Georgia Institute of Technology
School of Earth and Atmospheric Sciences

Course title:	Mineral Surface Geochemistry
Course number:	EAS 4803/8803-YT
Term:	Spring 2018
Credit hours:	3
Time & location:	MW 3:05-4:25pm, ES&T L1105

Instructor: Prof. Yuanzhi Tang
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Office hours: MW 12-1pm or by appointment

Overview
Fundamental principles concerning mineral surface properties, element distribution at the mineral-water interface, and analytical techniques relevant to interfacial reactions.

Course Outcome
Chemical reactions occurring at the mineral-fluid interfaces are ubiquitous on Earth and other planets. They control the transport and distribution of a wide range of nutrients, carbon, metal, and organic and inorganic contaminants. In this course, we will learn the fundamental principles concerning mineral surface properties, element distribution in aqueous solutions and at the mineral-water interface, as well as a range of analytical techniques that are relevant to these interfacial reactions. We will also host guest lectures on selected topics and tour user facilities (if schedule allows).

Learning Outcomes
Upon completion of this course, students will be able to:

- Describe the main minerals that are important in environmental systems
- Become familiar with the basics of crystal chemistry
- Understand the fundamental principles of mineral surface structure
- Understand the principles controlling metal ion interaction at mineral-water intersurfaces
- Become acquainted with the roles of microorganisms in controlling mineral formation and dissolution
- Understand the principles and applications of common analytical techniques relevant to interface reactions
- Develop skills that are necessary for scientific discussion and for the analysis of current scientific literature

Recommended Textbook
There are no assigned textbooks for the course. Course material will be based on class notes, handouts, and assigned readings. It is important that everyone has access to mineralogy and aqueous geochemistry textbooks. The following are recommended:

- Cornelis Klein & Barbara Dutrow.2007. The manual of mineral science. 23th Edition. Wiley.
- Donald Langmuir. 1997. Aqueous environmental geochemistry. Prentice Hall.

Below are a few additional useful reference books:

- Werner Stumm and James J. Morgan. 1996. Aquatic chemistry: Chemical equilibria and rates in natural waters. Wiley.
    - Hard copy and online access available at GT library
- Kurt Konhauser. 2007. Introduction to Geomicrobiology. Blackwell Publishing.

- Garrison Sposito. 2004. The surface chemistry of natural particles. Oxford.
- Susan Brantley, James Kubicki, Art White. 2007. Kinetics of water-rock interaction. Springer.

Evaluation and Grading
Those with final grades between 90-100% are guaranteed an A; 80-89.9% are guaranteed at least a B; 70-79.9% are guaranteed at least a C; 60-69.9% are guaranteed at least a D; anyone earning a course grade less than 60 will receive an F. Grade cutoffs might be lowered but not raised.

- **Participation (5%).** If you miss 6 classes, you will not pass.
- **Assignments and projects (55%).** Besides regular homeworks, there will also be an assignment on instrumental proposal. Because we will cover a range of analytical techniques, the students will pick an instrument that is relevant for their background and/or research, and write a 2-page proposal that describes the research needs, experimental set up, and expected outcomes. More detailed instructions will be given in class. Graduate students will be asked to answer more questions in regular homeworks, as well as relate the instrumental proposal to their own research.
- **Midterm (20%).** Graduate students will be required to answer extra questions. Extra credit questions might also be given, where undergraduate students will have more opportunities (questions) for extra credits.
- **Term paper (15%) and presentation (5%).** This paper should be a critical review on a topic of interest to the student and is relevant to chemical processes occurring at mineral-fluid interfaces. The term paper should be typed in a standard word processor and be 10-12 pages in length. It should contain an introduction that presents the importance of the topic in geochemistry or environmental science and outlines the rest of the paper. The discussion on the topic should highlight the recent progress made on the topic, and should provide recommendations for research progress that needs to be made in the future. Students will also deliver a final presentation on their term paper topic at the end of class. More details on the term paper topic selection and format will be discussed in class.

Late policy All material handed in late will be deducted 10% per day.
Attendance: Note if you miss 6 classes, you will not pass. The Institute Absence policy is available at: www.catalog.gatech.edu/rules/4/

Academic Integrity
Academic dishonesty will not be tolerated. This includes cheating, lying about course matters, plagiarism, or helping others commit a violation of the Honor Code. Plagiarism includes reproducing the words of others without both the use of quotation marks and citation. Students are reminded of the obligations and expectations associated with the Georgia Tech Academic Honor Code and Student Code of Conduct, available online at www.honor.gatech.edu.

Learning Accommodations
If needed, we will make classroom accommodations for students with documented disabilities. These accommodations must be arranged in advance and in accordance with the Office of Disability Services (http://disabilityservices.gatech.edu).

Tentative topics
- Coordination chemistry, chemical bonding
- Principles of crystal chemistry
- Common minerals (e.g. carbonates, phosphates, silicates, metal oxides)
- Mineral surface structure and properties
- Interactions at mineral-fluid interface: dissolution/precipitation, substitution, adsorption, redox reaction

- Role of mineral-fluid interactions on controlling contaminant/nutrient fate and transport, chemical weathering, and biomineralization
- Analytical techniques for mineral-water interface studies

Participation Grade Details:
Student participation will be an important contributor to actively learning and learning from each other.
Participation grades will be posted monthly. Class participation will be evaluated as follows:
•90-100%: always attend, participating often by asking questions or actively working with classmates on
in class exercises.
•80-90%: Less than two unexcused absences, participating often
•70-80%: 2 to 4 unexcused absences, participating in class activities
•< 70%: More than 4 unexcused absences. Likely irregular participation.

Example class schedule (Fall 2016)

Week	Date	Lecture	Deadlines	Reading*
1	8/22	Introduction and overview		
	8/24	**Basics of crystal chemistry:** - Bonding, coordination, closest packing		Klein Ch3, Ch4 (p66-68), Shannon 1976
2	8/29	- Pauling's rules, unit cell		Klein Ch4 (p68-83), Ch6
	8/31	- Point symmetry - Translational symmetry, Bravais Lattices	HW #1	Klein Ch6 (109-129) Klein Ch7 (p143-164)
3	9/5	Labor Day, no class		
	9/7	- Space groups, crystal systems, crystallographic axes, Miller indices		Klein Ch7 (164-168) Klein Ch6 (p129-134)
4	9/12	- Substitution **Minerals:** - Silicates (classification, tectosilicates)	HW #1 due	Klein Ch5 (p96-99) Klein Ch18 (p434-438, 467-482)
	9/14	- Silicates (phyllosilicates, clay minerals) - Metal oxides (Fe, Mn oxides)	HW #2	Klein Ch18 (p456-467) Klein Ch16 (p368-375)
5	9/19	**Techniques:** XRD (guest lecture)		Klein Ch14 (p308-321)
	9/21	**Minerals:** Carbonates, phosphates, sulfates		Klein Ch17 (p399-403, 406)
6	9/26	**Aquatic ions**	HW #2 due	Langmuir Ch3 (p82-99, 112-114)
	9/28	**Mineral surface properties:** - Surface structure, surface charge **Reactions at mineral-fluid interface:** - Adsorption	HW #3	Langmuir Ch10 (p343-353) Langmuir Ch10 (p353-371)
7	10/3	- Sorption isotherm - Electric double layer		Langmuir Ch10 (p353-371) Maurice Ch6 (p153-157)
	10/5	- Surface complexation models - Case study	HW #3 due	Maurice Ch6 (p155-163) Arai 2001, Elzinga 2009
8	10/10	Fall Recess, no class		
	10/12	Homework and midterm review		
9	10/17	**Midterm**		
	10/19	**Techniques:** Synchrotron X-ray techniques	HW #5	
10	10/24	**Reactions at mineral-fluid interface:** - Mineral dissolution, chemical weathering		Langmuir Ch7 Optional: Brantley Ch5
	10/26	- Precipitation and nucleation		Stumm Ch6, Rimer 2010
11	10/31	**Techniques:** - SEM/TEM (guest lecture)		Maurice Ch4
	11/2	- AFM, XPS, vibrational spectroscopy	HW #4	Maurice Ch4
12	11/7	- NMR (guest lecture)		
	11/9	**Reactions at mineral-fluid interface:** - Oxidation-reduction	Term paper topic due	Langmuir Ch11 MIsra Ch8
13	11/14	- Nanoparticles (guest lecture)	HW #4 due	Maurice Ch13
	11/16	**Microbe-mineral interactions:** - Biosorption - Bioweathering		Maurice Ch12 Optional: Konhauser Ch3 Optional: Konhauser Ch5
14	11/21	- Biomineralization	HW #5 due	Maurice Ch12 Optional: Konhauser Ch4
	11/23	Thanksgiving Break, no class		
15	11/28	Term paper presentations	Presentation due	
	11/30	Term paper presentations		
16	12/5	Term paper presentations	Term paper due	

Note:

- Klein (Cornelis Klein & Barbara Dutrow. 2007. The manual of mineral science. 23th Edition. Wiley)
- Langmuir (Donald Langmuir. 1997. Aqueous Environmental Geochemistry. Prentice Hall)
- Maurice (Patricia Maurice. 2009. Environmental Surfaces and Interfaces from the Nanoscale to the Global Scale. Wiley)
- Stumm (Werner Stumm. 1992. Chemistry of the Solid-Water Interface. Wiley)
- Konhauser (Kurt Konhauser. 2007. Introduction to Geomicrobiology. Blackwell Publishing)