Chemical Hydrogeology
GEO 476M/GEO 387C

Spring 2012
GEO 3.222
MWF 3:00-4:30

Instructor:	Phil Bennett
	EPS 2.204: 1-3587, pbennett@mail.utexas.edu
Office Hours:	MWF: 4:30-5:30; T/Th: 10:30-12:30 or by appointment
TA:	Lindsey Sydow
	GEO 5.xxx:
Office Hours:	TBA

I. Rationale for this course:

The chemistry of groundwater is an equal partner to the physical flow of groundwater in the study of hydrogeology, and the quality of water often is the motivation to investigate groundwater. Suitability of water for a particular use, anthropogenic contamination of water, or reactions between water and the atmosphere and mineral surfaces are all part of the study of chemical hydrogeology.

II. Course Aims and Objectives:

Aims

This course is an introduction to theoretical and practical aspects of aqueous geochemistry, including chemical thermodynamics and kinetics, acid-base chemistry, mineral dissolution and precipitation, redox reactions in natural waters, coordination chemistry, and surface chemistry. Case examples of natural and contaminated ground waters from the literature will be reviewed, and the data will be examined in class using computer mass-balance and equilibrium modeling techniques.

Specific Learning Objectives:

By the end of this course, students will:

a) Be able to evaluate data from experiments to derive kinetic rate constants, and to use kinetics to predict the change in the composition of water over time.
b) Understand the basic thermodynamics of aquatic chemical systems, the concept of free energy, and the link between free energy, chemical equilibrium, the solubility in water, and the effect of temperature on equilibrium. Use equations of state to predict the direction and extent of reactions between phases in a spreadsheet based model.
c) Be intimately familiar with acids and bases in water, and reactions involving both weak and strong acids and bases. Be able to use the presented basic equations to solve for pH in a variety of aqueous systems, and to use these equations to estimate the contribution of acid-base reactions to water composition. Understand the carbonate system in natural waters, and the reactions between carbonate minerals and acids/bases. Use mass balance and equilibrium equations to determine how carbonate minerals react in different systems, and how perturbations in pH will influence carbonate reactions.

d) Be introduced to the basic concepts of complexation chemistry, the speciation and mobility of metals in water, and the role of ligand-metal chemistry in geochemistry.
e) Be familiar with the chemistry of silicate weathering, particularly feldspars, and the concepts of incongruent dissolution, rate limiting reactions, and the use of log activity-activity diagrams to express stability fields. Be familiar with the structure of clay minerals, and basis of ion exchange reactions, and the impact of ion exchange reactions on water composition.
f) Understand oxidation reactions and equilibria in natural water, and the ideas of redox buffering, microbial redox reactions, and terminal electron acceptor processes. Understand the influence of redox reactions on acid-base chemistry and weathering.

III. Format and Procedures:

This course consists of two lecture periods each week, and one computer-based recitation session each week. The lectures are interactive and participation and discussion are expected, with the expectation of individual effort and contribution during lecture and recitation. Recitation will involve computer modeling, on-line data search and retrieval, and problem solving.

This course carries the Quantitative Reasoning flag. Quantitative Reasoning courses are designed to equip you with skills that are necessary for understanding the types of quantitative arguments you will regularly encounter in your adult and professional life. You should therefore expect a substantial portion of your grade to come from your use of quantitative skills to analyze real-world problems.

IV. My Goals

My goal is for students to gain a fundamental understanding of aquatic chemistry as it applies to the geochemistry of mineral-water reactions, and learn to use it as a tool in hydrogeology and environmental science.

V. Course Requirements:

1. **Class attendance and participation policy:**
   - **(a)** Attendance is not required for lecture but is required for recitation, and credit will be accumulated for attending recitation and completing the in-class assignments. It is extremely difficult however to learn the material without attending lecture, and every effort should be made to come, even if you come late or need to leave early.
   - **(b)** It is expected that students participate during class, and be ready to answer questions, solve problems, and participate in thought experiments and demonstrations. Participation contributes to the final recitation grade.

2. **Religious Holy Days**

   By UT Austin policy, you must notify me of your pending absence at least fourteen days prior to the date of observance of a religious holy day. If you must miss a class, an examination, a work assignment, or a project in order to observe a religious holy day, I will give you an opportunity to complete the missed work within a reasonable time after the absence.

3. Course Readings/Materials:

Required:

(Appelo and Postma, (2005) Geochemistry, Groundwater, and Pollution, 2nd Ed..

Recommended:

Drever, J.I., (1996) The Geochemistry of Natural Waters (3rd ed),
Snoeyink, V.L. and Jenkins, D. Water Chemistry,
Stumm, W and Morgan, J. (1994) Aquatic Chemistry 3rd Ed.
Garrels and Christ (1965) Solutions, Minerals, and Equilibria.

4. Examinations

There will be one in-class mid-term exam, and the exam is available in modified form on the web site right now. What I mean is that you will know exactly what the form of the questions will be in advance, but you will not know the final version of the question, such as the mineral, the partial pressure, or the pH. This exam typically takes 2.5 hours to complete, and is conducted on the Wednesday before Spring Break during the regular class period. The exam is closed book and closed notes. In addition, there will be a second take-home midterm exam a few weeks later.

5. Final Project

The final project will be an in-depth analysis of an aquifer, using all of the modeling tools introduced during the course. This is a lengthy and important component of the course, and should be started before spring break!!. You will be given the chemical data and background material for the project in the first few weeks of class

6. Homework Assignments

There will be several problem sets assigned from the primary and secondary texts. The assignments are long, but most students have told me that the only way they learned the material (and pass the exams) was by working lots of problems. You can work these problems alone, or in groups, but you are responsible for turning in your own final product. If you let this slide, though, or rely on others in your group to do the problems, it is virtually impossible to pass the midterm exams.

a. **Policies**:

- Makeup Exams are not allowed except under extraordinary circumstances.
- Homework assignments are typically assigned on Monday, and are due one week after they are assigned in class.
- Late homework assignments will receive 50% credit until the last week of the instructional semester.
- There are no extra credit assignments available for this class.
- There is no final exam

7. Use of Blackboard in class

In this class I use Blackboard—a Web-based course management system with password-protected access to distribute course materials, to communicate and collaborate online, to post grades, to submit assignments, and to give you online quizzes and surveys. You can find support in using Blackboard at the ITS Help Desk at 475-9400, Monday through Friday, 8 a.m. to 6 p.m., so plan accordingly.

VI. Grading Procedures: Grades will be based on:

	GEO 387C)	(GEO 376M)
Final Project	30%	25%
Midterm 1	25%	25%
Midterm 2	15%	15%
Problem Sets	20%	25%
Recitation	5%	5%

VII. Academic Integrity

University of Texas Honor Code
The core values of The University of Texas at Austin are learning, discovery, freedom, leadership, individual opportunity, and responsibility. Each member of the university is expected to uphold these values through integrity, honesty, trust, fairness, and respect toward peers and community. Any work submitted by a student in this course for academic credit will be the student's own work. For this course, collaboration is allowed for homework assignments and final projects. You are encouraged to study together and to discuss information and concepts covered in lecture and the sections with other students. You can give "consulting" help to or receive "consulting" help from such students. However, this permissible cooperation should never involve one student having possession of a copy of all or part of work done by someone else, in the form of an e mail, an e mail attachment file, a diskette, or a hard copy.

Should copying occur, both the student who copied work from another student and the student who gave material to be copied will both automatically receive a zero for the assignment. Penalty for violation of this Code can also be extended to include failure of the course and University disciplinary action.

During examinations, you must do your own work. Talking or discussion is not permitted during the examinations, nor may you compare papers, copy from others, or collaborate in any way. Any collaborative behavior during the examinations will result in failure of the exam, and may lead to failure of the course and University disciplinary action.

VIII. Other University Notices and Policies

1. **Use of E-mail for Official Correspondence to Students**

All students should become familiar with the University's official e-mail student notification policy. It is the student's responsibility to keep the University informed as to changes in his or her e-mail address. Students are expected to check e-mail on a frequent and regular basis in order to stay current with University-related communications, recognizing that certain communications may be time-critical. It is recommended that e-mail be checked daily, but at a minimum, twice per week. The complete text of this policy and instructions for updating your e-mail address are available at http://www.utexas.edu/its/policies/emailnotify.html.

2. **Documented Disability Statement**

Any student with a documented disability who requires academic accommodations should contact Services for Students with Disabilities (SSD) at (512) 471-6259 (voice) or 1-866-329-3986 (video phone). Faculty are not required to provide accommodations without an official accommodation letter from SSD. *(Note to Faculty: Details of a student's disability are*

confidential. Faculty should not ask questions related to a student's condition or diagnosis when receiving an official accommodation letter.)

- Please notify me as quickly as possible if the material being presented in class is not accessible (e.g., instructional videos need captioning, course packets are not readable for proper alternative text conversion, etc.).

- Please notify me as early in the semester as possible if disability-related accommodations for field trips are required. Advanced notice will permit the arrangement of accommodations on the given day (e.g., transportation, site accessibility, etc.).

- Contact Services for Students with Disabilities at 471-6259 (voice) or 1-866-329-3986 (video phone) or reference SSD's website for more disability-related information: http://www.utexas.edu/diversity/ddce/ssd/for_cstudents.php

3. Behavior Concerns Advice Line (BCAL)

If you are worried about someone who is acting differently, you may use the Behavior Concerns Advice Line to discuss by phone your concerns about another individual's behavior. This service is provided through a partnership among the Office of the Dean of Students, the Counseling and Mental Health Center (CMHC), the Employee Assistance Program (EAP), and The University of Texas Police Department (UTPD). Call 512-232-5050 or visit http://www.utexas.edu/safety/bcal.

4. Q drop Policy

The State of Texas has enacted a law that limits the number of course drops for academic reasons to six (6). As stated in Senate Bill 1231:

> "Beginning with the fall 2007 academic term, an institution of higher education may not permit an undergraduate student a total of more than six dropped courses, including any course a transfer student has dropped at another institution of higher education, unless the student shows good cause for dropping more than that number."

5. Emergency Evacuation Policy

Occupants of buildings on the UT Austin campus are required to evacuate and assemble outside when a fire alarm is activated or an announcement is made. **The evacuation assembly point is the MLK statue, at the SW corner of the JGB building.**

- Familiarize yourself with all exit doors of the classroom and the building. Remember that the nearest exit door may not be the one you used when you entered the building.
- If you require assistance to evacuate, inform me in writing during the first week of class.
- In the event of an evacuation, follow my instructions or those of class instructors.

Do not re-enter a building unless you're given instructions by the Austin Fire Department, the UT Austin Police Department, or the Fire Prevention Services office.

Every student has the *right* to learn as well as the *responsibility* not to deprive others of their right to learn. Every student is accountable for his or her actions.

VIII. Tentative Course Schedule: ***This syllabus represents my current plans and objectives. As we go through the semester, those plans may need to change to enhance the class learning opportunity. Such changes, communicated clearly, are not unusual and should be expected.*

Date	TOPIC	READING
18-Jan	**Chemical Principles** Orientation; Properties of Water; H-Bonding; Water analyses	A&P Ch. 1
23-Jan	**Chemical Kinetics:** Basic Kinetics; Collision theory; Reaction mechanisms. Catalysis and rate laws, Examples	A&P Ch. 4
30-Jan	**Chemical Equilibrium**, Energy and Work; Free energy, and Equilibrium Non ideal behavior of ions and molecules in solution	A&P Ch. 4
1-Feb	**12th Class Day. Last day to Drop with Refund**	
6-Feb	**Mineral Solubility** Solubility and solubility product, Salting in, Common Ion Effect,	A&P Ch. 4
13-Feb	**Acid-base chemistry**, Equilibrium calculations; Multiprotic acids and ionization fractions; pC pH diagrams	S&J Ch. 4.-4.5
20-Feb	**Carbonic Acid Equilibria**: Alkalinity, and acidity, CO_2 Equilibria K_H and gas exchange,	A&P Ch. 5 S&J Ch. 4.8-4.13
27-Feb	**Carbonate Minerals**: Ksp, dissolution, precipitation, Carbonate solubility	A&P Ch. 5
5-Mar	**Field Trip: Bull Creek Carbonate Chemistry**	
7-Mar	**MIDTERM #1**	
10-18 Mar	**SPRING BREAK**	

WEEK	TOPIC	READING
19-Mar	**Complexes, Metals and Coordination Chemistry** Hydrothermal waters, toxic metal mobility, PhreeqC modeling	A&P Ch. 7
26-Mar	**Silicate Weathering** dissolution kinetics and solubility; Silicate stability, phase diagrams and weathering.	A&P Ch. 8
2-Apr	**Silicate Weathering** Clays and Clay minerals	A&P Ch. 8
9-Apr	**Surface Chemistry** Mineral Surfaces, Ion Exchange, Sorption/Desorption,	A&P Ch. 6
16-Apr	**Redox**: stoichiometry and half reactions, Nernst eq.; pe, Eh, pe/pH diagrams,	A&P Ch. 9
23-Apr	**Natural Water Redox** Geomicrobiology and Microbial Redox systems; Acid mine drainage;	A&P Ch. 9
30-Apr	**Contaminant Hydrochemistry** Contaminants and contaminant transport	A&P Ch. 10