Chemistry 777, Physical Chemistry of Surfaces
Dept of Chemistry, University of Wisconsin-Madison
Fall Semester, 2018
2:30 to 3:45 PM, T Th Room 8335 Chemistry

Instructor: Gilbert Nathanson, 7321 Chemistry, 262-8098, nathanson@chem.wisc.edu

Office hours: immediately after class and by appointment

Course Credits: 2-3

Catalog Course Description
Structure, thermodynamics, kinetics, and reactivity of molecules at liquid and solid interfaces, with applications to monolayers, wetting, film growth, catalysis, and atmospheric chemistry.

Catalog Requisites: Graduate/professional standing

Instructional Mode: classroom instruction

How Credit Hours are Met
This class meets twice a week for two 75-minute periods and can be taken for either 2 or 3 credits. Students enrolled for 2 credits are expected to engage over the course of the semester in at least 90 hours of course learning activities, which include class attendance, reading, writing, problem sets, studying, and other work as described in the syllabus. Students enrolled for 3 credits are expected to engage in at least 135 hours of learning activities, which includes an additional poster presentation on a surface science technique.

Course Learning Outcomes
Upon completion of this class, you should be able to
1) grasp and articulate fundamental ideas involved in the physical chemistry of surfaces presented in class and in readings
2) work through basic calculations as practiced in problem sets to gauge the role played by liquid and solid surfaces in everyday phenomena
3) connect with the vast literature of surface chemistry
4) appreciate current directions in surface science
5) do simple but revealing demonstrations of surface phenomena
6) learn to express and defend your thoughts at one or two poster sessions during the course
7) explore a surface science topic that stimulates you to think creatively and independently about surface science research, as practiced through the end-of-semester poster presentation.

Brief Outline
1. Introduction to solid and liquid interfaces: intermolecular forces and surface tension, packing, crystal periodicity, and molecular orientation

2. Interfacial thermodynamics of single and multi-component systems: surface tension and capillarity, adsorption isotherms, wetting, surface segregation

3. The motions of surface molecules: surface phonons and capillary waves

4. Phases of insoluble monolayers at the gas-liquid and gas-solid interfaces and film growth

5. The surface chemical bond: physisorption, chemisorption, interfacial solvation

6. Kinetics and dynamics of collisions, adsorption, diffusion, and desorption at gas-solid and gas-liquid interfaces

7. Surface chemical reactions: examples from industrial catalysis and atmospheric chemistry

The major techniques of surface chemistry (photon, electron, ion, molecule) will be introduced throughout the classes and at the mid-semester poster session.

Hands-On Activities in Class. We will perform hands-on activities in many of the classes to demonstrate and explore a surface-science topic. These activities are fun and illuminating.

Grading and Requirements
1) Homework Problems. These are essential for working out concepts discussed in class and in the readings. You may certainly work together, but please write your solutions individually.

2) There are no exams.

3) Poster Presentation and Summary. You will be asked to present a poster at a poster session during the last week of class, along with a written summary.

3) Students enrolling for 3 credits will also present a mid-semester poster on a surface science technique. I will also ask you to construct a surface techniques website for the class.

The end-of-semester poster topic can describe an original proposal or you can survey a set of literature papers. It should *not* be a report on your own research, although the topic may be motivated by your research. Instead, it should flow directly from concepts that you have learned in this class and your own curiosity. More details will be provided later. Past students have commented that the poster sessions are a terrific learning and teaching experience.

Class grades are determined by your performance on homework, poster presentation, written summaries, and participation in class.

Textbooks
No purchases required. Here are ones I draw from, several downloadable for free:

*Kurt Kolasinski, *Surface Science*, Wiley, 3rd edition, 2012. Focuses on gas-solid interfaces with emphasis on dynamics. Follow links on library.wisc.edu. **Please download the book at** library.wisc.edu**.** Kolasinski also has his own web site. $70 on Amazon. Mostly solid surfaces.

Li and Somorjai: *Surface Chemistry and Catalysis*, Wiley, 2nd edition, 2010. Focuses on gas-solid interfaces and catalysis (not liquids). $148 on Amazon. Mostly solid surfaces.

Butt, Graf, and Kappl, *Physics and Chemistry of Interfaces*, 3rd edition (2013), Wiley. $54 on Amazon. Mostly liquid surfaces**. Please download first edition (2004)** at library.wisc.edu.

*G. Ertl, *Reactions at Solid Surfaces*, 2009, focuses on Nobel Laureate's own extensive research. **Please download the book at library.wisc.edu.**

K. Oura, V. G. Lifshits, A. Saranin, A. V. Zotov, M. Katayama, *Surface Science*, 2013, Springer. All solids – lots of neat topics. $120 on Amazon.

G. T. Barnes and I. R Gentle, *Interfacial Science* (2nd ed, 2011), Oxford. More elementary than Butt, but very clear. $47 on Amazon. Mostly liquid surfaces. The first 22 pages are viewable at https://books.google.com/books/about/Interfacial_Science_An_Introduction.html?id=2XWcAQAAQBAJ&printsec=frontcover&source=kp_read_button#v=onepage&q&f=false

J. Hudson, *Surface Science*, Wiley, **1st edition in 1992 is downloadable** at library.wisc.edu. Thorough and rigorous, unusual for its coverage of both liquid and solid surfaces. Good chapters on liquids, but highly mathematical. Worth downloading.

D. K. Chattoraj and K. S. Birdi, *Adsorption and the Gibbs Surface Excess* (1984) Springer. **Book is downloadable** at library.wisc.edu. Just liquid surfaces and surfactants.

P.-G. De Gennes, Capillarity and Wetting Phenomena – Drops, Bubbles, Pearls, Waves. Simple arguments hide complex ideas. 2004. Inspiring.

Norskov and friends, *Fundamental Concepts in Heterogeneous Catalysis*, Wiley, 2014. All about catalysis from a theoretical perspective. **Book is downloadable** on library.wisc.edu.

J. C. Vickerman and I. S. Gilmore, *Surface Analysis – The Principal Techniques*, Wiley, 2009. **Book is downloadable** at library.wisc.edu.

A. Adamson and A. Gast, *Physical Chemistry of Surfaces*, Wiley, 6th edition, 1997. A classic and comprehensive text. You can find older versions in many offices.

J. W. Gibbs, *On the Equilibrium of Heterogeneous Substances*, 1878, starting on page 219, https://en.wikisource.org/wiki/Scientific_Papers_of_Josiah_Willard_Gibbs,_Volume_1/Chapter_IIIb. Gibbs created the thermodynamics of surfaces, anticipating research up to this day.

R. Defay and I. Prigogine, *Surface Tension and Adsorption*, 1966. More than you want to know about the thermodynamics of surfaces. Very precise and one-of-a-kind derivations.

C.V. Boys, *Soap Bubbles and the Forces which Mould Them*, 1959. If you like demos, you will love this book. Viewable at https://www.gutenberg.org/files/33370/33370-h/33370-h.htm.

I will occasionally assign reading from the electronic books. I will also hand out excerpts from textbooks, particularly on liquid surfaces, and assign journal articles for readings. I will try to upload my powerpoint presentations just before class.

Web-Based Instruction for Solid Surfaces
http://www.chem.qmw.ac.uk/surfaces/scc/
Dr. Roger Nix, *An Introduction to Surface Chemistry*, University of London
Remarkably well-constructed, not-too-detailed course on solid-state surface chemistry. We will use this site throughout the semester.

Galleries of Solid Surface Structures and Miller Index Notation
http://surfexp.fhi-berlin.mpg.de/
Creates picture of surfaces from entered coordinates (Surface Explorer)

http://www.fhi-berlin.mpg.de/%7Ehermann/Balsac/pictures.html
picture gallery of surface structures/Berlin (Balzac)

http://www.fhi-berlin.mpg.de/KHsoftware/Balsac/SSDpictures.html
picture gallery from the NIST surface structure database