Chem 311: Chemistry Across the Periodic Table
Spring 2019

Instructional Team

Instructor: **Professor Daniel C. Fredrickson**
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Teaching Assistants: **Katherine Ziebarth**, kziebarth@wisc.edu (sections 601 and 602)
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Laboratory director: **Dr. Chad Wilkinson**

Course Attributes

Description: Explores the properties, reactions and uses of elements and compounds, with emphasis on coordination chemistry of transition-metal ions, bioinorganic chemistry, solid-state structure and main-group elements. The weekly three-hour laboratory introduces students to the synthesis and characterization of inorganic compounds.

Breadth – Physical Sci. Counts toward the Natural Sci requirement
Level – Intermediate
L&S Credit – Counts as Liberal Arts and Science credit in L&S

Credit units: 4 (3 hours/week of lecture material, 4 hours/week of discussion/lab activities)
Lectures: MWF 1:20pm-2:10pm; 1315 Chemistry
Laboratories: T or R, 7:45am-11:50am, meeting in 2373 Chemistry before going to room 1329
T or R, 1:20pm-5:25pm, meeting in 2381 Chemistry before going to room 1329

Instructional mode: face-to-face.

Course website: https://canvas.wisc.edu/courses/140580

Aims of Chem 311

Overview: The 118 known elements are the building blocks of every substance on earth. In Chem 311 you will learn about patterns of reactivity among chemical families, unique properties of selected elements, and how these reactivity patterns and properties are manifest in biological and industrial applications. The course will emphasize coordination chemistry of the transition metals, bioinorganic and solid-state chemistry. You will learn about reactivity through laboratory exploration and problem solving. Students in Chem 311 are expected to have successfully completed Chem 104, Chem 109, Chem 115 or an equivalent with a grade of C or above.

Topics Covered:

1. *Quantum Mechanics and the Periodic Table.* Basic features of quantum mechanical systems; the hydrogen atom; atomic orbitals; multi-electron atoms; relationship between atomic subshell structure and the periodic table; atomic properties and their periodic trends.

2. *Chemical Bonding Concepts.* Types of chemical bonding and the van Arkel-Ketelaar triangle; molecular orbital theory; frontier molecular orbitals; the hard and soft acids and bases concept.

3. *Coordination Chemistry.* History; structures and isomerism; nomenclature; bonding models; crystal field splitting, electron configurations, and magnetic properties; reactions of coordination compounds, including mechanisms and kinetics; the application of the hard and soft acids and bases concept; the chelate effect; bioinorganic chemistry.

4. *Solid State Chemistry.* The solid state and crystallinity; types of crystals; common crystal structure types; solid state synthesis; properties of solid state materials; bonding and energetics in the solid state.

5. Descriptive Chemistry of the Main Group Elements. Discovery; production; crystal structures; selected compounds; key applications.

Learning outcomes:

Upon completing this course, students will be able to:

1. Recognize how the structure of the periodic table reflects the quantum mechanical nature of atoms and the electrons they contain.
2. Recall the three-dimensional shapes and nodal properties of the atomic orbitals, rationalize them in terms of the compromise between kinetic and potential energies of electrons, and apply them in explanations and predictions of bonding and reactivity.
3. Explain trends in atomic properties in terms of the shell structures of atoms, trends in effective nuclear charge, the shapes of the atomic orbital radial wavefunctions, and electrostatic energies.
4. Distinguish between the nature and energetic origins (quantum mechanical and electrostatic) of the three fundamental bonding types, and express their varying weights within different compounds using the van Arkel-Ketelaar triangle.

5. Construct simple molecular orbital diagrams, and apply molecular orbital-based concepts to the rationalization and prediction of chemical phenomena.
6. Visualize the structures and isomerism of transition metal coordination compounds, interpret nomenclature relevant to these compounds, and write out the various types of reactions they undergo.
7. Interpret the structures, reaction mechanisms, and properties (spectroscopic and magnetic) of transition metal compounds in terms of bonding concepts, particularly molecular orbital theory and crystal field theory.
8. Describe the nature of solid state compounds and their atomic arrangements, classify solid state compounds according to the types of bonding that lead to their periodic arrangements, visualize and recognize common crystal structure types, and recall structural and physical phenomena unique to crystalline materials.
9. Assimilate new chemical information, particularly descriptive chemistry, in an effective way through the application of the abilities described above.
10. Effectively communicate scientific results, interpretations, and conclusions through writing.
11. Apply a range of laboratory techniques, apparatus, and instrumentation to the synthesis and characterization of inorganic compounds.

Course Organization and Expectations

A recommended study strategy for this course is: (1) read the assigned material, complete the pre-class problem sets, and prepare questions regarding unclear points before each lecture, (2) attend class, take your own notes, and actively participate in class exercises, (3) as soon as possible after class, recopy your notes and elaborate on them with any details that you did not have time to write down, and (4) solve any follow-up problems that are provided. While reading the text or other passages, rather than taking detailed notes, it can be more effective to jot down possible quiz questions about what you're reading, then test yourself on later them later (active recall provides stronger integration of material than repeated but passive exposure). Also, become fluent with drawing structures, orbitals, reactions, and other aspects of the visual language of chemistry. When you encounter problems that you cannot solve, refer to the text, your notes, library resources, your fellow students, or the course instructor and TAs during their office hours. Forming a study group to review and problem solve is an excellent way to learn chemistry.

To help you to master the new material presented in this course, specific learning objectives will be provided for each unit and its associated exam. These objectives will be available on the course Canvas page. Use the learning objectives to guide your work on the problem sets and practice exams for that course unit. Practice exams keyed to the learning objectives are also available in the same location. Fully worked out answer keys will be made available for you to use to check your work on the practice exams at least two days before the exam.

Various learning activities are offered to meet the needs of different types of students; however, if you find that your learning needs are not being met or that you are not satisfied with some aspect of the course please bring your concerns to Prof. Fredrickson or your TA.

Evaluation Strategies: Two midterm exams, the best 25 of 28 problem sets, the best 9 of 11 in-class quizzes, twelve laboratory exercises, and a final exam will form the basis for your grade in Chem 311. The midterm exams will be held in-class on March 4 and April 22 (both Mondays). The final exam will be held at 7:45-9:45 AM on Fri. May 10. Please notify Prof. Fredrickson and your TA of any conflicts promptly.

Text, Resources & Materials

Textbook: *Descriptive Inorganic, Coordination, and Solid-State Chemistry*, 3rd Edition, Glen E. Rodgers, Brooks/Cole Cengage, 2012, available within the Canvas course as an eTextbook. As noted in the Course Guide, this course is participating in the UW-Madison Engage eText Pilot. On your tuition bill there will be a charge of $20.62 for the eText (compared to the print textbook's list price of $159.95). *You do not need to purchase a print version of the textbook.* Your eText is available via the Engage tool in your Canvas course page. Engage works best when viewed online in Firefox or Chrome.

To access your eText, follow these steps:

1. In the menu at the left of the screen on the Canvas page, click on "Engage eText" to open the Engage reading platform.
2. Click on "Launch Unizin Engage".
3. Read the EULA and click on "I agree" at the end.
4. Click on the image of the textbook's cover to read the book.

To learn more about how the eText works, follow these steps:

1. Follow steps 1 and 2 above.
2. In the top right corner of Engage, click on your initials/photo.
3. Click on the Help link.
4. Click on "Students" to access quick overviews of how to navigate the platform and all the general studying/learning features – reading, note-taking, highlighting, questioning, printing, bookmarking, searching, and collaborating.

Please familiarize yourself with the Engage platform before the first day of class. A short demo of Engage can be found *here*. Additional resources can be found in the *Engage* and the *UW-Madison KnowledgeBase*. If you wish to *opt-out* of using the Engage eText, please contact me at *danny@chem.wisc.edu* before doing so. If you wish to request an accessible version of the eText, please contact the McBurney Disability Resource Center as soon as possible. More information is available *here*.

Calculator: An inexpensive calculator is required. It should have capabilities for square roots, logarithms and exponentiation (antilogarithms), and exponential (scientific) notation operations. You may use programmable calculators in this course.

Auxiliary Materials: The following materials may be purchased from Alpha Chi Sigma (AXΣ) in the Chemistry Student Computer Lab (room 1375). Be ready to pay with your WisCard (lab manual and lab coat) and cash (lab notebook and goggles).

Lab Manual: *Chemistry 311, Laboratory Manual*, Spring 2019 edition. (Only sold by AXΣ.)

Lab Notebook: Carbonless laboratory notebook with duplicate pages. You will need a new notebook for Chem 311 because you will use all the pages. Sold by AXΣ or the bookstore.

Safety Goggles: Industrial quality eye protection is required at all times when you are in the lab. AXΣ sells safety goggles that completely seal around the eyes and fit over regular glasses. These goggles meet our safety requirements.

Lab Coat: A lab coat must be worn at all times when you are in the lab.

***Chem 311* Course Homepage:** Much material for this course is only available via the course homepage. You should have access to the 311 materials on this site (https://canvas.wisc.edu/courses/140580) if you are enrolled in this course. If you have a problem logging in, and you have been registered for Chem 311 for at least two days, send an email to instructional technology specialist Dr. Rachel Bain, rbain@chem.wisc.edu.

Coursework for Chem 311

Problem Sets: Pre-class problem sets will be posted on the Chem 311 Canvas site ahead of the Wednesday and Friday lectures, and will be due at 11:55pm on the day before the lecture. These will generally involve completing a reading and answering of some basic questions about it on an on-line form. At the beginning of Wednesday and Friday lectures, the answers to the questions will be given as a mechanism to communicate some of the straight-forward factual information relevant to the course material that does not require substantial discussions. Each problem set is worth up to 4 points, with the lowest three problem set scores being dropped. Assuming the class attendance and participation is high, the full 4 points will be awarded for completion of each problem set before the deadline. If class attendance is low or those attending seem unfamiliar with the problem set content, more detailed grading may be carried out.

Interactive Quizzes: Aside from exam days, Monday lecture sessions involve quizzes that will handed out to the class, often associated with a reading provided ahead of time. During the first 15 minutes or so of the session, students will work individually to solve the quiz questions, writing in black ink. Next, students will be allowed to discuss the problems with a partner (who should be different for each quiz) from the same section for about 10 minutes, and may edit or add to their answers using blue ink. Each student will then trade their quizzes with their partner. As the instructor explains the solutions and elaborates on their significance, each student will grade their partner's answers in red ink following a provided rubric and assign a *simulated* exam score. Each pair will turn in their quizzes together to their TA. Every quiz will be worth up to 11 points toward a maximum total of 99 (with the two lowest scores being dropped). 9 points will be based on the quiz performance and 2 points corresponding to the quality of the grading on the partner's quiz.

Laboratory: The Chem 311 laboratory is designed to be an integral part of your learning experience, and will represent 30% of your total grade (300 of 1000 points). In the lab, you will focus on two primary objectives: the synthesis of compounds and the analysis of their structure. These are essential goals of modern inorganic chemistry research. Your lab exercises will give you the opportunity to explore the reactivity of a wide variety of elements with your own hands, and you will experience the beauty and variety of inorganic compounds. Many people who become inorganic chemists were inspired by their lab experience.

Laboratory Reports/Assignments and their point values are listed here:

LabWrite assignment		5
Malachite Bead		20
Polysiloxanes	CPR	30
Prussian Blue		10
UV-Vis Tutorial		10
IR Tutorial		10
Rhodium Rainbow		10
Rhodium Rainbow Follow-up		10
Lewis Acid-Base Adduct	CPR	30
DMSO Complexes		20
Magnetic Susceptibility	CPR	30
Nickel Series		40
Cobalt(salen)	CPR	40
Nickel Nanotechnology		15
OLED		20
Total		300

Calibrated Peer Review (CPR): Four of your lab reports will be evaluated using Calibrated Peer Review (CPR) a system designed to help you learn how to write a scientific report. Using CPR you will also learn how to recognize a well-written scientific report, how to evaluate your own writing, and how to review and evaluate other students' work.

CPR requires that you demonstrate your ability to recognize good scientific writing by a process called calibration. During calibration, you will be asked to read three versions of the same laboratory report and to recognize the good and bad aspects of each report. CPR will then ask you questions about each report so that you can demonstrate that you can distinguish a poor report from an average and a good report. The calibration process is to ensure that when you evaluate the reports of other students you can do so in a consistent and fair way. It is also designed to teach you how to recognize when a report you have written is good enough to submit for evaluation by others.

CPR involves a process called peer review that is used to evaluate scientific papers to decide whether they should be published. When a scientist completes a research study, writes a report, and submits the report to a scientific journal for publication, the editor of the journal must decide whether to publish the report, to ask the author to revise it, or to decline to publish because the

report is not good enough. Other scientists who do research similar to that reported in the paper—peer reviewers—are asked to review the paper and provide to the editor their opinions regarding its quality. Peer reviewers provide constructive, courteous criticism of the paper, which the editor returns to the author so that the author can improve the paper. In Chem 311 you will serve as a peer reviewer of your own laboratory report and of the reports of three other students.

For each experiment with a CPR report you will write an individual laboratory report and prepare it for upload to CPR. Then you will review three laboratory reports that your instructors have written. The three reports illustrate high quality, medium quality, and low quality. You will use these reports to calibrate your ability to recognize a well written report; part of your grade will depend on how well you calibrate. Next, you will read and review three laboratory reports by other students in Chemistry 311. As is often true in peer review of scientific papers, the reports will be anonymous—you won't know who wrote each report you review. As is almost always true in peer review of scientific papers, the reviewers will also be anonymous—after the reviews are completed, you won't know who the three reviewers of your report were. At the end of the process you will be able to see the reviews of your work and use them to improve your subsequent lab reports. Chem 311 TAs have observed that after using CPR the quality of students' lab reports increases significantly, which is good because whatever your future career the ability to report scientific results is going to be an important skill that potential employers will value.

***Lab Report Criteria**:* Any scientific report should provide information in a format that is easily assimilated and interpreted by a reader. As you write each lab report consider these questions and make certain that you have addressed each of them in your report. Your TA will use these criteria to evaluate your report but note that some will be weighted more strongly than others; it is not sufficient just to check off each box but rather the overall presentation and report quality is what counts.

1. Does the title describe the report content concisely, adequately and appropriately?

2. Does the abstract convey a sense of the full report concisely and effectively? Is there a clear statement of the overall findings?

3. Does the introduction provide sufficient information for the reader to understand the concepts tested, the purpose, and the scientific context of this laboratory exercise?

4. Is the procedure clearly and completely described with an appropriate level of detail that would allow someone to reproduce the experiment?

5. Are the results described clearly and with sufficient support? Are the findings, observations, and characterization data presented logically and appropriately?

6. Are figures and tables used effectively in this report, providing clear and accurate information?

7. Does this report successfully integrate figures and tables with the text? Do the figures and tables help to create a concise and effective presentation?

8. Does the discussion include a summary of the findings and back up this summary with specific reference to the results? Is there sufficient explanation of the results and is it presented

logically? Are the results effectively placed in a broader scientific context?

9. Are the conclusions clearly stated and well supported?

10. Are there three or more references to appropriate sources of information and are they cited using ACS format?

You will also be evaluated on the attention to safety and effectiveness of your laboratory work and on the quality of your laboratory notebook, which should contain a legible and complete record of the experiment.

Finally, the requirement of punctual attendance in lab and the completion of your lab reports will be enforced. Coming to the lab session or turning in a report late will result in a 20% penalty being assessed when your score is entered in the grade book.

Exams: There will be two midterm examinations and a final exam which collectively will be worth up to 501 points, accounting for about 50% of the possible points for this class. These exams may draw on any material previously introduced in the course, and with one goal being to assess how well you have integrated the ideas discussed into your thinking about chemistry. Learning objectives, study questions, and practice exams for each unit will be posted ahead of each exam.

A recommended strategy for preparing for the exams is: (1) review the learning objectives for the exam referring to your notes or the text if necessary, (2) work the study questions associated with each objective, spending more time working problems on those topics you find most challenging, (3) simulate the test taking situation by working the practice exam in 50 minutes in a quiet place, (4) "grade" your own test using the answer key as your guide, (5) review and test yourself on those areas that you identify as weak, working extra problems in these areas to reinforce your knowledge.

Grades

Your grade will be based on a maximum of 1000 points divided as follows:

Your best 25 of 28 pre-class problem sets (4 points each)	100 points
Your best 9 of 11 in-class quizzes (11 points each)	99 points
Twelve laboratories and associated assignments *(each week's experiment is listed in the calendar)*	300 points
Two midterm exams @ 125 points each *(dates and times are listed in the course calendar)*	250 points
Final Exam *(date and time is listed in the course calendar)*	251 points
Total	1000 points

Letter Grades: Final letter grades will be based upon the following absolute scale:

A	860 points or more
AB	830 to 859 points
B	770 to 829 points
BC	710 to 769 points
C	600 to 709 points
D	500 to 599 points
F	<499 points

If you score the number of points indicated, then you will receive at least the corresponding letter grade, regardless of how many other students achieve the same grade. **There is no curve.** Therefore, it is to your benefit (and to your friends' benefit) that you help other students learn and they help you learn. If necessary, adjustments (generally small) will be made at the end of the semester. **Prof. Fredrickson will not discuss the adjustment process**. However, any changes to the threshold will never lower your final letter grade, but may possibility raise it.

Important Administrative Information

Electronic Mail: You are encouraged to contact Prof. Fredrickson by email at danny@chem.wisc.edu if you have questions about anything to do with the course. Electronic mail is available at all times of day and night, so you can send messages whenever something comes to mind. Please include the words "Chem 311" in the subject line of any message you send to him or your TAs. NOTE: *Messages sent without this in the subject line will likely be buried very quickly!*

What To Do If You Are Sick, Or Otherwise Unable To Attend An Exam or Lab: If you are unable to attend a specific lab session because of an unavoidable schedule conflict, for example a religious observance, an athletic activity, or a family obligation, contact your TA as soon as possible to reschedule. *Make up labs can be arranged only during the week when the entire class is doing a lab exercise, so planning ahead is important.* If you find that you are unable to attend lab because you are ill, contact your TA as soon as possible. He or she will discuss your situation and decide what to do. **If circumstances arise unexpectedly that preclude your taking an exam, please contact your TA and Prof. Fredrickson before the scheduled exam time.** We recognize that in an emergency situation, you may not be able to contact us in a timely way.

Chemistry Resource Facilities - Computer Room, Study Room, Undergraduate Chemistry Office, Chemistry Library: Computers are available for use in room 1375 Chemistry. Room 1371 is a study room for chemistry students. The staff in the Undergraduate Chemistry Office, room 1328, can assist you with enrollment, advising, and many other things.

Cell Phone / Computer Policy: If you bring a cell phone to class or lab, please silence it for the duration of the class or lab period. If there is a situation that absolutely requires you to answer your cell phone during a class, please set the phone to silent/vibrate and sit in a location where

you do not disturb other students when leaving the classroom to accept a call. Computers may not be used during class or the lab sessions.

Academic Policies

ACADEMIC INTEGRITY: By enrolling in this course, each student assumes the responsibilities of an active participant in UW-Madison's community of scholars in which everyone's academic work and behavior are held to the highest academic integrity standards. Academic misconduct compromises the integrity of the university. Cheating, fabrication, plagiarism, unauthorized collaboration, and helping others commit these acts are examples of academic misconduct, which can result in disciplinary action. This includes but is not limited to failure on the assignment/course, disciplinary probation, or suspension. Substantial or repeated cases of misconduct will be forwarded to the Office of Student Conduct & Community Standards for additional review. For more information, refer to https://conduct.students.wisc.edu/academic-integrity/

ACCOMMODATIONS FOR STUDENTS WITH DISABILITIES: McBurney Disability Resource Center syllabus statement: "The University of Wisconsin-Madison supports the right of all enrolled students to a full and equal educational opportunity. The Americans with Disabilities Act (ADA), Wisconsin State Statute (36.12), and UW-Madison policy (Faculty Document 1071) require that students with disabilities be reasonably accommodated in instruction and campus life. Reasonable accommodations for students with disabilities is a shared faculty and student responsibility. Students are expected to inform me of their need for instructional accommodations by the end of the third week of the semester, or as soon as possible after a disability has been incurred or recognized. I will work either directly with the student [you] or in coordination with the McBurney Center to identify and provide reasonable instructional accommodations. Disability information, including instructional accommodations as part of a student's educational record, is confidential and protected under FERPA." http://mcburney.wisc.edu/facstaffother/faculty/syllabus.php

INSTITUTIONAL STATEMENT ON DIVERSITY: "Diversity is a source of strength, creativity, and innovation for UW-Madison. We value the contributions of each person and respect the profound ways their identity, culture, background, experience, status, abilities, and opinion enrich the university community. We commit ourselves to the pursuit of excellence in teaching, research, outreach, and diversity as inextricably linked goals. The University of Wisconsin-Madison fulfills its public mission by creating a welcoming and inclusive community for people from every background – people who as students, faculty, and staff serve Wisconsin and the world." https://diversity.wisc.edu/

Tentative Schedule for Chem 311, Spring 2019

Date	Topic	Textbook	Laboratory
	1. Quantum Mechanics and the Periodic Table		
W, 1/23	Schrödinger equation and electron energies	Chapter 1	No Lab
F, 1/25	Atomic orbitals; shielding; effective nuclear charge		
M, 1/28	*Interactive Quiz 1*: Quantum mechanics		
W, 1/30	The periodic table; chemical periodicity	Chapter 9	Malachite Bead
F, 2/1	Periodic trends, atomic properties		
M, 2/4	*Interactive Quiz 2*: Periodic trends		
	2. Chemical Bonding Concepts		Polysiloxanes
W, 2/6	Chemical bonding		(CPR Report)
F, 2/8	Chemical bonding		
M, 2/11	*Interactive Quiz 3*: Chemical Bonding		Prussian Blue,
	3. Coordination Compounds		Rh rainbow.
W, 2/13	Coordination compounds	Chapters 2, 3	IR. UV-vis
F, 2/15	Coordination compounds		tutorials
M, 2/18	*Interactive Quiz 4*: Coordination compounds		
W, 2/20	Crystal field theory	Chapters 4	Lewis adducts (CPR Report)
F, 2/22	Crystal field theory		
M, 2/25	*Interactive Quiz 5*: Crystal field theory		
W, 2/27	Reactions of coordination compounds	Chapter 5	DMSO Complexes
F, 3/1	Reactions of coordination compounds		
M, 3/4	**Exam I** (location TBA)		Magnetic
W, 3/6	Reactions of coordination compounds	Chapter 5, 6	Susceptibility
F, 3/8	Bioinorganic chemistry		(CPR Report)
M, 3/11	*Interactive Quiz 6:* More coordination chemistry		
	4. Solid State Chemistry		Nickel Series
W, 3/13	The solid state; types of crystals; lattices	Chapter 7	
F, 3/15	Solid state synthesis, Common structure types		
3/16-24	*No class—Spring Recess*		
M, 3/25	*Interactive Quiz 7*: Crystal structures		Nickel Series
W, 3/27	Crystal lattice energies	Chapter 8	Co(salen)
F, 3/29	Crystal lattice energies, band structures		
M, 4/1	*Interactive Quiz 8*: Crystal lattice energetics		
W, 4/3	Hydrogen and hydrides	Chapters 10, 11	Co(salen)
F, 4/5	Oxygen and oxides		
M, 4/8	I*nteractive Quiz 9:* H and O		
	5. Descriptive Chemistry	Chapters 12, 13	Co(salen)
W, 4/10	Group 1: Alkali metals		(CPR Report)
F, 4/12	Group 2: Alkaline earth metals		
M, 4/15	I*nteractive Quiz 10:* Groups 1 and 2		
W, 4/17	Group 13: Boron and the group 13 metals	Chapters 14, 15	Ni Nanotech/ Ru(bpy)
F, 4/19	Group 14: Si and its congeners		
M, 4/22	**Exam II (**location TBA)		
W, 4/24	Group 15: Pnicogens	Chapter 16, 17	OLED Checkout
F, 4/26	Group 16: Chalcogens		
M, 4/29	I*nteractive Quiz 11:* Groups 14-15		
W, 5/1	Group 17: Halogens	Chapters 18, 19	No Lab
F, 5/3	Group 18: Noble Gases		

Final Exam: Friday, May 10, 2019, 7:45-9:45 AM