but at a much slower rate. Again,

the experiments with  $\text{NO}_3^-$  present react at faster rates. In the dark controls, MSA(aq) remains near zero throughout the experiment. Final MSA(aq) levels are lower in experiments with *am*-FeOOH than experiments and controls without *am*-FeOOH, which are more comparable to the initial theoretical MSIA(aq) concentration of 1300  $\mu\text{M}$ . Interestingly, pH increased 0.21 (experiment) and 0.23 (light control) pH units.

#### 4.2.5.2. Methane Sulfinic Acid and Dimethyl Sulfoxide

For one of the photochemical experiments, DMSO was added to the *am*-FeOOH-hv-MSIA experiment. Results from Fe(II),  $\text{H}_2\text{O}_2$ , and S oxidation product measurement in the photochemical experiment including *am*-FeOOH, DMSO, and MSIA are shown in Figures 64, 65, and 66, respectively.

When DMSO is added to the Fe-hv-MSIA experiment (light blue in Figure 64), Fe(II) formation is slightly reduced during the first 5 hours after which Fe(II) formation in the Fe-hv-MISA-DMSO experiment levels out and seems to slightly surpass that observed without DMSO. Fe(II) formation is higher and occurs at a faster rate initially in the experiments with MSIA, when compared to the trend observed in both the Fe-hv-DMSO and Fe-hv controls. Little change is observed in the dark controls.

$\text{H}_2\text{O}_2$  levels for the Fe-hv-MSIA-DMSO experiment steadily increased to a concentration above 20  $\mu\text{M}$  (Figure 65). For the experiment with MSIA, levels initially increased to 45  $\mu\text{M}$  after an hour, upon which levels steadily decreased to  $\sim 25$   $\mu\text{M}$ .  $\text{H}_2\text{O}_2$  levels for the experiment with DMSO followed a similar trend to the experiment with both MISA-DMSO; however, levels surpass that observed in the MSIA-DMSO experiment after 240 min and are the highest observed (almost 40  $\mu\text{M}$ ) by the end of the

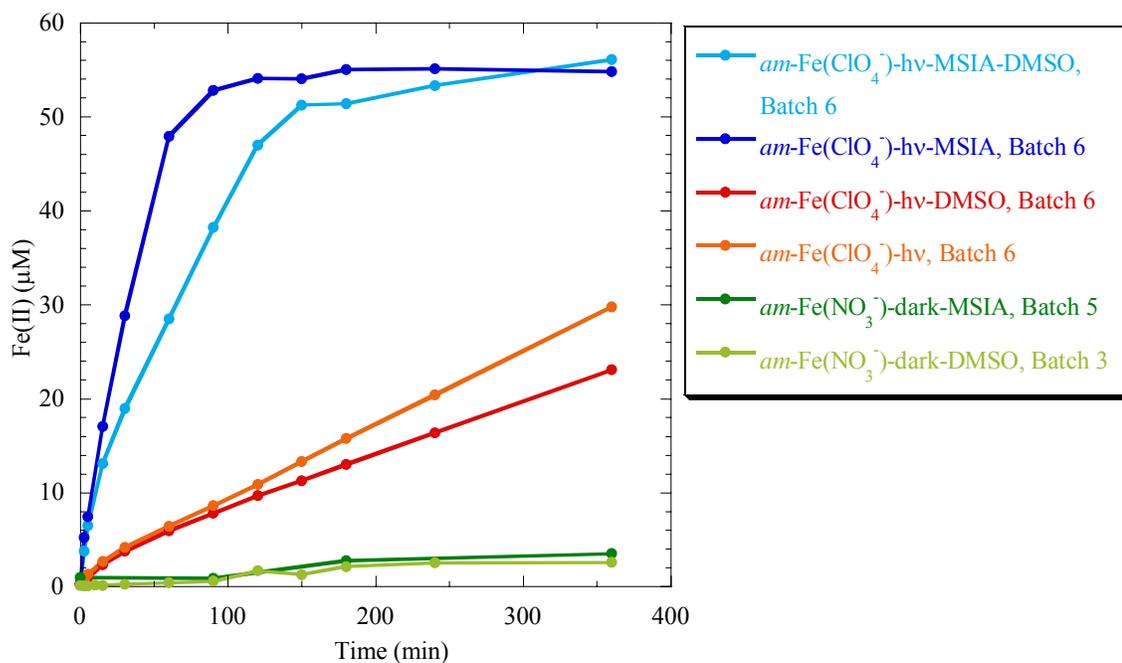


Figure 64. Photoreductive dissolution of ferrihydrite in the presence of light, methane sulfinic acid, and dimethyl sulfoxide.

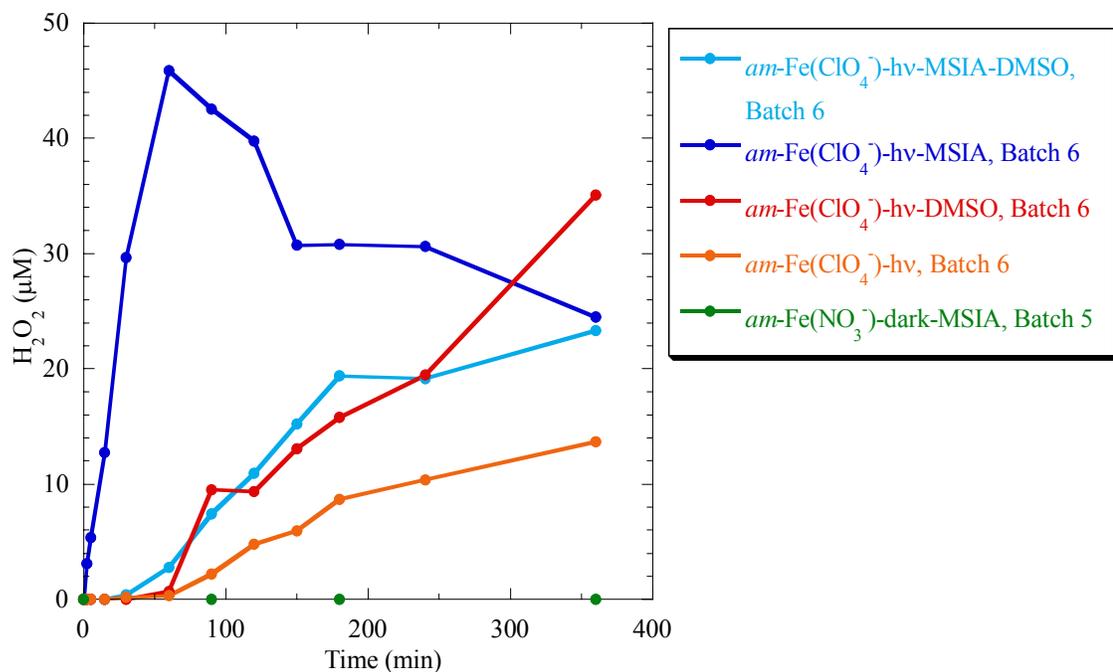


Figure 65. Hydrogen peroxide concentration of ferrihydrite, light, methane sulfinic acid, and dimethyl sulfoxide.

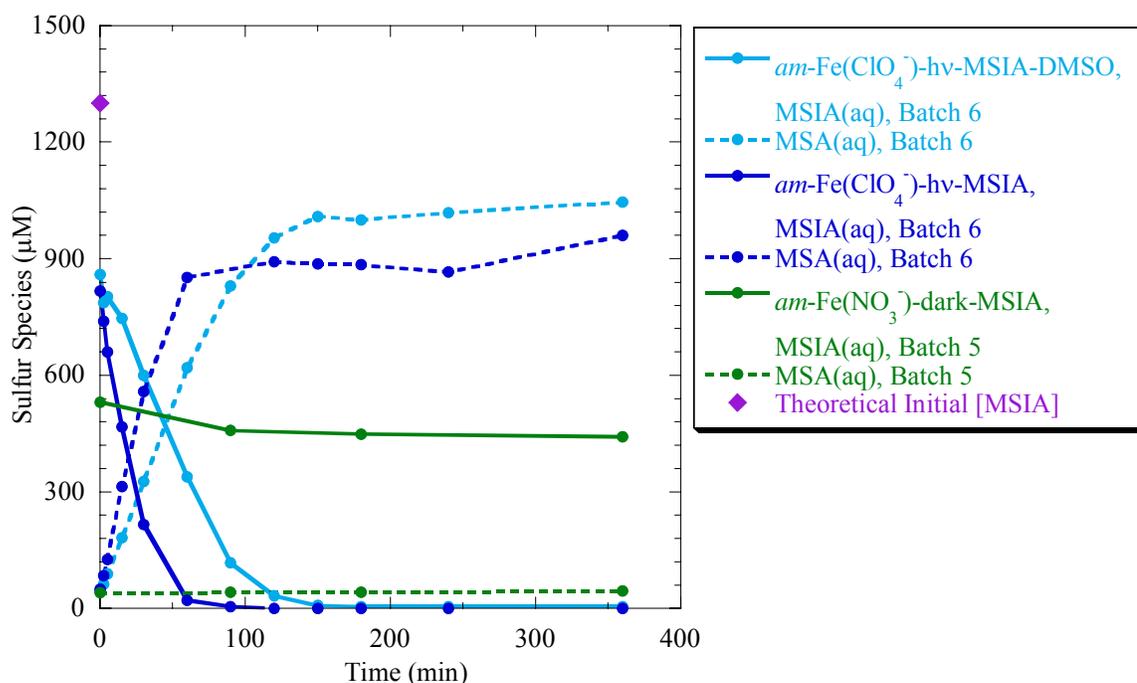


Figure 66. Sulfur oxidation product formation in the presence of ferrihydrite, light, methane sulfinic acid, and dimethyl sulfoxide with respective dark control.

experiment when compared with the other experiments and controls. The light control has lower amounts of H<sub>2</sub>O<sub>2</sub> than the experiments with DMSO, MSIA, and MSIA-DMSO.

In the MSIA experiment and the experiment with MSIA and DMSO, MSA(aq) forms at a rate similar to that of the decrease in the concentration of MSIA(aq) (Figure 66). In the MSIA-DMSO experiment, this process occurs at a slightly slower rate. The crossover point for MSIA(aq)/MSA(aq) occurs after an hour at a concentration of 475 µM versus half an hour at a concentration of 400 µM for the experiment without DMSO. After 90 min, concentrations of MSA(aq) in the MSIA-DMSO experiment exceed that of the experiment without DMSO. Levels in the dark control remain constant throughout the experiment. Experiments Fe-hv-DMSO, Fe-hv, and Fe-dark-DMSO for MSIA(aq) and MSA(aq) all remained at zero and are not plotted for simplicity. In this reaction the

pH dropped from an initial 5.35 to 4.77 (-0.58 pH units) compared with an increase of 0.52 in the light control.

#### 4.2.5.3. Methane Sulfinic Acid Initial Rates

In order to compare the effect of the presence of MSIA on the reduction of Fe(III) to Fe(II) in the presence of light, measured initial rates were determined by calculating the slope of the tangent nearest to the zero point. Because  $\text{Fe}(\text{OH})^{2+}$  is the dominant Fe(III) species, which undergoes photochemical reduction to produce Fe(II) (Reaction 1), the following rate law can be written to describe the measured initial rates (Equation 5) (Moffett and Zika, 1987):

$$\text{rate} = k[\text{Fe}(\text{OH})^{2+}] = \frac{d[\text{Fe}(\text{II})]}{dt} = -\frac{d[\text{Fe}(\text{OH})^{2+}]}{dt} \quad (5)$$

Results from Figures 58, 61, and 64 are presented in Table 10.

Table 10. Apparent Initial Iron(II) Photochemical Production Rates for Photochemical Simulation Experiments with Methane Sulfinic Acid

Figure	Experiment/Control	pHi	Measured rate <sub>i</sub> , $d[\text{Fe}(\text{II})]/dt$ ( $\text{M s}^{-1}$ )
58	<i>am</i> -Fe(ClO <sub>4</sub> <sup>-</sup> )-hv	4.78	$4.9 \times 10^{-9}$
58	<i>am</i> -Fe(ClO <sub>4</sub> <sup>-</sup> )-hv-MSIA <sup>a</sup>	5.35	$3.8 \times 10^{-8}$
61	<i>am</i> -Fe(NO <sub>3</sub> <sup>-</sup> )-hv <sup>b</sup>	3.77	$2.2 \times 10^{-8}$
61	<i>am</i> -Fe(NO <sub>3</sub> <sup>-</sup> )-hv-MSIA <sup>a,b</sup>	4.32	$1.6 \times 10^{-7}$
64	<i>am</i> -Fe(ClO <sub>4</sub> <sup>-</sup> )-hv-MSIA-DMSO <sup>a,c</sup>	5.35	$3.8 \times 10^{-8}$
64	<i>am</i> -Fe(ClO <sub>4</sub> <sup>-</sup> )-hv-DMSO <sup>c</sup>	4.24	$5.0 \times 10^{-9}$

Note: *i* = initial; MSIA = methane sulfinic acid; DMSO = dimethyl sulfoxide.

<sup>a</sup>[MSIA]<sub>*i*</sub> = 0.0013 M.

<sup>b</sup>[NO<sub>3</sub><sup>-</sup>]<sub>*i*</sub> = 0.0006 M.

<sup>c</sup>[DMSO]<sub>*i*</sub> = 0.0353 M.

#### 4.2.5.4. Ultraviolet-Visible Absorption of the Iron-Methane Sulfinic Acid Complex

To determine if a radiation absorbing reaction complex may be formed between selected S species and Fe(III) on the surface of *am*-FeOOH or in solution, UV-vis absorption spectroscopy was carried out. Absorbance scans were measured for solutions of Fe, MSIA, and Fe-MSIA and are shown in Figure 67. The pH of all solutions prepared was between 3.5 and 4.0 or otherwise adjusted to this range.

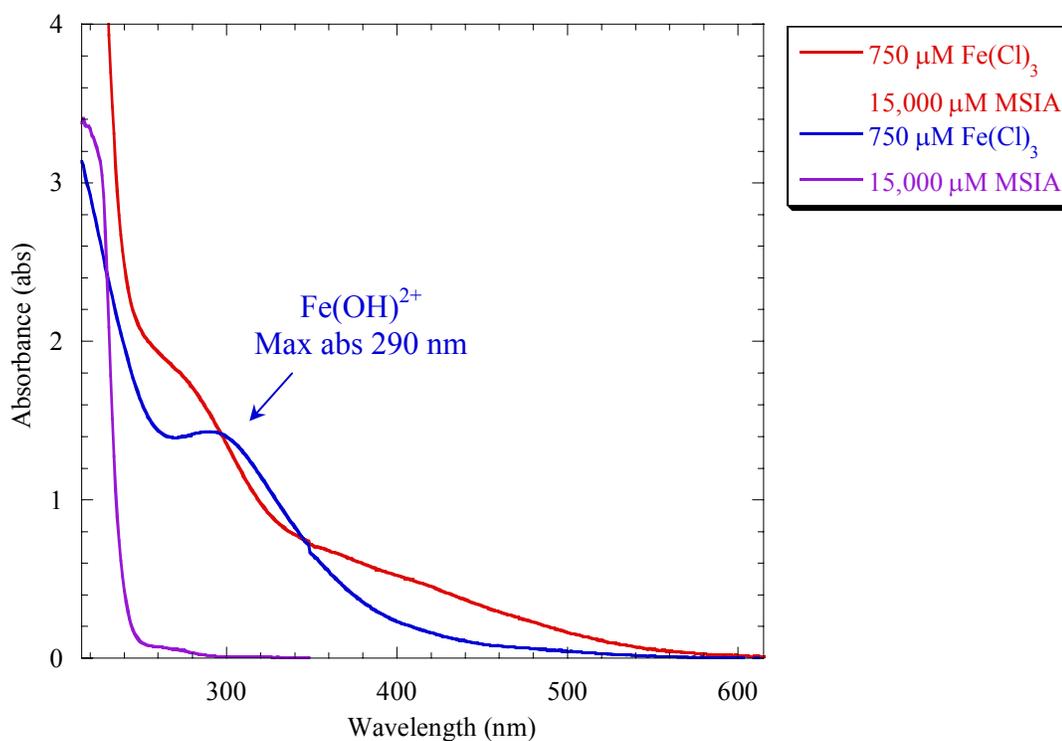


Figure 67. Iron(III) UV-visible absorbance spectra of iron, methane sulfinic acid, and iron-methane sulfinic acid solutions.

#### 4.2.6. Methane Sulfinic Acid

In the initial photochemical experiment using MSA as the selected S species, an amount of MSA representative of concentrations found in the atmosphere (0.04 M) was added. This amount was too high and saturated the IC column. Generalized

concentrations of oxidized S species were still obtained through the measured signal response and the slope of the calibration curve, though these values extended far beyond the range of standards in the calibration curve. The concentration of MSA added was lowered to 620  $\mu\text{M}$ . Results from Fe(II),  $\text{H}_2\text{O}_2$ , and S oxidation product measurement for both concentrations are plotted for comparison in Figures 68, 69, 70 and 71.

The photoreductive dissolution of Fe is larger and occurs at a faster rate in the presence of MSA (red in Figure 68) compared to the control. Fe(II) concentrations are greater than 85  $\mu\text{M}$  in the presence of MSA versus 24  $\mu\text{M}$  in the light control. However, at the much larger MSA concentration (0.04 M), the Fe(II) concentration initially increases rapidly to 20  $\mu\text{M}$  and then decreases after 30 min. This level continues to gently rise and fall to 10  $\mu\text{M}$  by the end of the experiment. Levels of Fe(III) in the experiment and controls remain near zero, with the exception of *am*-FeOOH in the presence of 0.04 M MSA (Figure 69). Fe(III) levels increase to 45  $\mu\text{M}$  after 150 min, drop sharply to 25  $\mu\text{M}$  at 180 min, increase to 55  $\mu\text{M}$  at 240 min, and drop back to 25  $\mu\text{M}$  by the end of the experiment.

$\text{H}_2\text{O}_2$  levels steadily increase until nearing 140  $\mu\text{M}$  at the end of the experiment with 620  $\mu\text{M}$  MSA (red in Figure 70). In the presence of 0.04 M MSA, levels initially increase, drop after 15 min, and slowly increase after 90 min. By the end of the experiment, concentrations (40  $\mu\text{M}$ ) are still higher than the light control, which increase much slower to  $\sim 24$   $\mu\text{M}$ . It is important to note that trends in  $\text{H}_2\text{O}_2$  levels are similar to trends observed in Fe(II) levels, especially for this experiment with MSA. This trend occurs with some of the other experiments as well.

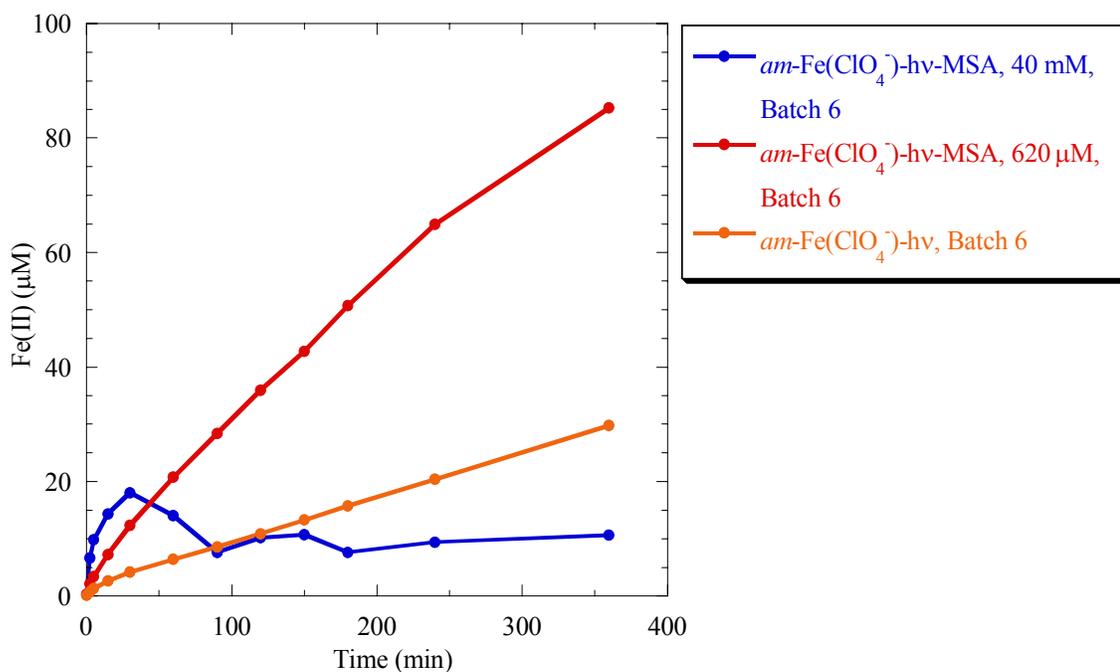


Figure 68. Photoreductive dissolution of ferrihydrite in the presence of light and methane sulfonic acid.

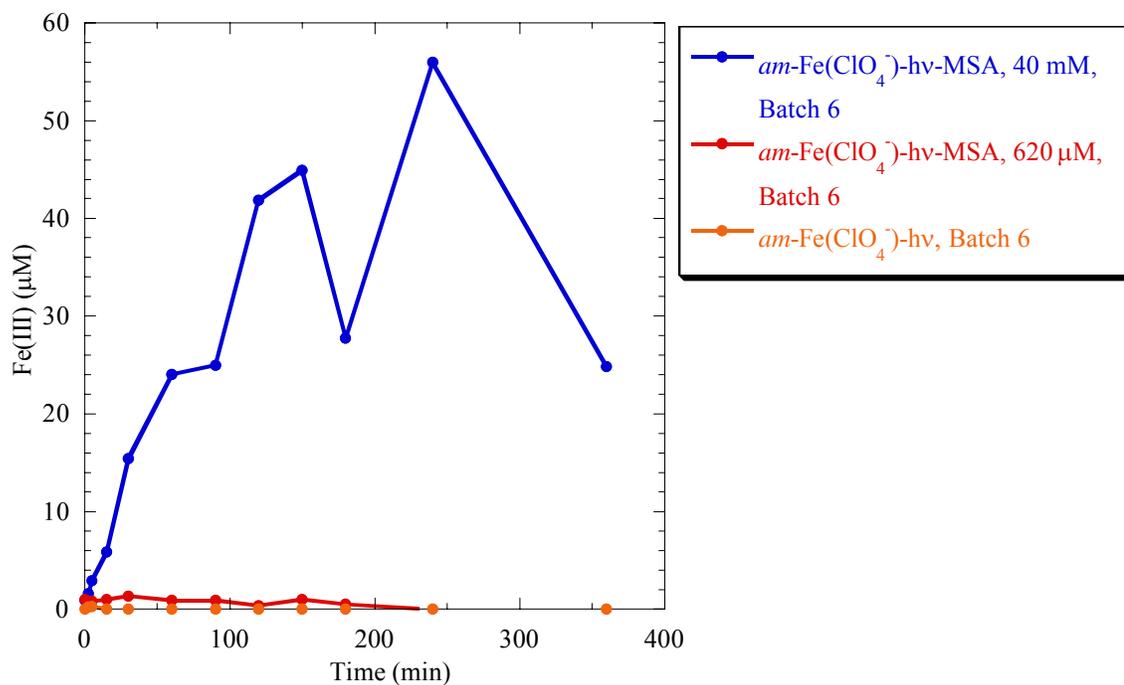


Figure 69. Iron(III) production of ferrihydrite in the presence of light and methane sulfonic acid.

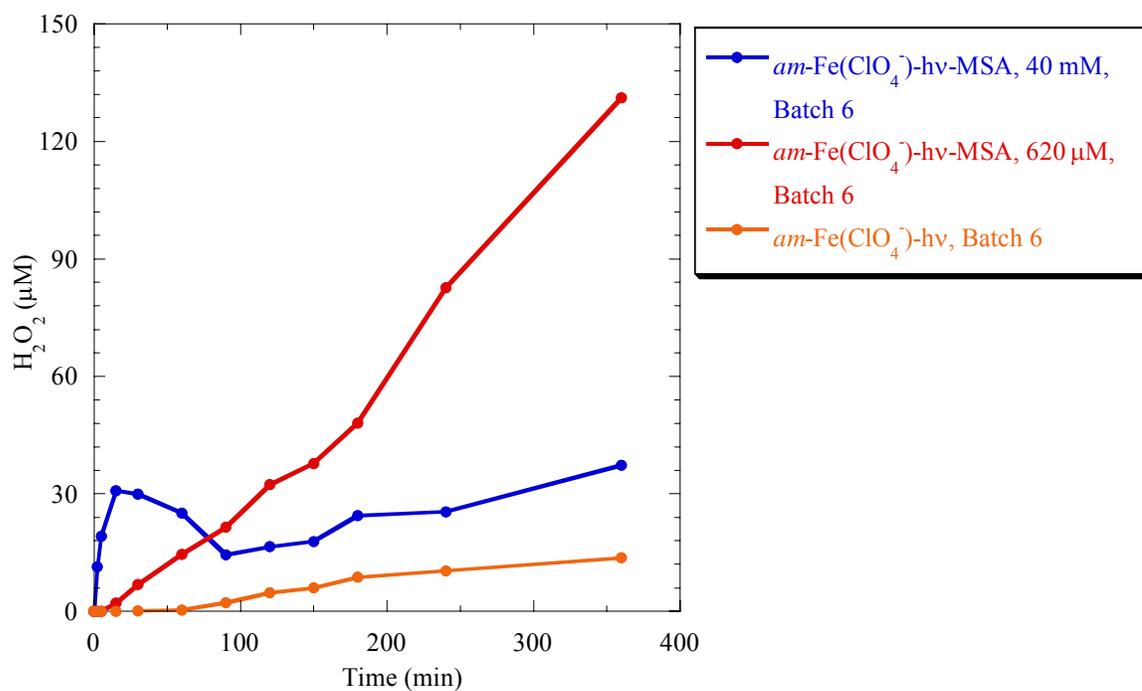


Figure 70. Hydrogen peroxide formation for ferrihydrite, light, and methane sulfonic acid.

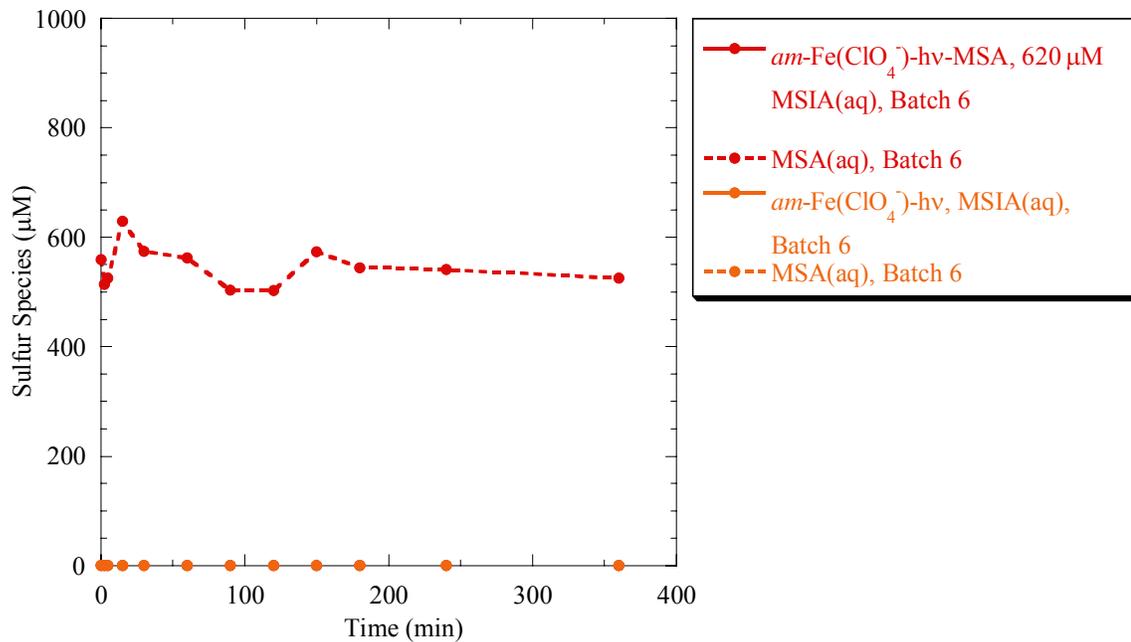


Figure 71. Sulfur oxidation product formation in the presence of ferrihydrite, light, and methane sulfonic acid with respective light control.

S product concentrations are plotted in Figure 71. MSA levels remain below  $4 \times 10^4 \mu\text{M}$  in the *am*-Fe(ClO<sub>4</sub><sup>-</sup>)-hv-MSA experiment with 40 mM of MSA added and is not shown. MSA levels remain around 500  $\mu\text{M}$  in the 620  $\mu\text{M}$  MSA experiment and seem to drop slightly in the experiment with 40 mM MSA. The average pH increase for experiments with MSA is  $0.17 \pm 0.28$ .

## CHAPTER 5

### DISCUSSION

#### 5.1. Photochemical Experiments

From the presented results, some of the DMS derived oxidation products enhance the photoreductive dissolution of Fe more than others. These results are discussed in the following sections; however, the discussion does not follow the order presented in Chapter 4. In order to understand the underlying mechanisms involved in this system, central points are presented first. Important reactions are compiled in Table 11.

##### 5.1.1. *Methane Sulfinic Acid Enhances Iron(II) Photoreductive Dissolution*

The photoreductive dissolution of Fe is significantly enhanced in the presence of MSIA (Figure 58) compared to the light control. The measured initial rate ( $4.9 \times 10^{-9} \text{ M s}^{-1}$ ) without MSIA is less than one order of magnitude lower compared to the observed initial rate with  $1.3 \times 10^{-3} \text{ M MSIA}$  ( $5.6 \times 10^{-8} \text{ M s}^{-1}$ ) (Table 10). Fe(II) generation in the control in the absence of MSIA is known to occur due to the photolysis of  $\text{Fe}(\text{OH})^{2+}$  (maximum absorption at 295 nm) (Table 11, Reaction 1) (Faust and Hoigné, 1990; King et al., 1993). The steep increase of Fe(II) in the presence of MSIA is accompanied with a rapid increase in  $\text{H}_2\text{O}_2$  formation (Figure 59) and decrease in MSIA (Figure 60). After an hour, when Fe(II) levels off, most of the MSIA in the *am*-FeOOH-hv-MSIA experiment has been oxidized to MSA (Figure 60) and  $\text{H}_2\text{O}_2$  concentrations (Figure 59) begin to drop.

These data indicate that MSIA enhances Fe(II) photoproduction as  $\text{H}_2\text{O}_2$  is formed. A likely mechanism is that a Fe(III)-MSIA surface complex is formed,

Table 11. Compilation of Key Reactions

Reaction Number	Reaction
1	$\text{Fe(III)(OH)}^{2+} \xrightarrow{(295 \text{ nm}) h\nu} \text{Fe(III)-OH}^* \rightarrow \text{Fe(II)} + \text{HO}^\bullet$
6a	$\text{NO}_3^- \xrightarrow{(302 \text{ nm}) h\nu} \text{NO}_3^{*-} \rightarrow \text{NO}_2 + \text{O}^{\bullet-}$
6b	$\text{O}^{\bullet-} \xrightarrow{\text{H}_2\text{O}} \text{HO}^\bullet + \text{OH}^-$
7	$\text{H}_2\text{O}_2 \xrightarrow{(254 \text{ nm}) h\nu} \text{HO}^\bullet + \text{HO}^\bullet$
8	$\text{C}_2\text{O}_4^{\bullet-} + \text{O}_2 \rightarrow \text{O}_2^{\bullet-} + 2\text{CO}_2$
9	$2\text{O}_2^{\bullet-} + 2\text{H}^+ \rightarrow \text{H}_2\text{O}_2 + \text{O}_2$
10	$\text{HO}^\bullet + \text{HO}^\bullet \rightarrow \text{H}_2\text{O}_2$
12	$\text{CH}_3\text{SO}_2\text{H} + 2\text{Fe(III)} + \text{H}_2\text{O} \xrightarrow{h\nu} \text{CH}_3\text{SO}_3\text{H} + 2\text{Fe(II)} + 2\text{H}^+$
13	$\text{CH}_3\text{SO}_2\text{H} + \text{H}_2\text{O} + \text{O}_2 \xrightarrow{h\nu} \text{CH}_3\text{SO}_3\text{H} + \text{HO}^\bullet \quad (\text{slow})$
14a	$\text{CH}_3\text{SO}_2\text{H} + \text{HO}^\bullet \rightarrow [\text{CH}_3\text{SO}_2\text{H} - \text{HO}^\bullet] \quad (\text{fast})$
14b	$[\text{CH}_3\text{SO}_2\text{H} - \text{HO}^\bullet] + \text{O}_2 \rightarrow \text{CH}_3\text{SO}_3\text{H} + \text{HO}_2^\bullet \quad (\text{slow})$

similar to the  $\text{Fe(III)-C}_2\text{O}_4^{2-}$  complex, which can then undergo LMCT reaction through the absorption of UV-vis radiation (Reaction 12) (Pehkonen et al., 1993; Zuo, 1995).



$\text{H}_2\text{O}_2$  production is associated with the  $\text{Fe(III)-C}_2\text{O}_4^{2-}$  LMCT reaction through the formation of  $\text{C}_2\text{O}_4^{\bullet-}$  and  $\text{O}_2^{\bullet-}$  (Reactions 8 and 9) (Zuo and Hoigné, 1992). In the present case,  $\text{O}_2^{\bullet-}$  formation is the likely precursor for  $\text{H}_2\text{O}_2$  from the photon-induced LMCT

reaction of the Fe(III)-MSIA complex. A proposed mechanism is shown in Figure 72, analogous to the Fe(III)-C<sub>2</sub>O<sub>4</sub><sup>2-</sup> reaction (Figure 17).

In the proposed mechanism, for every MSIA oxidized, two oxidation steps occur to produce one MSA (S oxidation state increases from two to four). Therefore, potentially two Fe(III) can be reduced to form two Fe(II) and in the process generate two H<sup>+</sup> (Figure 72). However, the pH change in the Fe-MSIA reaction does not coincide with this reaction, most likely because of the buffering effect of the Fe hydroxide particles. O<sub>2</sub> and H<sub>2</sub>O that are involved in the subsequent elementary steps as part of the oxidation of MSIA may be transformed to O<sub>2</sub><sup>•-</sup>. O<sub>2</sub><sup>•-</sup> can undergo reactions to produce H<sub>2</sub>O<sub>2</sub> (Reactions 9 and 10), especially at acidic conditions where H<sup>+</sup> is abundant. Thus, once MSIA has been depleted, there is no O<sub>2</sub><sup>•-</sup> to lead to the formation of H<sub>2</sub>O<sub>2</sub> and it is then consumed by the Fenton Reaction (Reaction 3) and photolysis (Reaction 7). H<sub>2</sub>O<sub>2</sub> concentrations in the experiment with MSIA appear to eventually run parallel with the increase in H<sub>2</sub>O<sub>2</sub> concentration in the light control (Figure 59), which is controlled by the photochemical reduction of Fe(OH)<sup>2+</sup> (Reaction 1) and recombination of HO<sup>•</sup> to form H<sub>2</sub>O<sub>2</sub> (Reaction 10).

Further support for the notion that the Fe(III)-MSIA complex reacts similarly to the Fe(III)-C<sub>2</sub>O<sub>4</sub><sup>2-</sup> complex is provided by the observed similarity in the structure of carboxylic acids to the structure of MSIA. Fe(III) complexes with organic acids, such as C<sub>2</sub>O<sub>4</sub><sup>2-</sup>, at the site of the oxygen anion on the carboxylic acid functional group (—COOH). This Fe(III) complexation also occurs in siderophores containing α-

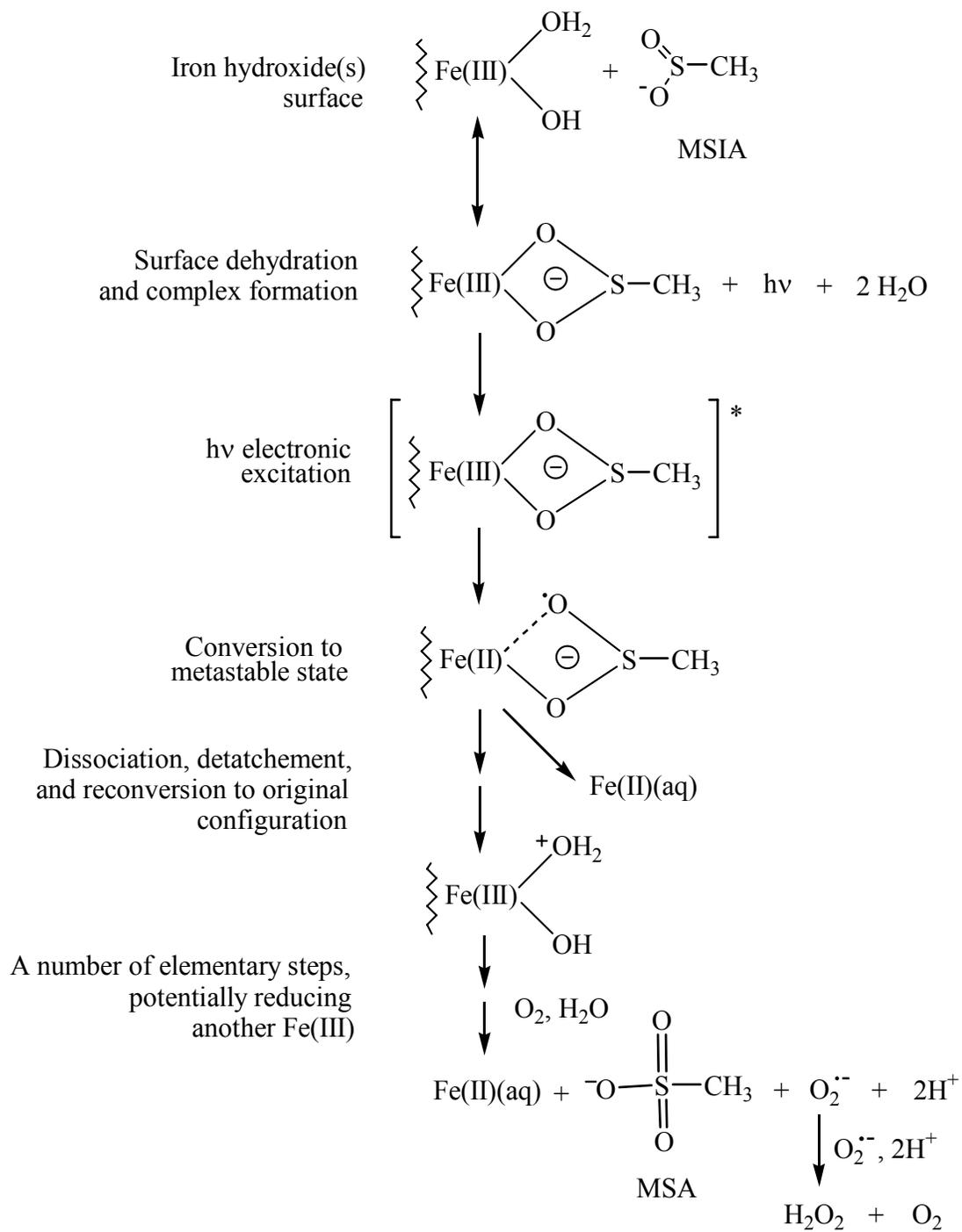


Figure 72. Proposed mechanism for the ligand-to-metal charge transfer reaction of methane sulfinic acid with iron(III).

hydroxycarboxylic acid groups, which are known to undergo light-induced LMCT reactions to yield Fe(II) as well (Barbeau et al., 2003).

MSIA contains a sulfinic acid functional group ( $\text{—SOOH}$ ), which is very similar in structure to the carboxylic acid, the only difference being an S atom replaces the C atom whereby S and C have similar electronegativities of 2.589 and 2.544, respectively (Miessler and Tarr, 1999). Further support of this hypothesis is provided by the fact that this potential complex between Fe(III) and MSIA absorbs light at a characteristic wavelength in the visible range in order to undergo the LMCT. The presence of a ligand shifts the spectrum of light absorption to longer wavelengths, thus lowering the energy necessary for Fe(III) reduction. To the best of our knowledge, this wavelength of absorbance has not been determined in the literature. Therefore, UV-vis absorbance spectroscopy was used to measure the wavelength of light absorption of the complex.

Results from the UV-vis absorption of Fe, MSIA, and Fe-MSIA solutions are shown in Figure 67. The pH of all solutions was adjusted within the range of 3.5 to 4.0 to ensure that  $\text{Fe(OH)}^{2+}$  was the predominant Fe(III) species. The Fe solution absorbs at  $\sim 290$  nm, which is confirmed in the literature (Faust and Hoigné, 1990; King et al., 1993). MSIA alone exhibited significant absorption only in the lower wavelengths ( $< 260$  nm), with a maximum absorbance at 202 nm. In the Fe-MSIA solution, where the concentration of MSIA was 20 times that of added Fe, the absorbance peak shifts to a lower wavelength ( $\sim 275$  nm) and there is an increase in absorbance ( $\sim 0.4$  abs). In addition, there is an increase in absorbance beyond 340 nm in a broad shoulder that tails off after 500 nm, indicating that MSIA may be bound to Fe(III) as a ligand that is shifting

the spectrum of light absorption to longer wavelengths of lower energy. This broad absorption band between 350 and 500 nm is only present in the Fe-MSIA mixture and compares to absorption bands centered around 300 nm for the Fe-C<sub>2</sub>O<sub>4</sub><sup>2-</sup> complex (Faust and Hoigné, 1990; Zuo and Hoigné, 1992) and 430 nm for  $\alpha$ -hydroxycarboxylic function group complexation with Fe(III) in siderophores (Borer et al., 2005).

When interstitial NO<sub>3</sub><sup>-</sup> is present in the MSIA experiment, the initial rate of Fe(II) formation is increased by a factor of 4.2 in addition to the magnitude (225  $\mu$ M vs. 55  $\mu$ M at 360 min) when compared to the MSIA experiment without interstitial NO<sub>3</sub><sup>-</sup> (i.e., Batch 6, Fe perchlorate) (Figure 61 and Table 10). In comparison, when interstitial NO<sub>3</sub><sup>-</sup> is present in the MSIA experiment and light control, the rate of Fe(II) formation increases by a factor of 7.3 in the presence of MSIA.

As the *am*-FeOOH particles undergo photoreductive dissolution during the experiment, NO<sub>3</sub><sup>-</sup> impurities trapped inside the crystal lattice are released. In the presence of light, NO<sub>3</sub><sup>-</sup> undergoes photolysis to produce HO<sup>•</sup> (Reactions 6a and 6b). Therefore, the presence of NO<sub>3</sub><sup>-</sup> may provide a steady stream of HO<sup>•</sup>. As in the experiment with MSIA, H<sub>2</sub>O<sub>2</sub> concentrations began to drop after MSIA was depleted. Almost half way through the experiment, though, H<sub>2</sub>O<sub>2</sub> levels began to increase presumably from NO<sub>3</sub><sup>-</sup> photolysis. Interestingly, this effect was not observed in experiments using perchlorate batches and added NO<sub>3</sub><sup>-</sup> for reasons not known at this time.

Perhaps the surface charge is different since we observe that initial dissolved MSIA concentrations are lower when NO<sub>3</sub><sup>-</sup> is present interstitially. This provides further support that more MSIA may be bound to the surface of *am*-FeOOH, which ultimately

results in more MSA released into solution and higher Fe(II) concentrations through the LMCT reaction. However, our results present a contradiction in that we observe less H<sub>2</sub>O<sub>2</sub> production. If a LMCT reaction is occurring, we should observe more H<sub>2</sub>O<sub>2</sub> production as previously discussed. It appears as if NO<sub>3</sub><sup>-</sup> inside the crystal lattice has a more prominent effect on Fe(II) photochemical production than externally available NO<sub>3</sub><sup>-</sup>; however, additional experiments need to be run in order to better answer this question.

In Figure 63, the MSIA-MSA crossover point occurs faster when either interstitial or added NO<sub>3</sub><sup>-</sup> is present. MSIA oxidation occurs faster and results in even larger amounts of MSA because additional HO<sup>•</sup> is available from NO<sub>3</sub><sup>-</sup> photolysis. The reaction occurs significantly faster in the experiments with *am*-FeOOH because of the proposed LMCT reaction of the Fe-MSIA complex (Reaction 12). In addition, some HO<sup>•</sup> is produced from Fe(OH)<sup>2+</sup> photolysis (Reaction 1); however, contributions from this reaction are not as significant.

#### 5.1.2. Dimethyl Sulfoxide Indirectly Enhances Iron Photoreductive Dissolution

When adding DMSO to the *am*-FeOOH-MSIA experiment, Fe(II) formation is slightly reduced during the first few hours after which Fe(II) formation in the MSIA-DMSO experiment seems to surpass that observed without DMSO (Figure 64). The presence of DMSO seems to be inhibiting the formation of Fe(II) in the first few hours of irradiation. The measured initial rate in the light control without MSIA and DMSO is much lower ( $4.9 \times 10^{-9} \text{ M s}^{-1}$ ) compared to the measured initial rate with MSIA and DMSO ( $3.8 \times 10^{-8} \text{ M s}^{-1}$ ) (Table 10). Thus, the presence of MSIA and DMSO increases

the initial rate of Fe(II) formation by a factor of 7.8. However, MSIA alone increases the initial rate of Fe(II) formation by a factor of 7.8. This may be a function of DMSO occupying active surface sites on the *am*-FeOOH surface, thereby decreasing the interaction of MSIA with Fe(III) on the surface. This also provides further evidence that it is only MSIA that may be capable of photoreductive dissolution of Fe(III) in a LMCT reaction.

In terms of H<sub>2</sub>O<sub>2</sub> production (Figure 65), the presence of DMSO in addition to MSIA (light blue) also appears to inhibit its formation when compared to the experiment with only MSIA. The production of H<sub>2</sub>O<sub>2</sub> is inhibited because DMSO is an efficient HO<sup>•</sup> scavenger, which might be the precursor for the H<sub>2</sub>O<sub>2</sub> that we observe (Bardouki et al., 2002). Again, after MSIA is depleted, the rate of H<sub>2</sub>O<sub>2</sub> production decreases and then appears to parallel the light control (orange). In the DMSO experiment (red), Fe(II) concentrations steadily increase, along with H<sub>2</sub>O<sub>2</sub> concentrations. Again, in Figure 66, it appears as if DMSO is inhibiting the reaction because the MSIA-MSA crossover point is slower for the MSIA-DMSO experiment. MSA concentrations for the MSIA-DMSO experiment are slightly larger (by ~90 μM) at the end of the experiment and still seem to be increasing. This is most likely because MSA is derived from both DMSO and MSIA.

The photoreductive dissolution of Fe does not appear to be enhanced by DMSO when compared to the control without (Figure 34). In fact, after an initial period of identical rates, the light control consistently appears to be slightly higher after 90 min, indicating there may be an inhibition in Fe(II) formation caused by the presence of DMSO. However, comparing the Fe(II) concentration for Batch 6 with batches of

increasing interstitial  $\text{NO}_3^-$  concentration (Figure 37), it appears that higher interstitial  $\text{NO}_3^-$  concentrations yield higher Fe(II) concentrations, in both the controls and experiments. Thus, there seems to be a relationship between interstitial  $\text{NO}_3^-$  and Fe(II) photoproduction so as to indicate that  $\text{NO}_3^-$  may be indirectly involved in the observed reaction. In aqueous solutions, DMSO will react rapidly ( $k = 4.5 \times 10^9 \text{ M}^{-1} \text{ s}^{-1}$ ) with  $\text{HO}^\bullet$ , which is produced from  $\text{NO}_3^-$  and  $\text{H}_2\text{O}_2$  photolysis (Bardouki et al., 2002). MSIA has been identified as the main intermediate from this reaction. MSIA can then react with Fe(III) through a LMCT reaction to yield Fe(II). MSIA will also react rapidly ( $k = 1.2 \times 10^{10} \text{ M}^{-1} \text{ s}^{-1}$ ) with  $\text{HO}^\bullet$  to form MSA, the major end product (Bardouki et al., 2002). Higher concentrations of both MSIA and MSA are observed in the DMSO experiments with higher concentrations of interstitial  $\text{NO}_3^-$  (Figure 39).

DMSO reactions (Figure 37) also show differences in Fe(II) formation. Batch 4 (40  $\mu\text{M}$  interstitial  $\text{NO}_3^-$ ) was comparable in terms of Fe(II) formation to Batch 6 (no interstitial  $\text{NO}_3^-$ ), which demonstrates that removal of the  $\text{NO}_3^-$  from the crystal lattice decreases the enhancement of the photoreductive dissolution of Fe. There was an exception to this observation. Though Batches 2 and 5 were prepared in the same manner (i.e., from  $\text{Fe}(\text{NO}_3)_3 \cdot 9\text{H}_2\text{O}$  and with 3 days dialysis), XRD scans showed differences (Table 7, Chapter 4.1.1., and Appendix D) in addition to interstitial  $\text{NO}_3^-$  concentrations. Despite having a lower interstitial  $\text{NO}_3^-$  concentration, Batch 2 (400  $\mu\text{M}$   $\text{NO}_3^-$ ) yielded much higher levels of Fe(II) ( $\sim 200 \mu\text{M}$ ) in a linear fashion, while the initial rate of Batch 5 (600  $\mu\text{M}$   $\text{NO}_3^-$ ) leveled off and only reached  $\sim 20 \mu\text{M}$  Fe(II). This is the only case where it appears that the difference in Fe(II) concentrations is not dependent on

interstitial  $\text{NO}_3^-$  concentrations. This may be explained by the fact that each batch was unique, although efforts were made to prepare batches under the same conditions. The only potential difference in batch preparation could have arisen from the difference in freeze-drying time (more than 3 days for Batch 2 vs. 3 days for Batch 5). Larger freeze-drying vials were used for initial batches that resulted in longer freeze-drying times that may have affected  $\text{NO}_3^-$  concentration within the crystal lattice.

Another interesting trend that was observed with *am*-FeOOH batches containing  $\text{NO}_3^-$  was an increase in pH in the light controls. The amount of this increase in pH appeared to be dependent on interstitial  $\text{NO}_3^-$  concentration, as batches with higher concentrations of interstitial  $\text{NO}_3^-$  yielded a larger increase in pH. This can be explained by the production of  $\text{OH}^-$  from the photolysis of  $\text{NO}_3^-$  (Reactions 6a and 6b).

$\text{H}_2\text{O}_2$  levels were surprisingly higher when *am*-FeOOH was in the presence of DMSO compared with the light control (Figure 35). This suggests that  $\text{H}_2\text{O}_2$  may be produced from the oxidation of DMSO; however, DMSO oxidation products (i.e., MSIA and MSA) are not observed (Figure 36). DMSO, though, may also be oxidized to forms of S species that are undetectable, such as  $\text{DMSO}_2$ .  $\text{DMSO}_2$  is formed from the oxidation of DMS through a different reaction pathway or from the oxidation of DMSO by  $\text{HO}^\bullet$  or  $\text{O}_2$  (Figure 18).  $\text{DMSO}_2$ , though potentially present, is not observed in the experiments because it does not form an anion that can be detected using IC. However, its potential reaction with  $\text{NO}_3^-$  derived  $\text{HO}^\bullet$  to form further oxidized S species (i.e.,  $\text{SO}_2$ ) cannot be excluded.

It is important to note that there may be two competing mechanisms for  $\text{H}_2\text{O}_2$  production, which is suggested by the inconsistency in results. In the presence of DMSO and MSIA there is less  $\text{H}_2\text{O}_2$  than in the presence of MSIA alone (Figure 65). However, when no MSIA is present, the presence of DMSO increases the formation of  $\text{H}_2\text{O}_2$ . At this point, we cannot tell specifically which mechanisms are responsible for the observed  $\text{H}_2\text{O}_2$  productions.

The AM 1 filter was removed for experiments with DMSO only. There appeared to be a pattern with results from different batches with less and more interstitial  $\text{NO}_3^-$ . Batches 1 and 5 had larger amounts of  $\text{NO}_3^-$  and exhibited larger concentrations of Fe(II) and S oxidation products when the AM 1 filter was removed. For Batch 1 (Figure 43), Fe(II) concentration is much higher without the AM 1 filter. Again, DMSO appears to inhibit the initial formation of Fe(II). For Batch 5 (Figure 47), Fe(II) inhibition by DMSO appears to last longer, until levels suddenly increase an order of magnitude. For Batch 1 (Figure 44), MSIA is formed, along with MSA at a faster rate. For Batch 5 (Figure 48), a similar reaction trend is observed with MSA concentrations 25 times MSIA concentrations. This is not seen in the experiments with the AM 1 filter and is mostly a result of the rapid formation of  $\text{HO}^\bullet$  from  $\text{NO}_3^-$  photolysis (Reactions 6a and 6b).  $\text{HO}^\bullet$  rapidly oxidizes DMSO to MSIA, which can then form a complex with Fe(III) to undergo LMCT and thus produce the end product, MSA. In the process, the solution is becoming more acidic, dropping an average of  $1.10 \pm 0.36$  pH units for Batches 1 and 5, which aids in dissolution and stabilization of Fe(II). However, acidity and  $\text{Fe}(\text{OH})^{2+}$  photolysis by themselves are not sufficient to explain the amount of Fe(II) formed, thus reinforcing that

once the MSIA is produced, it is likely to undergo LMCT with Fe(III) on the surface of *am*-FeOOH particles to produce Fe(II) and MSA.

Interestingly, in Batch 5, Fe(III) levels rise to 40  $\mu\text{M}$ , and suddenly drop after 150 min, whereas levels slowly and steadily rise with the filter. After 150 min,  $\text{H}_2\text{O}_2$  levels rise from zero to 70  $\mu\text{M}$  with no AM 1 filter. At this point, it is not understood what mechanisms are driving the concurrent depletion of Fe(III) as  $\text{H}_2\text{O}_2$  is formed.

With lesser amounts of  $\text{NO}_3^-$  (Batches 3 and 6), little difference is observed between experiments with and without the AM 1 filter (Figures 45 and 52). Very little MSIA and MSA are observed (Figures 46 and 53). Overall, MSA concentrations after 6 hours are more than two orders of magnitude larger in Batches 1 and 5.

Interestingly, reactions with  $\text{DMSO}_2$ , MSIA, and MSA show higher Fe(II) concentrations than experiments with DMSO.

### 5.1.3. Methane Sulfinic Oxidation Reactions

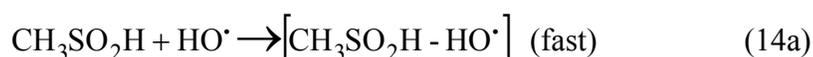
In Figure 60, the initial MSIA concentration and initial slopes of MSIA consumption (i.e., MSA formation) for the experiment with *am*-FeOOH and the light control without *am*-FeOOH are very different. First, in the presence of *am*-FeOOH, the measured initial MSIA(aq) concentration ( $\sim 830 \mu\text{M}$ ) is much lower than the theoretical MSIA(aq) concentration (1300  $\mu\text{M}$ ). This is believed to be a result of the surface chemistry on the *am*-FeOOH particles since this effect is not observed in the control without *am*-FeOOH and the measured initial MSIA concentration (1200  $\mu\text{M}$ ) is closer to the theoretical concentration. Because the surface of *am*-FeOOH is positively charged below a pH (equal to the point of zero charge (pzc)) between 7 and 8 (Schwertmann and

Cornell, 1991) and MSIA is deprotonated above a pH of 2 (Barcellos da Rosa et al., 2000) and thus negatively charged, MSIA will bind to the surface of *am*-FeOOH. The bound MSIA is removed when the solution is filtered through the 0.45  $\mu\text{m}$  filter to remove particles for analysis of analytes. As a result, the MSIA(aq) concentration in solution is correspondingly lower.

However, there is also a difference between the measured initial MSIA concentration in the experiment and dark controls (Figure 60). With *am*-FeOOH, the initial MSIA concentration is  $\sim 290 \mu\text{M}$  lower in the dark control. This may be in part due to the fact that Batch 6 was used in the experiment, while Batch 5, a  $\text{NO}_3^-$  batch, was used in the dark control, which may affect the initial pH ( $\text{pH}_i$ ). The  $\text{pH}_i$  for Batch 6 was 5.35, while it was 4.30 for dark control with Batch 5. This suggests that the presence of interstitial  $\text{NO}_3^-$  may change surface charge in addition to acid-base properties of the Fe hydroxide surface groups, which will change the amount of MSIA attached to *am*-FeOOH surfaces.

However, a lower initial MSIA concentration is also observed in the dark control without *am*-FeOOH ( $\sim 210 \mu\text{M}$  lower) and does not appear to be a function of pH, since the initial pH values for the hv-MSIA ( $\text{pH}_i = 5.69$ ) and dark-MSIA ( $\text{pH}_i = 5.78$ ) experiments are similar. It is not clear why the concentration of initial MSIA(aq) observed in the dark control is so different from the initial concentration of MSIA(aq) in the experiment with light in the absence of *am*-FeOOH. Although some of the MSIA decomposition may be attributed to the thermal decomposition of MSIA, this would have contributed equally in both of the controls.

The initial slopes for MSIA consumption between the experiment with *am*-FeOOH and without are also very different. The initial slope is very rapid in the presence of *am*-FeOOH, slows after 15 min, and is completely depleted by 90 min. MSIA is rapidly oxidized by the LMCT reaction described above. In comparison, the control without *am*-FeOOH displays a slow initial slope that continues to increase exponentially, until after 240 min, when the rate slows due to the depletion of MSIA. The initial formation of MSA is an exact mirror image of the MSIA decomposition thus implying it is the direct product of MSIA. This trend indicates that the oxidant, most likely HO<sup>•</sup>, must first be formed through photochemical reaction (i.e., Reaction 13), to initiate MSIA oxidation (Reactions 14a and 14b) (Yin et al., 1990).



Bardouki et al. (2002) reported a first order photolysis rate for MSIA (rate =  $k[\text{MSIA}]$ ;  $k = 3 \times 10^{-5} \text{ s}^{-1}$ ). Since MSIA photolysis (Figure 63, ochre) is first order, this rate can be obtained by plotting the natural log of [MSIA] versus time in seconds. The decay of MSIA should be linear and the slope is  $k$ . In our case, the slope does not appear linear because we observe an exponential rate increase, most likely because there is an additional reaction occurring by a radical species (Figure 73). In fact, it appears that there are two rates occurring (delineated by the red and blue curve fit lines), indicating that two reactions are driving the decomposition of MSIA in the presence of light. A

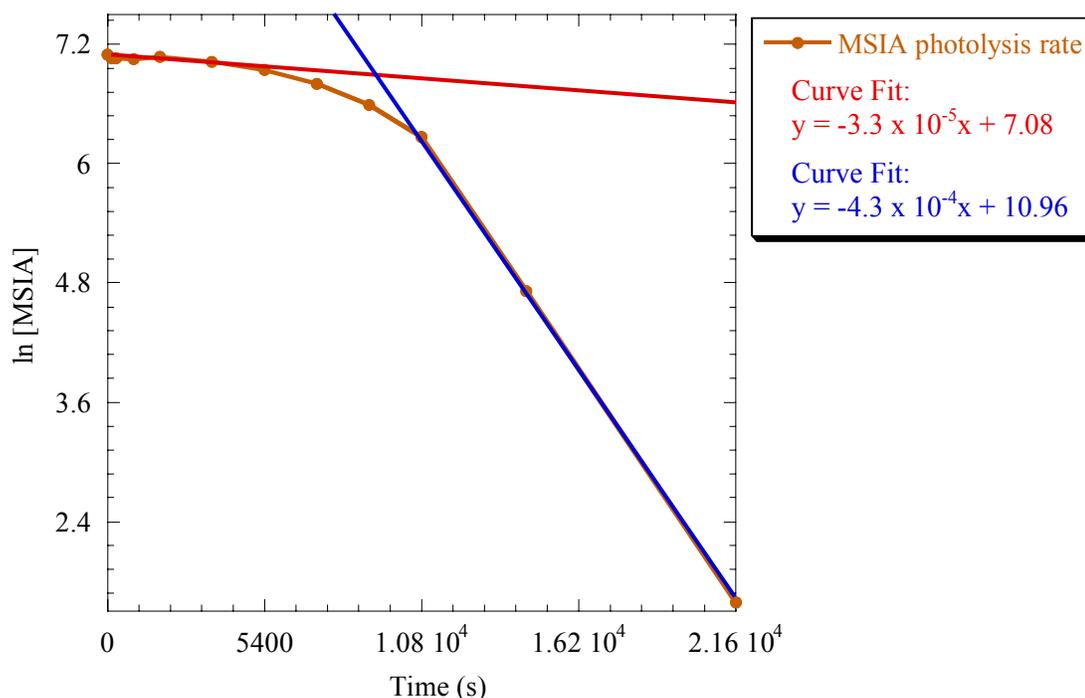


Figure 73. Graph of the photolysis of methane sulfinic acid.

straight line through the initial 15 min (900 s) of the plot of  $\ln[\text{MSIA}]$  versus time for our MSIA photolysis data yields a  $k = 3.3 \times 10^{-5} \text{ s}^{-1}$  (Figure 73, red line). This value is comparable to the  $k$  reported by Bardouki et al. (2002), yet it is difficult to determine if they calculated their reported rate constant in this manner because a graph of MSIA photolysis is not shown.

A straight line through the last three data points of Figure 73 (blue line) yields a rate constant of  $k = 4.3 \times 10^{-4} \text{ s}^{-1}$ . This reaction appears to be second order (i.e., rate =  $k[\text{MSIA}][\text{HO}^\bullet]$ ) in that the rate is dependent on not only the concentration of MSIA, but also some other reactant, such as  $\text{HO}^\bullet$ . However, our calculated rate constant does not compare well with the rate constant reported for with the decomposition of  $\text{HO}^\bullet$  reported by Bardouki et al. (2002) ( $k = 1.2 \times 10^{10} \text{ s}^{-1}$ ). Thus, it appears that some other radical or

oxidant may be driving this second reaction. At this point, it is difficult to determine the reactions driving MSIA photolysis with much certainty.

There is little evidence in the literature that supports the notion that  $O_2^{\bullet -}$  oxidizes organic molecules, thus, it is not considered as a likely oxidant in the following reactions. In fact, Sawyer and Valentine (1981) found that  $O_2^{\bullet -}$  is generally not a reactive oxidant of organic and inorganic molecules. Once initiated, the reaction rate continues to increase, indicating that the supply of oxidant may be catalytically produced. At this point it is uncertain whether the  $HO_2^{\bullet}$  can continue to react further. According to Yin et al. (1990), it appears that  $HO_2^{\bullet}$  can continue to react further with MSIA.  $HO_2^{\bullet}$  can be reduced again, and in the presence of  $H^+$ , which is present in the reaction medium (pH ~3 to 4), and form  $H_2O_2$ .  $H_2O_2$  can then undergo photolysis to produce  $HO^{\bullet}$ .

We observed that over 17% of MSIA is oxidized over a 6-hour period in the dark (Figure 63, light green) due to thermal decomposition at ~22 °C (room temperature), further indicating that oxidation of MSIA to MSA is initiated by the presence of light.  $HO^{\bullet}$  appears to be a likely oxidant; however,  $H_2O_2$  concentrations for the hv-MSIA control were BDL. Thus, at this point, it is not clear where the oxidant is derived from.

For the light control with  $NO_3^-$  added (Figure 63, light blue),  $HO^{\bullet}$  from  $NO_3^-$  photolysis is immediately available. Therefore, reaction occurs immediately, resulting in a steeper initial rate that continues until MSIA is depleted. Compared to the light control without  $NO_3^-$  (ochre), there appears to be an initial delay in MSIA oxidation, until oxidation begins to occur in an exponential fashion. This provides further evidence that the delay in MSIA oxidation in the light control is a result of a delay in  $HO^{\bullet}$  formation or

some other radical or oxidant (Reaction 13). It is important to note that this is the only time a reaction is observed from the effects of added  $\text{NO}_3^-$ . In previous experiments, when  $\text{NO}_3^-$  was added, a reaction was typically not observed. This occurrence was quite different from the presence of interstitial  $\text{NO}_3^-$ , which appeared to enhance the reaction.

In experiments where a reaction was observed, MSIA was completely oxidized to MSA without the formation of  $\text{SO}_4^{2-}$ , which was never observed as an oxidized S product in any of the experiments. However, in the atmosphere,  $\text{SO}_4^{2-}$  is observed and thought to form from the oxidation of the precursors MSA and  $\text{SO}_2$ . One study in the equatorial Pacific found a strong correlation between DMS,  $\text{SO}_2$ , and  $\text{HO}^\bullet$ , with  $\text{SO}_2$  being the major product formed from the  $\text{HO}^\bullet$ -initiated oxidation of DMS (Davis et al., 1999). In addition, a high degree of correspondence was found between  $\text{SO}_2$ ,  $\text{HO}^\bullet$ , and  $\text{H}_2\text{SO}_4$ , which suggests that the DMS oxidation product  $\text{SO}_2$  is the dominant gas phase S precursor to  $\text{H}_2\text{SO}_4(\text{g})$  formation.  $\text{SO}_2$  is rapidly oxidized to  $\text{SO}_4^{2-}$  in cloud droplets through reaction with  $\text{H}_2\text{O}_2$  (Pandis and Seinfeld, 1989). This oxidation can also occur in sea-salt aerosols with the dominant oxidant being  $\text{O}_3$  (Sievering et al., 1992).

$\text{SO}_4^{2-}$  may also not have been observed because there was no reaction pathway for its formation.  $\text{SO}_4^{2-}$  formation is thought to be associated with the abstraction pathway, while MSA formation is associated with the addition (Williams et al., 2001). For example, some studies of marine aerosol composition have found an inverse correlation between the MSA:NSS- $\text{SO}_4^{2-}$  ratio and temperature (Johansen et al., 2000). In the present study, reactions proceeded through the addition pathway as indicated by the formation and detection of MSIA, which would thus explain why no  $\text{SO}_4^{2-}$  was observed.

Another explanation for the lack of  $\text{SO}_4^{2-}$  formation may be due to the fact that the experiment was terminated after a 6-hour period. According to Bardouki et al. (2002), the formation of  $\text{SO}_4^{2-}$  could originate from further reaction of MSA with  $\text{HO}^\bullet$  radicals; however, this reaction is at least a factor of 50 to 100 slower compared to that of DMSO with  $\text{HO}^\bullet$  radicals. It may be possible that if the experiment were extended, allowing enough time for  $\text{SO}_4^{2-}$  production from MSIA and MSA oxidation, it would be observed.

In addition, HMSIA and HMSA were not observed in detectable concentrations. In the atmosphere, HMSA may be produced from the reaction of formaldehyde ( $\text{CH}_2\text{O}$ ) with  $\text{SO}_3^{2-}$ , which may form when  $\text{SO}_2$  dissolves in fog or cloud water (Neubauer et al., 1996; Voisin and Legrand, 2000). This may explain why HMSA was not observed, since  $\text{CH}_2\text{O}$  was not added to the reaction medium and  $\text{SO}_3^{2-}$  may not have been formed. HMSIA may also have not been observed for a similar reason, since there doesn't appear to be a reaction mechanism from DMSO to HMSIA.

#### 5.1.4. *Absence of Iron(III)*

Though Fe(III) concentrations during the photochemical experiments were expected to be low (0.1 mM to  $\mu\text{M}$  range), results for Fe(III) were generally not present at detectable levels on the micromolar scale, unless the pH dropped below 3. This occurred in the Batch 5 experiment with DMSO (no AM 1, Figure 48) and the Batch 6 experiment with MSA (40 mM, Figure 69), where the pH at 360 min was 2.74 and 1.60, respectively. These low pH values were a result of the formation of the acidic DMS oxidation products (i.e., MSIA and MSA) and added MSA, representative of current atmospheric concentrations. According to Figure 16, the concentration of dissolved

Fe(III) (i.e.,  $\text{Fe}(\text{OH})^{2+}$ ) increases at lower pH values, which may explain why Fe(III) concentrations were observed in only these experiments.

The reason for the rise and sudden drop at 150 min in Figure 48 and the rise and falling behavior observed in Figure 69 is not currently understood, though, this trend may be a result of nucleation and particle growth after Fe(III) is formed. This process may be slow enough to be observed here; however, it is speculation at this point and thus exemplifies the need for further experiments.

Another reason for the lack of observed Fe(III) is that there may not have been enough  $\text{H}_2\text{NOH HCl}$  added to reduce all of the Fe(III) in solution. However, this seems unlikely since it was assumed that the Fe(III) concentration in solution was no higher than  $5 \mu\text{M}$  and a liberal concentration of  $\text{H}_2\text{NOH HCl}$  ( $\sim 50 \mu\text{M}$ ) was added to ensure that all of the Fe(III) in solution would be reduced to Fe(II).

## 5.2. Future Experiments

We have shown that the DMS oxidation product MSIA is actively involved in the photochemical reductive dissolution of Fe on the surface of marine aerosol particles through an LMCT reaction (Reaction 12). The elementary steps of this proposed mechanism are not currently understood. It is conceivable that a similar complexation could occur at the oxygen anion site between Fe(III) and the anion forms of other DMS derivatives with sulfinic or sulfonic functional groups, such as HMSIA, MSA, HMSA, etc. Further investigation of these DMS derivatives can lead to a better understanding of the detailed mechanisms involved in the proposed LMCT reaction.

XRD scans of *am*-FeOOH collected during this study revealed little, if any, change in terms of crystal structure. This may be explained by the inherent amorphous structure of *am*-FeOOH, which made measuring and interpreting change in crystal structure after photochemical reaction difficult. To measure a change in crystal structure in future experiments, it would be better to initiate photochemical reactions with more crystalline Fe oxides, such as goethite or hematite. This may allow for easier interpretation of change (i.e., less amorphous to more amorphous) in crystal structure due to photochemical reaction. As mentioned previously, goethite and hematite were not selected for initial photochemical experiments in this thesis because ferrihydrite is the most likely form of Fe oxyhydroxides in the atmosphere. In addition, an amorphous structure will probably react more easily because less bonds are constraining surface Fe(III).

Surface area measurements to determine particle size were also difficult to interpret after reaction due to the freeze-drying process. In future experiments, it would be beneficial to utilize a laser particle counter that is capable of determining particle size or surface area while suspended in solution. During the photochemical experiments involving MSIA, the suspension seemed to become increasingly cloudy, implying the presence of small sized particles that will settle out slower and thus be available longer for reaction. This reprocessing of Fe phases is important in governing the reactions that will occur and the end products that will form in this system and within the atmosphere.

To study reaction mechanisms in the absence of O<sub>2</sub>, one of the Fe(II) oxidants, the reaction medium can be purged with N<sub>2</sub>. More detailed mechanistic studies of the

Fe(III)-MSIA complex are needed. Such studies would involve, for example, changing initial MSIA concentration and adding excess MSIA to better determine initial rates and to interpret kinetics, etc.

Halogens have been shown to play an important role in the cycle of sulfur in the atmosphere (von Glasow and Crutzen, 2004). Therefore, it would be interesting to add BrO to the reaction medium. It has been estimated that in the atmosphere, as much as 10% of the global oxidation of DMS to DMSO may occur from reaction with this halogen (Toumi, 1994). However, there are two serious problems with this hypothesis: 1) a significant source of BrO in the marine atmosphere has yet to be observed and 2) model simulations reveal that at night BrO would be rapidly depleted by reaction with CH<sub>2</sub>O, which is observed in significant levels at that time. CH<sub>2</sub>O, an oxidation product of hydrocarbons, is also produced through the oxidation of methane, one of the biogenic gases released from the surface of the oceans (Zafiriou et al., 1980). According to model calculations by von Glasow and Crutzen (2004), though, BrO strongly increases the oxidation of DMS even when at mixing ratios smaller than 0.5 pmol mol<sup>-1</sup>, indicating that this reaction may be important although a significant source has not been observed in the atmosphere.

Marine aerosols may provide surfaces for the conversion of Br<sub>x</sub> and O<sub>3</sub> to BrO (Toumi, 1994) in addition to a surface for the oxidation of DMS by BrO. In laboratory studies, BrO has been shown to oxidize DMS through the addition pathway (Figure 18) (Ingham et al., 1999; Toumi, 1994). During this project, an experiment with DMS was conducted; however, DMS is extremely volatile and very insoluble. As a result, the

effect on the photoreductive dissolution of Fe was difficult to measure due to the short-lived presence of DMS. The addition of BrO to the reaction medium may oxidize DMS to DMSO, a more soluble species, thus allowing us to initiate the reaction with DMS.

In future projects, once the kinetics and mechanisms governing Fe speciation in acidic pH representative of the atmosphere are more fully understood, a buffer (i.e., phosphate) at pH 8.3 will be used in the reaction medium to simulate ocean water. Eventually real ocean water will be used to better represent the natural environment. If the same reactions are observed in those experiments, these reactions are not only occurring in aerosol particles, but also in the surface of the ocean.

## CHAPTER 6

### SUMMARY AND CONCLUSION

MSIA enhances the reduction of Fe(III) to Fe(II) in the presence of light in a photochemical reaction involving the electron transfer from MSIA to surface Fe(III) on *am*-FeOOH. The complex that is formed between MSIA and surface Fe(III) absorbs maximum radiation around 280 nm with a broad shoulder tailing off between 350 and 500 nm. DMSO, a direct precursor of MSIA, displays a negative effect on Fe(II) photoproduction unless oxidized in the presence of increased UV radiation and  $\text{NO}_3^-$ , which yields  $\text{HO}^\bullet$  that enables DMSO oxidation to MSIA. This MSIA can then react with Fe as described above. The observed change in pH for experiments involving MSIA are insignificant compared to the changes observed for the DMSO experiments. This pH drop is largely attributed to the formation of acidic products, MSIA and MSA, and while this pH drop may stabilize the Fe(II) against oxidation (Stumm and Morgan, 1996), it does not contribute to the direct Fe(II) formation observed in these experiments.

Through the reduction mechanism described above, it is possible that phytoplankton may be obtaining necessary bioavailable Fe by increasing DMS emissions in open ocean regions, where physiological stressors, such as Fe limitation, are the first order determinants of the biological production of DMSP, and thus DMS (Sunda et al., 2002; Toole and Siegel, 2004). While the present experiments were carried out at pH values typical of the marine atmosphere (von Glasow and Sander, 2001), this mechanism is potentially also occurring in surface ocean water.

These results contribute to the understanding of feedback mechanisms that govern Fe speciation over remote open oceans by showing the relevance of marine biogenic influence on aerosol chemistry over open-ocean systems where phytoplankton feedback is controlled by environmental stressors, such as Fe limitation. To date, these mechanisms have not been incorporated into current modeling efforts, which have, in turn, not proven to be reliable in predicting soluble Fe (Hand et al., 2004).

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## APPENDIXES

### Appendix A

#### Common Abbreviations

Abbreviation	Definition
AM	air mass
<i>am</i> -FeOOH	ferrihydrite
aq	aqueous
atm	atmosphere
BDL	below detection limit
C <sub>2</sub> H <sub>2</sub> O <sub>4</sub> /C <sub>2</sub> O <sub>4</sub> <sup>2-</sup>	oxalic acid/oxalate
DMS	dimethyl sulfide
DMSO	dimethyl sulfoxide
DMSO <sub>2</sub>	dimethyl sulfone
DMSP	dimethylsulfoniopropionate
HMSA	hydroxymethane sulfonic acid
HMSIA	hydroxymethane sulfinic acid
HNLC	high nutrient low chlorophyll
HO <sub>2</sub> <sup>•</sup>	hydroperoxyl radical
IC	ion chromatography
IPCC	Intergovernmental Panel on Climate Change
LMCT	ligant-to-metal charge transfer
MSA	methane sulfonic acid
MSIA	methane sulfinic acid
NO <sub>3</sub> <sup>-</sup>	nitrate
O <sub>2</sub> <sup>•-</sup>	superoxide radical
SeaWiFS	sea-viewing wide field-of-view sensor
SO <sub>3</sub>	sulfur trioxide
SO <sub>4</sub> <sup>2-</sup>	sulfate
TOMS	total ozone mapping spectrometer
UV-vis	ultraviolet-visible

## Appendix B

Representative Data from Standards and  
Calibration Curves for Sulfur Species

Table B1. Representative Iron(II)(aq) Standards Data 06/28/2004

Concentration ( $\mu\text{M}$ )	Absorbance 562 nm
0.0	-0.0124
0.5	0.0037
1.0	0.0205
5.0	0.1258
25.0	0.6038
75.0	1.6139

Table B2. Representative Hydrogen Peroxide Standards Data 10/07/2004

Concentration ( $\mu\text{M}$ )	Relative Change			Average ( $\Delta\text{pA}$ )
	( $\Delta\text{pA}_1$ )	( $\Delta\text{pA}_2$ )	( $\Delta\text{pA}_3$ )	
1	3086	3118	3115	3106
5	4768	4730	4761	4753
10	7473	7531	7570	7525
25	16095	16328	16213	16212
50	30505	30505	30480	30497
75	41944	42024	41939	41969
100	51293	51312	51298	51301

Table B3. Representative Sulfur Species Standards Data 10/03/2004

Concentration ( $\mu\text{M}$ )	Sulfur Species (Peak Area)			
	MSIA	MSA	HMSIA	HMSA
5	24717	26919	27125	31757
30	169546	193603	193924	213298
100	598144	690373	656819	767594
150	982412	1137114	1068626	1322695
200	1309287	1520543	1414256	1750168

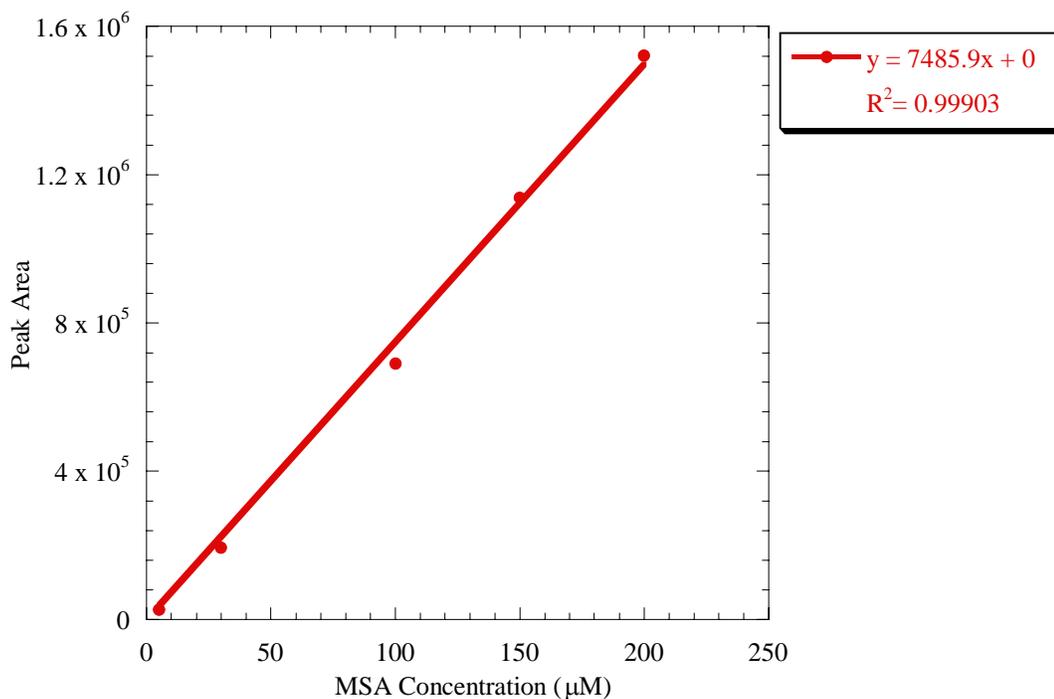


Figure B1. Standard curve data for methane sulfonic acid determination using the ion chromatograph. Values are determinations from standards ranging from 5 to 200 μM.

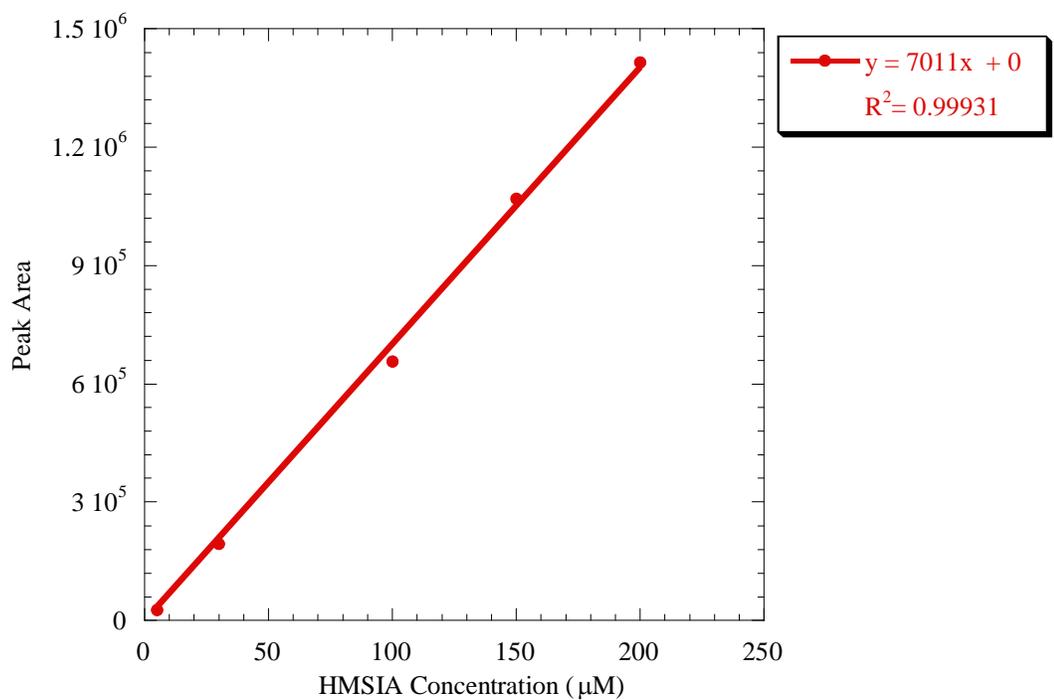


Figure B2. Standard curve data for hydroxymethane sulfinic acid determination using the ion chromatograph. Values are determinations from standards ranging from 5 to 200 μM.

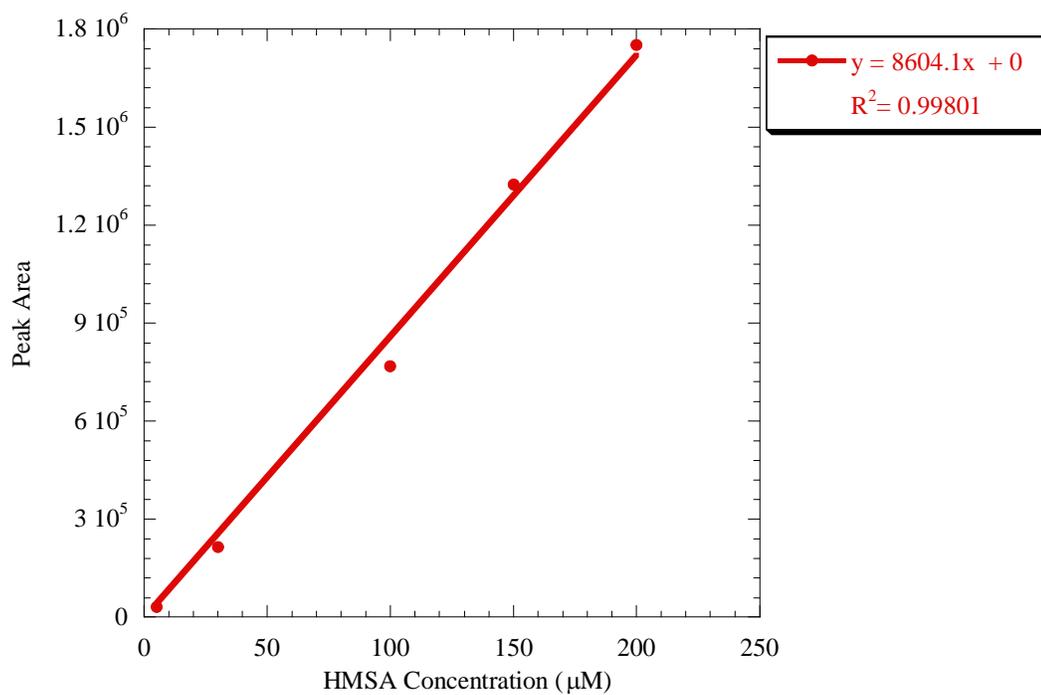


Figure B3. Standard curve data for hydroxymethane sulfonic acid determination using the ion chromatograph. Values are determinations from standards range from 5 to 200 µM.

## Appendix C

Representative Absorbance Scan (06/28/2004), Amperometric Response (10/07/2004),  
and Ion Chromatogram (10/03/2004)

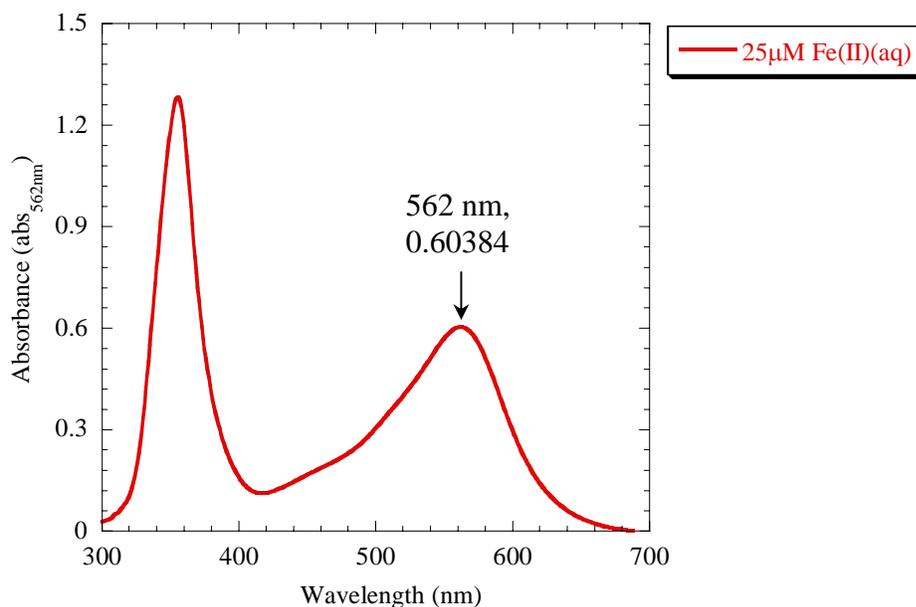


Figure C1. Representative absorbance scan of 25 μM standard of iron(II). Labeled peak shows analyte wavelength and absorbance value.

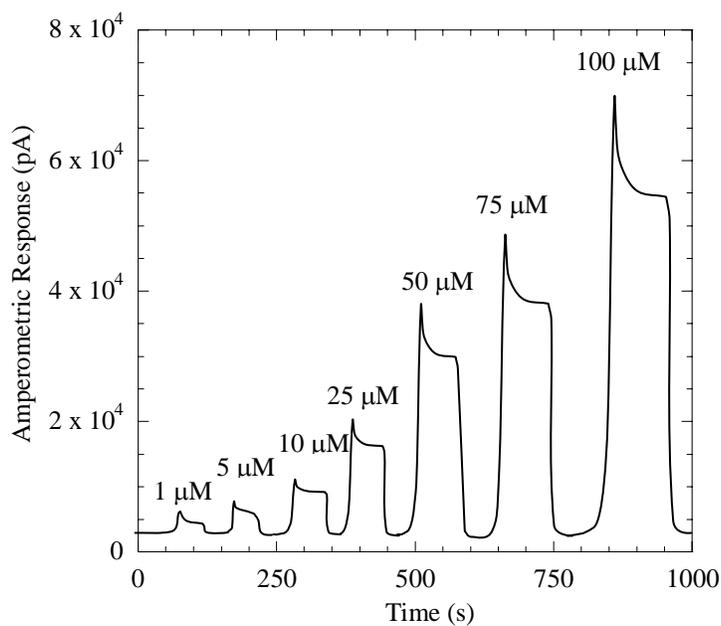


Figure C2. Representative amperometric response of hydrogen peroxide standards (1 to 100 μM).

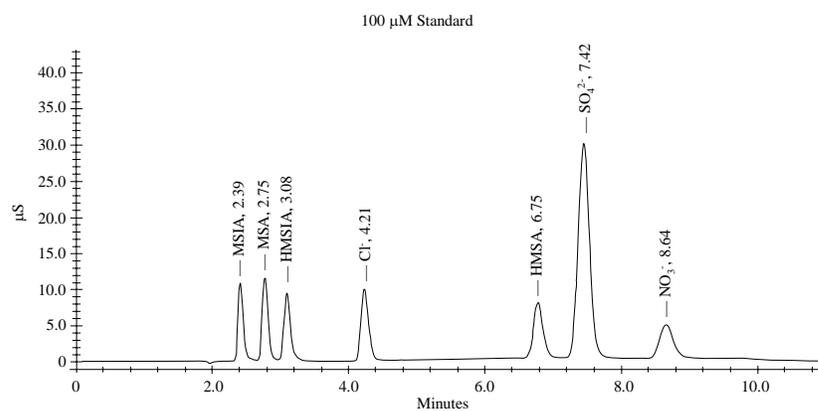


Figure C3. Representative ion chromatogram of 100  $\mu\text{M}$  standard. Peaks are labeled with characteristic retention times. Chloride ( $\text{Cl}^-$ ) and nitrate ( $\text{NO}_3^-$ ) were added to standard for quantification of amorphous ferrihydrite impurities.

## Appendix D

## Detection Limits

Table D1. Values for Establishing Z-cell Detection Limit

<i>n</i>	Blank (abs)	1.5 $\mu$ M (abs)
1	0.00043	0.1480
2	0.00255	0.1482
3	0.00438	0.1480
4	0.00398	0.1476
5	0.00555	0.1540
6	0.00540	0.1461
7	0.00600	0.1524
8	0.00863	0.1512
mean	0.00461	0.1494
standard deviation	0.00244	0.0028

Table D2. Values for Establishing Hydrogen Peroxide Probe Detection Limit

<i>n</i>	Blank ( $\Delta pA$ )	5.0 $\mu M$ ( $\Delta pA$ )
1	189	3067
2	154	2945
3	102	3088
4	123	3977
5	167	3481
6	115	3762
7	105	3715
8	127	3189
mean	135	3403
standard deviation	31	383

Table D3. Detection Limits for Iron, Hydrogen Peroxide, and Sulfur Species

Analyte	Detection Limit ( $\mu M$ )
Fe(II)	0.39
Fe(III)	0.39
H <sub>2</sub> O <sub>2</sub>	2.77
MSIA	1.19
MSA	0.82
HMSIA	5.24
HMSA	6.06
SO <sub>4</sub> <sup>2-</sup>	7.13

## Appendix E

## Measured Surface Areas and X-Ray Diffraction Scans

Table E1. Surface Area Measurement of Amorphous Ferrihydrite Batches Before and After Photochemical Reaction

<i>am</i> -FeOOH Batch	Surface Area (m <sup>2</sup> /g)			
	Before	After		
		Fe-hv-MSIA	Fe-hv-DMSO	Fe-hv
1	—	—	—	—
2	—	—	162	—
3	—	—	—	—
4	205	—	—	—
5	196	—	—	—
6	221	100	113	123
7	—	—	—	—

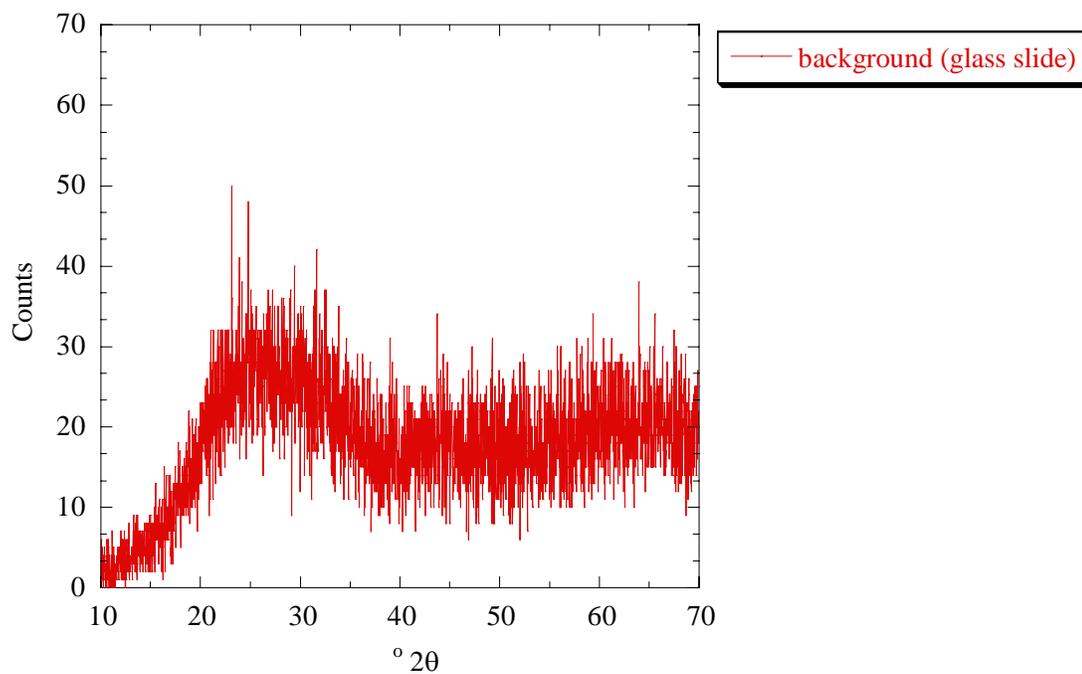


Figure E1. X-ray diffraction background scan (glass slide).

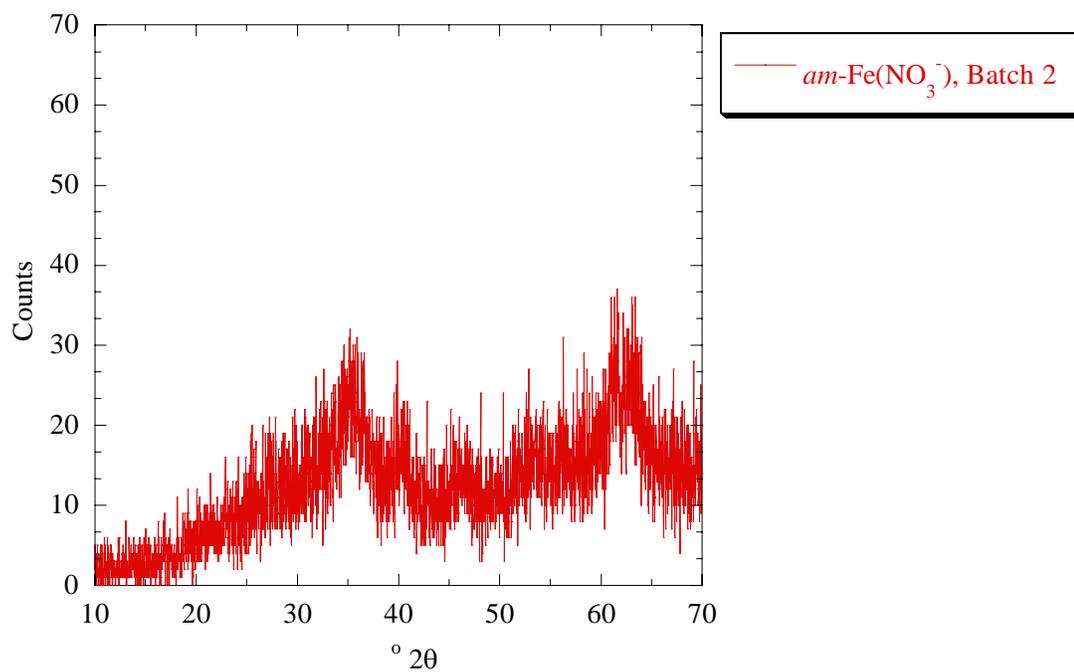


Figure E2. X-ray diffraction scan of ferrihydrite (Batch 2) prepared from iron nitrate before photochemical reaction.

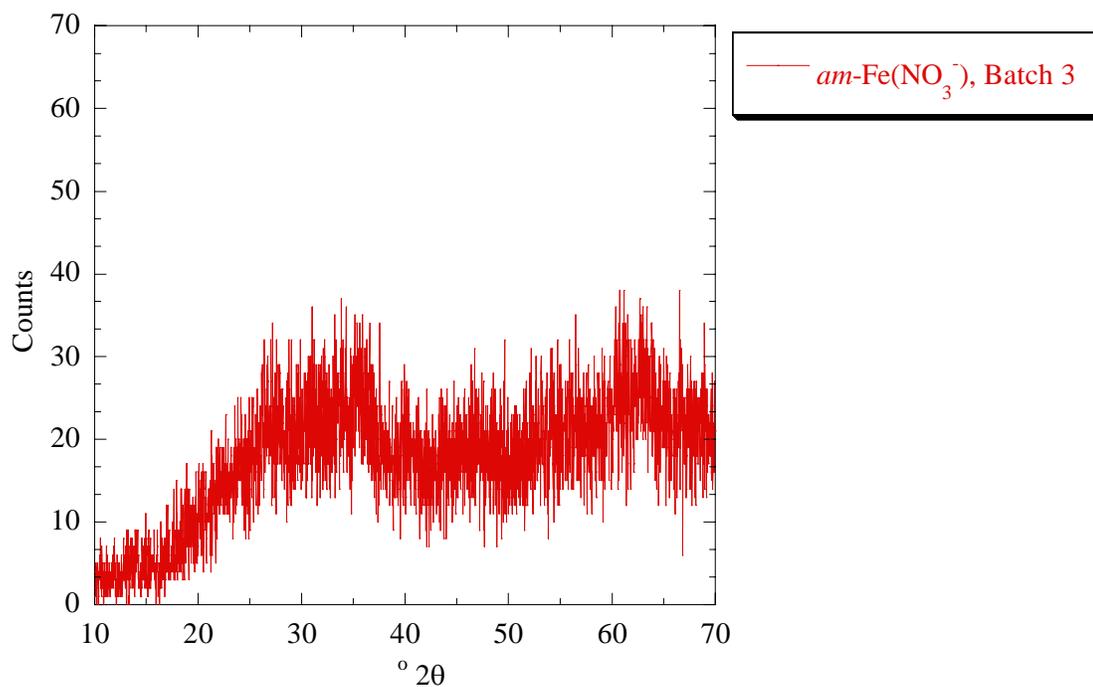


Figure E3. X-ray diffraction scan of ferrihydrite (Batch 3) prepared from iron nitrate before photochemical reaction.

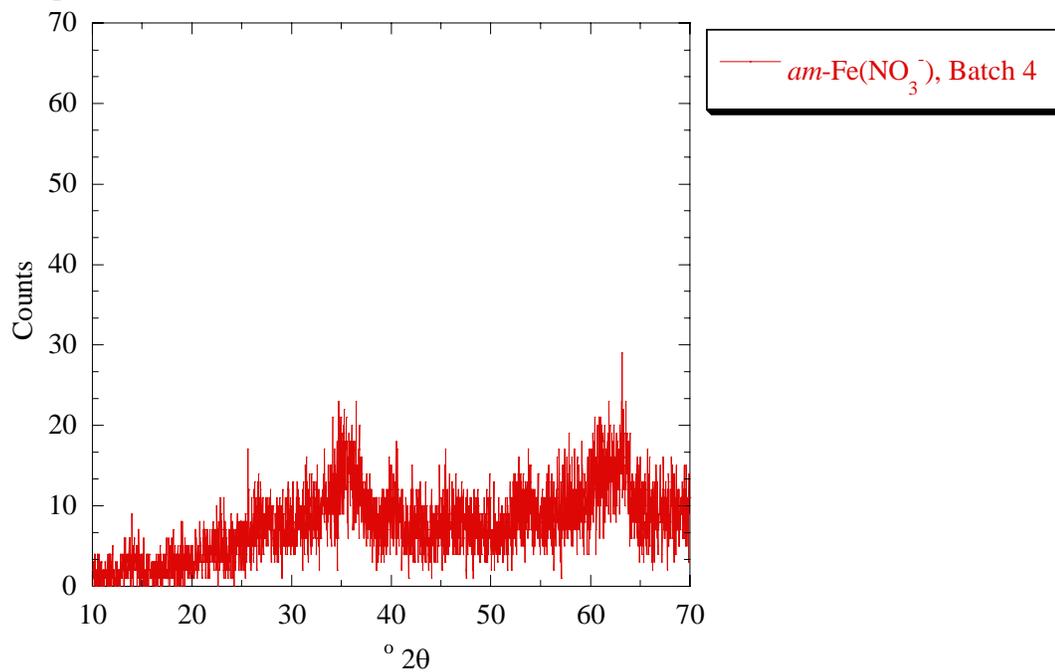


Figure E4. X-ray diffraction scan of ferrihydrite (Batch 4) prepared from iron nitrate before photochemical reaction.

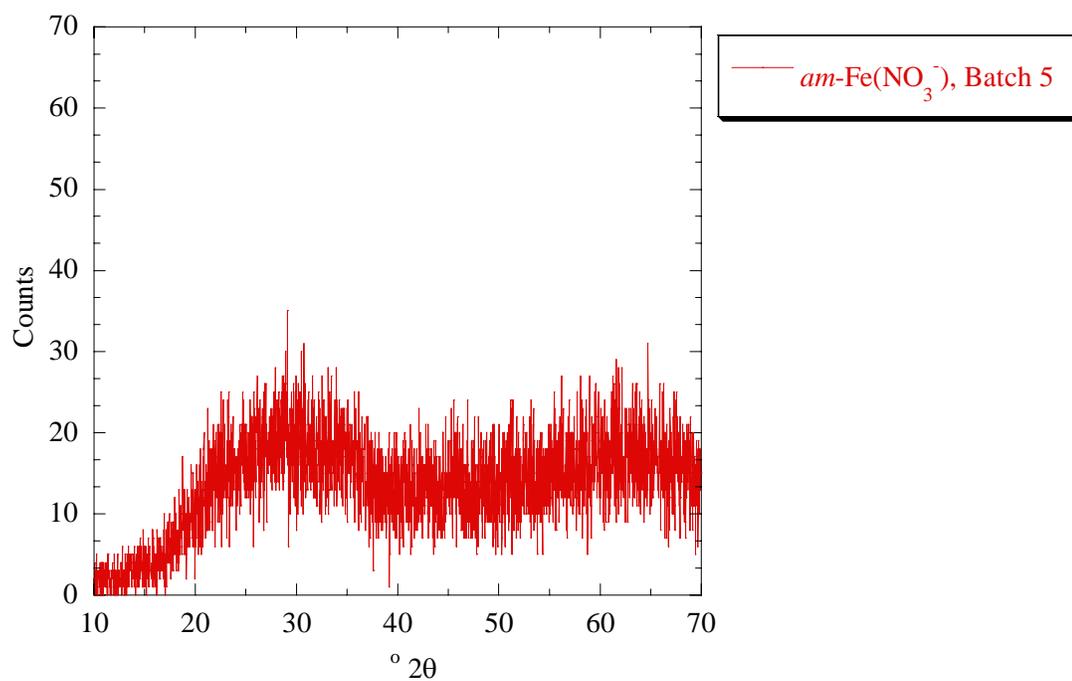


Figure E5. X-ray diffraction scan of ferrihydrite (Batch 5) prepared from iron nitrate before photochemical reaction.

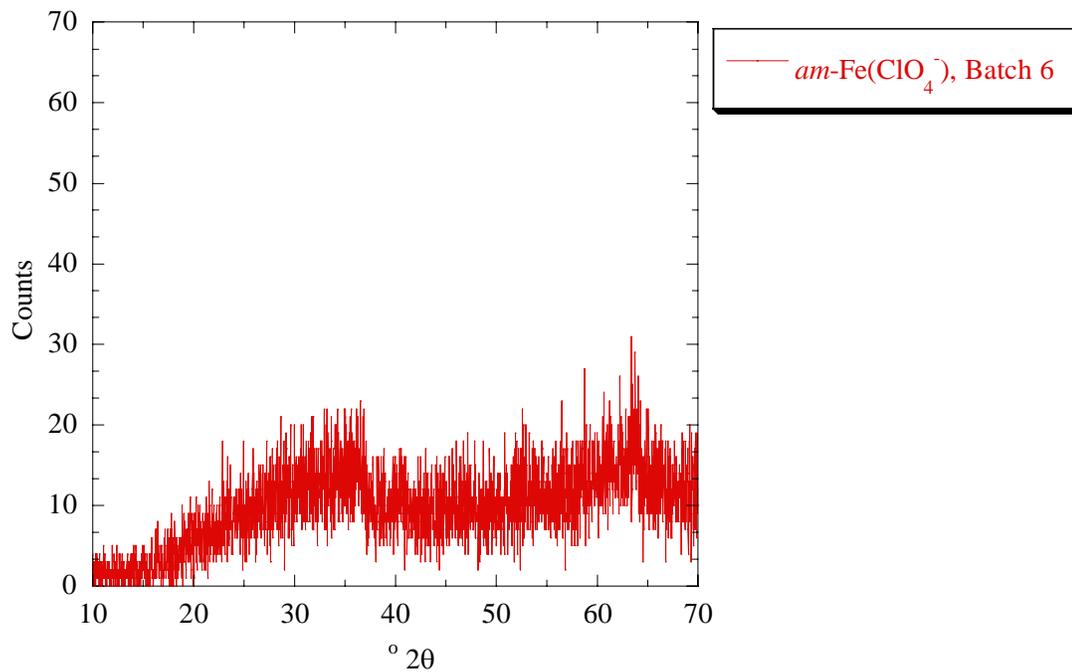


Figure E6. X-ray diffraction scan of ferrihydrite (Batch 6) prepared from iron perchlorate before photochemical reaction.

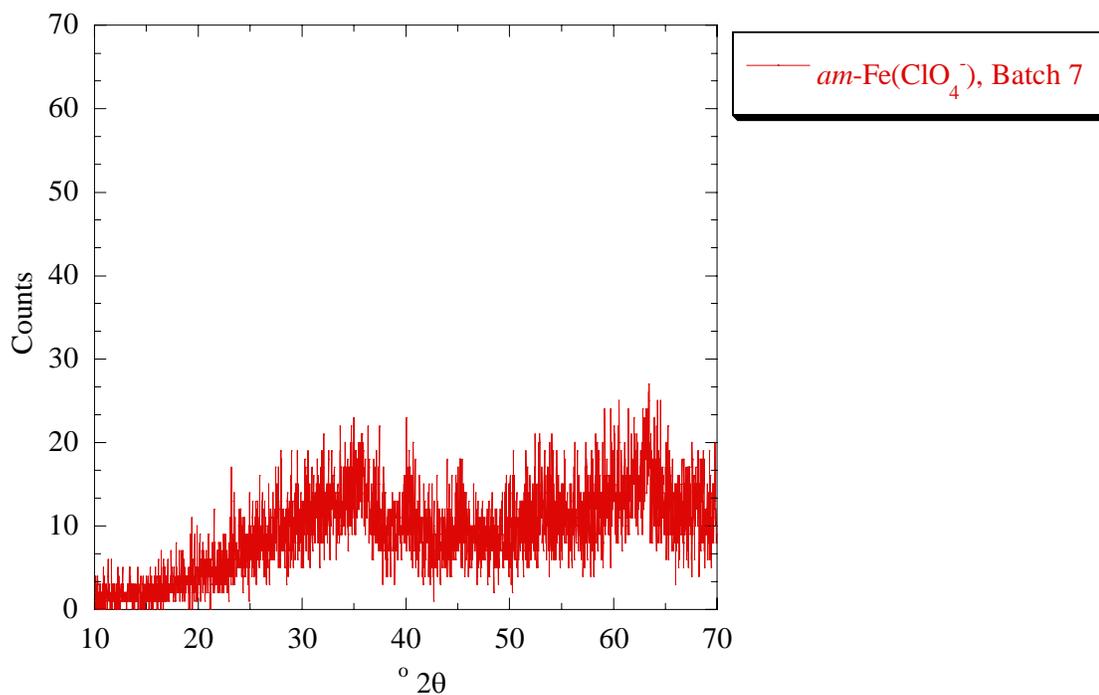


Figure E7. X-ray diffraction scan of ferrihydrite (Batch 7) prepared from iron perchlorate before photochemical reaction.

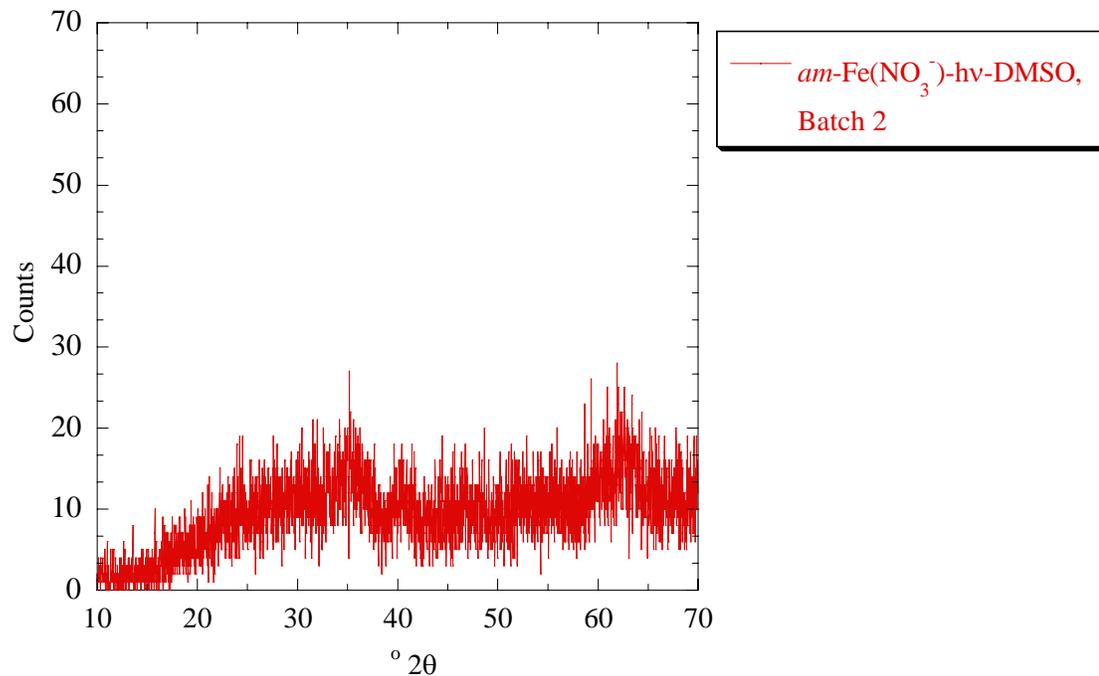


Figure E8. X-ray diffraction scan of ferrihydrite (Batch 2) prepared from iron nitrate after photochemical reaction in the presence of light and dimethyl sulfoxide.

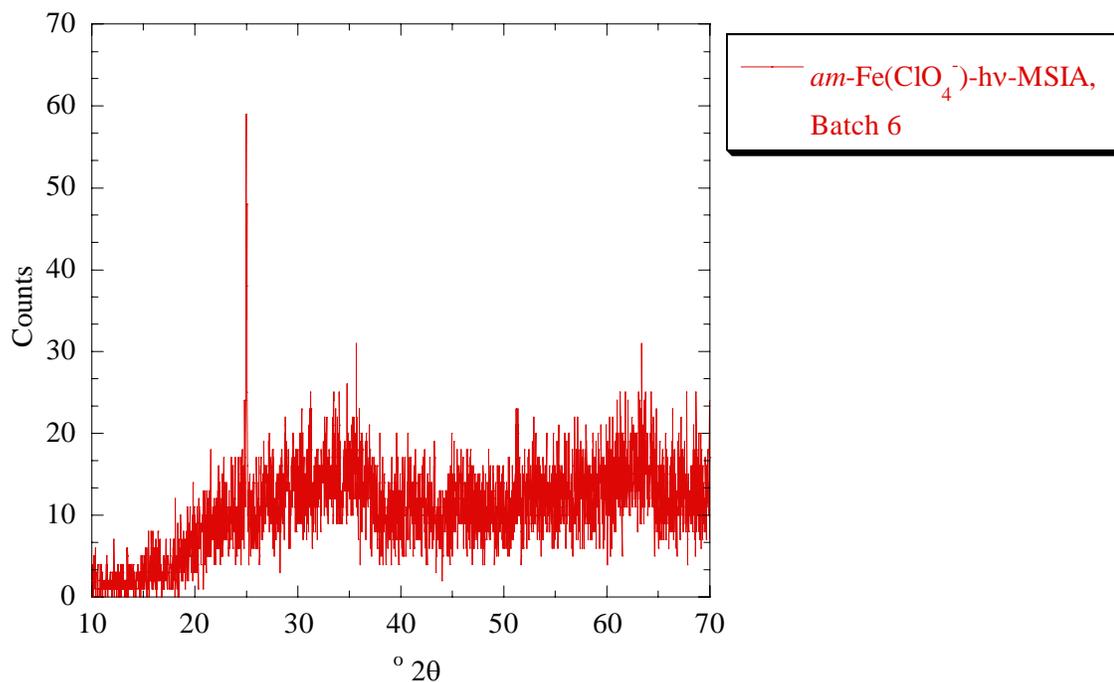


Figure E9. X-ray diffraction scan of ferrihydrite (Batch 6) prepared from iron perchlorate after photochemical reaction in the presence of light and methane sulfinic acid.

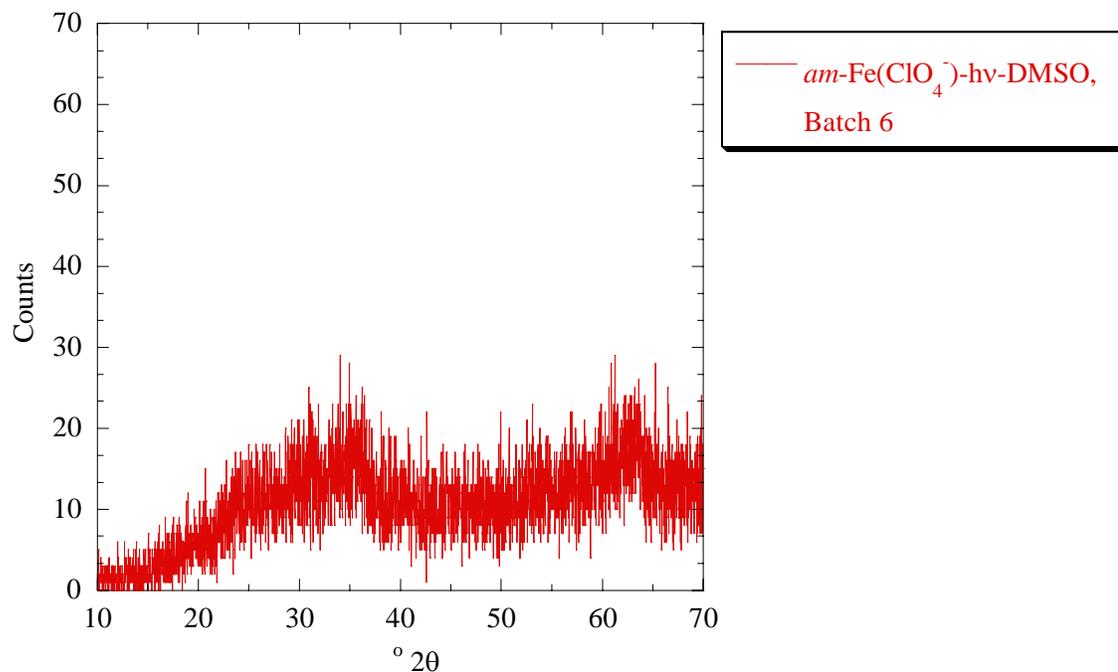


Figure E10. X-ray diffraction scan of ferrihydrite (Batch 6) prepared from iron perchlorate after photochemical reaction in the presence of light and dimethyl sulfoxide.

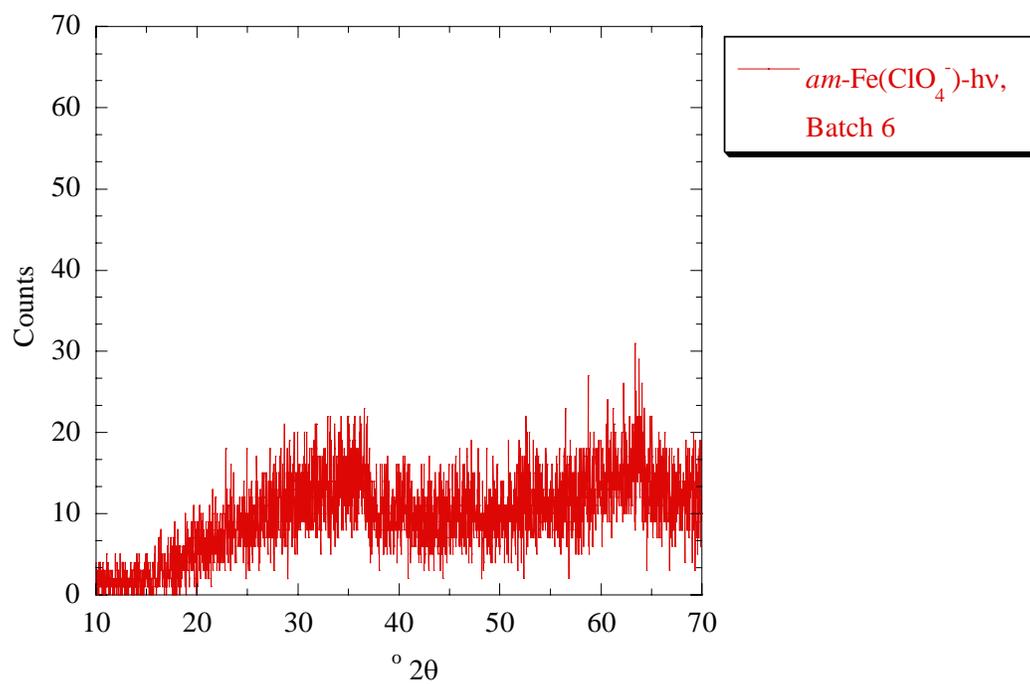


Figure E11. X-ray diffraction scan of ferrihydrite (Batch 6) prepared from iron perchlorate after photochemical reaction in the presence of light.

Appendix F

Photochemical Experimental Data



## Appendix G

Data from Ferrihydrite-Light-Dimethyl Sulfoxide with Oxalic Acid

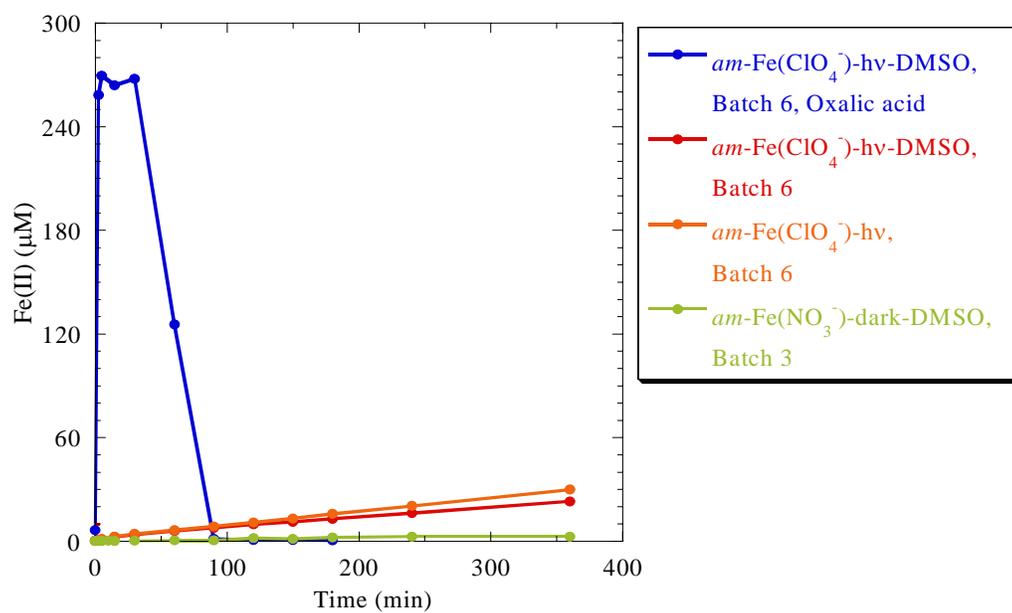


Figure G1. Levels of iron(II) for experiments with ferrihydrite in the presence of light, dimethyl sulfoxide, and oxalic acid.

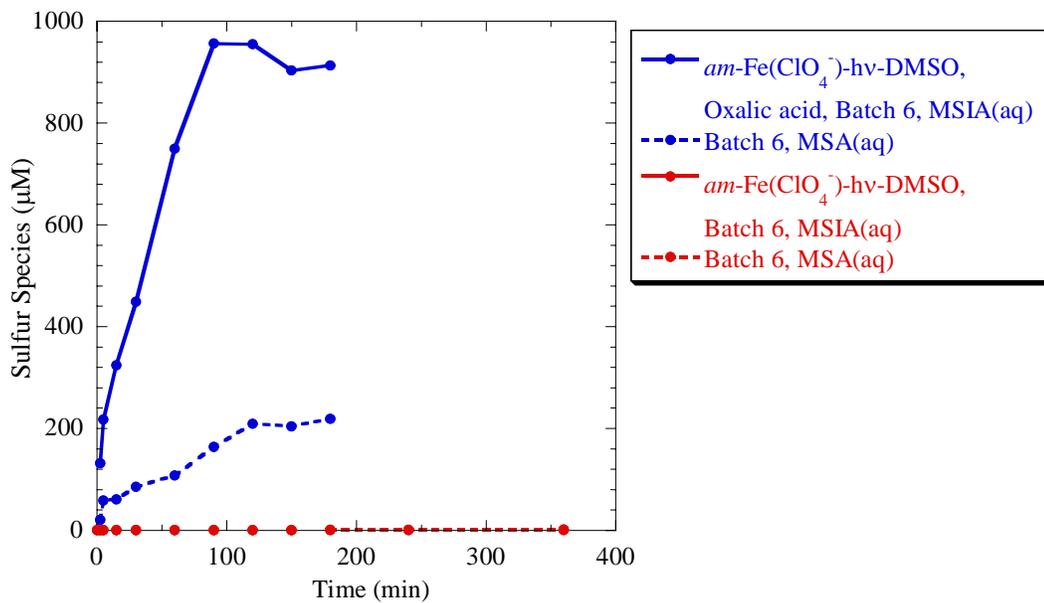


Figure G2. Levels of methane sulfinic acid and methane sulfonic acid for experiments with ferrihydrite in the presence of light, dimethyl sulfoxide, and oxalic acid. Light and dark controls are BDL and not shown.