ENVR419: Chemical Equilibria of Natural Waters
Fall 2015

Time: 11:00-12:15 Tuesday and Thursday
Location: 2304 McGavran-Greenberg
Instructors:
Orlando Coronell (coronell@unc.edu) and Scott Hauswirth (shauswirth@unc.edu)

Office Hours:
Hauswirth: 12:15-1:15pm TT and by appointment - 0020 Hooker Research Center
Coronell: 10:00-11:00am TT and by appointment, 163B Rosenau Hall

Website: `https://sakai.unc.edu/portal/site/envr419_2015`

1 Course Scope and Objectives

Water-phase chemical equilibria and kinetics are fundamental to many fields within the environmental sciences and engineering, including drinking water systems, waste water treatment processes, geochemistry, atmospheric and marine sciences. The overall goal of this course is to provide students with an understanding of the fundamentals of aqueous chemistry as they apply to both natural and engineered systems. The major topics covered in this course are: (1) chemical thermodynamic principles, (2) acid-base equilibria, (3) complexation and speciation of metals, (4) dissolution of gases and solids, and (5) redox chemistry. The focus of the course is on inorganic species, however, if time allows, the chemistry of organics in aqueous environments will be introduced.

The course is directed at upper-level undergraduates and beginning graduate students. There are no formal prerequisites, however, some background in undergraduate-level inorganic chemistry is assumed. Students without such a background should contact the instructors prior to registration.

The format of the course will be primarily lecture-based. Students will be assigned readings and problems sets that will provide practice in problem solving techniques. At the end of the course, students should be able to predict, in a quantitative manner, the equilibrium concentration and distribution of inorganic species in ground and surface waters under a variety of natural conditions, and to predict the impact of pollutants and of natural and engineered processes on these species.

2 Text

Benjamin, Mark (2014) *Water Chemistry,* ***Second Edition*** Long Grove, IL: Waveland Press, Inc.

3 References

Several additional texts that have been widely used for water chemistry course are listed below. Students are advised to refer to these texts for additional information or for difficult topics. Readings from these texts may be recommended throughout the course.

(1) Stumm, Werner and James J. Morgan (1996) *Aquatic Chemistry: Chemical Equlibria and Rates in Natural Waters.* New York: John Wiley and Sons, Inc.

(2) Snoeyink, Vernon L. and David Jenkins (1980) *Water Chemistry.* New York: John Wiley and Sons, Inc.

(3) Brezonik, Patrick and Arnold, William (2011) *Water Chemistry: An Introduction to the Chemistry of Natural and Engineered Aquatic Systems.* Oxford: Oxford University Press

4 Schedule

The schedule shown here provides an outline of the topics covered in this course, the number of lectures anticipated for each subject, the corresponding reading in the text (Benjamin), and the rough timing. Please note that this is a tentative schedule and may be adjusted based on the pace of the course.

Timing	Topic	# Lec.	Reading
August	Introduction. Chemical composition of natural waters, units, and other preliminaries.	1	Ch.1
	Thermodynamics. (1) Thermodynamic systems, laws of thermodynamics, functions of state. (2) Gibbs free energy, equilibrium constant, van't Hoff equation.	3	Ch. 4
September	Concentration-activity relationships, ionic strength.	1	Ch. 2
	Kinetics. HW #1 due.	2	Ch. 3
	Acids and bases. Types of acids, pH, pK_a, pK_b. Mono-, di-, and triprotic acids, strong and weak acids. Mass, charge, H-balance. Titrations and buffers.	6	Ch. 5–6
	EXAM 1 (Late-September to early-October): Thermodynamics, activity, kinetics, acids and bases.	1	
October	Carbonate system, CO_2 dissolution, alkalinity. HW #2 due.	4	
	Complexation. Coordination chemistry, ligands, dissociation constant, hydrolysis, chelation.	3	Ch. 9
	Solubility of solids. Dissolution and precipitation, solubility constant, solubility of sulfides, solubility of carbonates, solubility of metal oxides and hydroxides. HW #3 due.	2	Ch. 10

Timing	Topic	# Lec.	Reading
November	**EXAM 2** (Early November): Complexation, metal speciation, solids solubility, redox.	1	
	Redox. Oxidants and reductants, electronegativity, reduction potential, pE, Nernst equation, dissolved oxygen. HW #4 due.	4	Ch. 11-12
	Additional topics, time allowing. Organic compounds, surface chemistry, or applications.	2	TBD
December	Review. Course evaluations.	1	
	FINAL EXAM 12:00 Thursday, December 11		

5 Philosophy and Expectations

The topics covered in this course can be challenging, requiring understanding of fairly abstract concepts, rigorous quantitative problem solving, and careful attention to detail. Even students with chemistry and engineering backgrounds have found this course to be difficult. The focus of the course will be on solving problems, however, to do so effectively and efficiently, it is necessary *understand* the underlying concepts. Attempting to blindly plug in values to equations is strongly discouraged (for this class or anywhere else). It will ultimately serve your interests (and save time in the long term) to take the time to understand what you're doing and why you're doing it (again, for this class and elsewhere). That will be especially true in this course, as each topic builds on skills and concepts covered by preceding topics. For example, solving problems involving dissolution and precipitation (covered in October-November) uses techniques very similar to those used for acid and base equilibria (September).

Lectures will cover much of the course content, but can't (and won't) cover everything. In-class time will be interactive; you will have opportunities to work on problems in groups, you will be asked questions, and you may be asked to work out problems on the board. For this approach to work, you need to be prepared to participate. This will include reading the reading assignments prior to class (and thinking about what you're reading), starting homework assignments early (i.e., not the night before they are due), and, of course, showing up ready to learn.

Taking advantage of office hours has proven very helpful for many students, and you are encouraged to attend them for anything ranging from clarifying questions to subtle conceptual issues to detailed quantitative problems. At the same time, don't expect to be given the answers and do make a good-faith effort to solve problems yourself (some amount of struggling is good). This may include re-reading the text, consulting other texts (see above), working through example problems, and using internet resources (there are some good ones, but use caution). Discussion with other students can also be very helpful and is encouraged. The only caveat being that giving/receiving/trading answers to homework assignments is not acceptable, and only serves to cheat yourself/others of practice. In terms of workload, the traditional rule of thumb is to plan to spend 2-4 hours per week outside of class per credit hour, which would equate to roughly 6–12 hours per week for this (3 credit) course. Based on past feedback, this range is a reasonable estimate for this course. A certain amount of practice is required to obtain a working knowledge of the concepts and problem solving approaches, but the goal is not to overload you with work. If you are at the high end of the range, it would probably be a good idea to attend office hours.

Finally, feedback is very much welcome. We will likely periodically ask for feedback, but if there are aspects of the course (teaching styles, classroom activities, assignments, topics, etc.) that are especially useful or useless, let us know!

6 Assignments and Grading

Readings

Students will be expected to read the entirety of the text chapter(s) listed in the above schedule prior to the lectures on the corresponding topics and to bring any questions to class. In some cases, students may be advised to skip certain topics or may be assigned readings from other sources. The material that students are responsible for will be indicated in class.

Homework

There will be approximately five homework assignments. The primary goal of the homework is to provide students with practice solving problems in water chemistry. Students will have roughly two weeks for each assignment (due dates will be clearly indicated). While discussion of ideas and concepts between students in permitted and encouraged, homework assignments should be completed individually. Late assignments will not be accepted.

Quizzes

Periodic short (5-10 min) quizzes will be conducted to test understanding of basic concepts. Quizzes will be announced at least one class prior. Students who are not present for a quiz will receive a zero unless they have contacted the instructor ahead of time.

Exams

There will be two mid-term exams and one final exam. Exams will consist of two sections: conceptual short-answer questions and one to two quantitative problems. Calculators (NOT phones, tablets, laptops, etc.) may be used during the exams, and are in fact strongly advised. In general, the material covered by exams will closely follow that covered in lecture and on homeworks. The topics covered on each exam will be clearly indicated prior to the exam.

Final grades will be calculated as follows:

Homework	25%
Quizzes	10%
Exam 1	20%
Exam 2	20%
Final	25%

Letter grades will be assigned as follows:

Undergraduate		Graduate	
Percentage	Letter Grade	Percentage	Letter Grade
90–100	A	>90	H
75–89	B	70–90	P
60–74	C	50–70	L
50–59	D	<50	F
<50	F		

7 Honor Code

Students are expected to follow UNC's honor code. Discussion among students of ideas and concepts is allowed and encouraged, however, homework assignments are to be completed individually. Cheating on quizzes and exams is wholly unacceptable, and violators will be immediately reported to the Honor Court. I invite the students to visit the webpage dedicated to the Honor Code of UNC-Chapel Hill students (`http://honor.unc.edu/`). While in these matters there is no better steering wheel than honesty and good will, the Honor Code and what is referred to as The Instrument of Student Judicial Governance (`http://instrument.unc.edu/`) serve as a guideline to students in matters related to the good exercise of their freedom at UNC. For what directly concerns this class, students should not lie, cheat or steal and should be aware of what constitutes academic dishonesty as defined in Section IIB of The Instrument of Student Judicial Governance of which an excerpt is reproduced below (taken from:
`http://instrument.unc.edu/instrument.text.html#academicdishonesty`):

"...(Section II)B. Academic Dishonesty.

1. Plagiarism in the form of deliberate or reckless representation of anothers words, thoughts, or ideas as ones own without attribution in connection with submission of academic work, whether graded or otherwise.
2. Falsification, fabrication, or misrepresentation of data, other information, or citations in connection with an academic assignment, whether graded or otherwise.

3. Unauthorized assistance or unauthorized collaboration in connection with academic work, whether graded or otherwise.
4. Cheating on examinations or other academic assignments, whether graded or otherwise, including but not limited to the following:
   (a) Using unauthorized materials and methods (notes, books, electronic information, telephonic or other forms of electronic communication, or other sources or methods), or
   (b) Representing anothers work as ones own.

..."