MSE 480/CHEM 488 Fall 2021

SURFACE AND COLLOIDS

Instructor: Prof. Qian Chen
Fall Semester 2021
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Course Web Page: compass2g.illinois.edu

Look around you: everything you see is a surface! Surfaces, interfaces, and the distinctive behavior owing to them, pervade most of daily life, including life itself. Processes at surfaces pervade technology. They pervade environmental issues (rain and smog, soils, aerosols). They are even the basis for much of bioengineering (milk and cheese, proteins -- and even we ourselves, who consist of a dynamic collection of biocolloids contained in about 75% water). In this course we will seek to understand the general principles which unify these seemingly disparate phenomena. To understand this subject is interesting for its own sake. Since you are also likely to encounter surface and colloid phenomena in whatever work you undertake in the real world, understanding will help you to do a better job.

Textbook: This class is mostly organized around class notes. The subject is too young to have one comprehensive textbook. All the following suggested references are reserved in Grainger.

(1) Arthur W. Adamson and Alice P. Gast, **Physical Chemistry of Surfaces**, 6 edition, Wiley, New York, 1997. *A good reference book, but it's hard to read an encyclopedia.*
(2) Gabor A. Somorjai, **Introduction to Surface Chemistry and Catalysis, 2 Ed**, Wiley, New York, 2010. *Clearly written, comprehensive.*
(3) Andrew Zangwill, Physics at Surfaces, **Cambridge University Press**, Cambridge, 1988. *This is the physics point of view (electronic structure, phase transitions, epitaxy …) and complements the chemistry point of view in the book by Somorjai.*
(4) The recommended textbook for the second half of the class is:

Jacob N. Israelachvili, **Intermolecular and Surface Forces**, 3rd ed., Academic Press, New York, 2011. *Beautifully written, this is the best single text for the second half of the class. Available electronically from our collaborator.*

Assignments: There will be homework over the course of the semester. Late HW receives 1/2 credit. Graduate students taking the course with 4 credit hours will write a term paper, due on **Nov 30th, 2021.**

Exams: There will be one midterm and one final.

Tentative midterm date: Oct. 19, 2021. **Final date:** TBA

Grading: 3 credit hours:

Midterm (35%) + Final (45%) + Homework (20%)

4 credit hours:

Midterm (25%) + Final (40%) + Homework (15%) + Term Paper (20%)

Teaching Assistant (TA):

Johnny Smith, email: jwsmith6@illinois.edu

Office hours:

Johnny Smith (TA)

We have two forms of office hours:

Form 1: Fridays 3–4 pm, by Johnny through Zoom

Form 2: "Office Hour Forum" on Compass where you can ask any questions you may have on homework, or other issues relating to the class

- Johnny will be online at the usual office hour time (Fridays 2-3pm) to respond to your questions as best and quickly as he can. If you have questions outside of this time frame, you may still post in the forum and he will try to answer you in a timely manner, but emailing him is probably a better option.
- To post a question, click the "Create Thread" button and type your question in the subject box.

PART I: BASICS ABOUT SURFACES

1. Introduction

2. Distinctive features of interfaces

what is an interface? - how to describe an interface?

what are typical behavior patterns? real versus apparent area - surface to volume ratio -surface energy - surface structure and composition versus that of the bulk.

3 Surface energy

typical values -- how to measure it? -- reconstruction, relaxation, molecular orientation, melting, roughening -- how to evaluate surface structure?

4. Surface thermodynamics

origin of surface energy -- Gibbs dividing surface -- surface excess functions

Gibbs adsorption equation -- other implications

5. Adsorption isotherms

physisorption versus chemisorptions -- adsorption isotherms: Langmuir, BET,

etc. -- internal interfaces: critical micelle concentration

6. Monomolecular films

pressure-area diagrams -- Langmuir-Blodgett films -- self-assembled monolayers,

SAMs -- layer-by-layer self-assembly

7. Curved surfaces

capillary pressure: the Young-Laplace equation -- vapor pressure: the Kelvin equation -- implications: nanoparticles, adhesion, etc.

PART II: THE FORCES BETWEEN SURFACES

1. Introduction

Uses of colloids in technology - how to measure surface forces? Characterization of colloids.

2. Varieties of inter-particle forces

Scale-up from molecules to larger particles - van der Waals, electrostatic," structured liquids"

3. Van der Waals interactions

origin of r^{-6} - Hamaker constant - competititive van der Waals attractions -implications

4. Electrostatic interactions

why all interfaces are charged or polarized - the electric double layer – the screened Coulomb potential - examples of calculations - Stern layer - typical

DLVO behavior - zeta potential – examples

5. *Non-equilibrium and time-dependent interactions*

diffusion; hydrodynamics; flocculation kinetics.

PART III: FORCES DUE TO STRUCTURE IN LIQUIDS

1. Polymers

types of polymers - general features of polymers in solution - examples

2. Structured liquids (small molecules)

liquid structure at surfaces - forces that result - examples

3. Tribology and adhesion

PART IV: OUTLOOK

1. Review of the course

2. Frontier areas

selected depending on interests of the class

Policy on conflicts or emergencies:

(1) For time conflicts with other events (e.g. another scheduled exam), or an official UIUC activity (e.g. varsity athletics, band concert),
Regarding HW, please email official documentation (or scanned version) about the conflict at least **two weeks** before the homework due date. The HW due date will be extended.
Regarding the exam, please email official documentation (or scanned version) about the conflict at least **three weeks** before our exam date. An online make-up exam will be scheduled.

(2) If you will not be able to make it to the exam or submit HW on time due to serious illness or other emergent personal crisis (e.g. car accident) that are not described in (1), you must send emails to the TA (jwsmith6@illinois.edu) and the instructor (qchen20@illinois.edu) at the earliest possible opportunity, and submit a statement (or scanned version) from the professionals that are authorized to evaluate your situations (e.g. doctors, police). The statement needs to clearly explain that you are not physically capable of attending the exam or submitting HW on time. The HW due date will be extended for HW, and an online make-up exam will be scheduled for exam.

ADDITIONAL NOTES

I. Homework Submission Instruction

Homework will be given and submitted via Compass system.

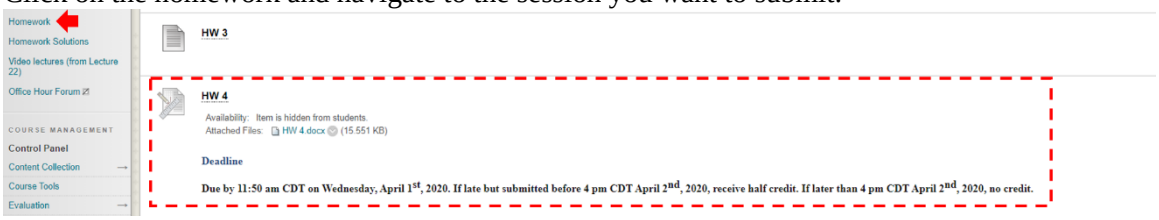
Note:

1. **Multiple attempts** are allowed for submission but **only the last attempt will be graded**.

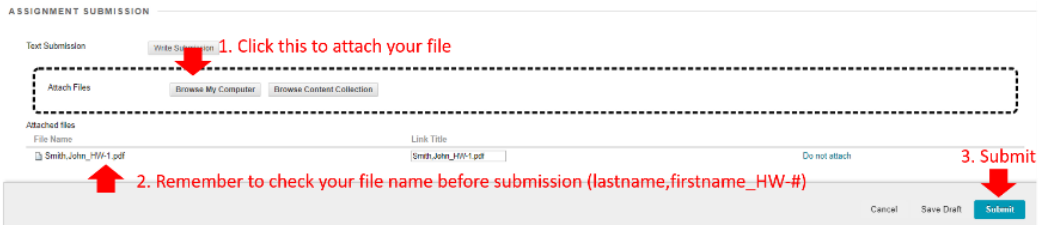
2. Both pdf and word document are acceptable, but typed answer is preferred. If you decide to write your homework, it is suggested to write it electronically using a tablet. It you decide to scan your homework, **make sure your scanned document is readable** to avoid losing points.

Submission steps:

- Click on the homework and navigate to the session you want to submit.



- Upload homework following the **naming convention: lastname_firstname_HW# (e.g., Chen_Qian_HW1).**
- Click submit!



II. Term Paper Instruction

Term paper

Topic: a topic that is related to the content of the class. Check with me if you have questions.
Format: type written. Font size no smaller than 11.
Word limit: 2500-3000 words (not counting references).

Content: Give the reader something beyond what one can obtain directly from the source materials.

- *Research and investigate.* Seek out relevant materials, and unify them into a clear presentation.
- *Synthesize.* Draw together diverse things to show patterns and relations.
- *Organize.* Give logical continuity and structure to diverse materials.
- *Analyze.* Provide your own critical analysis in which arguments are examined for evidence, validity, logic, and flaws.
- *Examine in a broader context.* Show how your topic fits into a broader context, relates to another field, or relates to historic precedents.
- *Outlook.* Going beyond what is known, discuss what is not known and why.

IMPORTANT:

(1) If plagiarism is detected (see the avoiding plagiarism document), the full score of the term paper goes to 20%.

(2) Term paper Due: 11 pm CST, Nov 30th, 2021. Electronic version sent to jwsmith6@illinois.edu

If late but submitted before 11 pm CST, Dec 1st, 2021, the full score of the term paper goes to 50%;
Later than the above time (11 pm CST, Dec 2nd, 2021), the full score goes to 0.

Campus Policies and Procedures regarding COVID-19

This section describes University policies and procedures that affect classroom operation during the COVID-19 pandemic. Listed only are the policy from the university in July of 2021. For thorough and live reference please go to: https://covid19.illinois.edu/covid-19-classroom-management-info/

For the Fall 2021 semester, all students (graduate, undergraduate, and professional) who are able to do so are required to be fully vaccinated (defined as 14 days after the final dose) with a university-accepted vaccine before beginning the fall semester if they plan to be on campus.

Following University policy, all students are required to engage in appropriate behavior to protect the health and safety of the community. Students are also required to follow the campus COVID-19 protocols.

Students who feel ill must not come to class. In addition, students who test positive for COVID-19 or have had an exposure that requires testing and/or quarantine must not attend class. The University will provide information to the instructor, in a manner that complies with privacy laws, about students in these latter categories. These students are judged to have excused absences for the class period and should contact the instructor via email about making up the work.

Students who fail to abide by these rules will first be asked to comply; if they refuse, they will be required to leave the classroom immediately. If a student is asked to leave the classroom, the non-compliant student will be judged to have an unexcused absence and reported to the Office for Student Conflict Resolution for disciplinary action. Accumulation of non-compliance complaints against a student may result in dismissal from the University.

Classroom access policies

To implement COVID-related guidelines and policies affecting university operations, instructional faculty members may ask students in the classroom to show their Building Access Status in the Safer Illinois app or the Boarding Pass. If the status is "Granted" that means the student is compliant with the university's COVID-19 policies–that is, the student either has had a university-approved COVID-19 vaccine or is in compliance with the on-campus COVID-19 testing program for unvaccinated students.

If a student's Building Access status says "Denied," the student will be asked to leave the classroom or office. Refusal will result in the student being reported to the Office for Student Conflict Resolution, who may invoke disciplinary action.

Face coverings

All students, faculty, staff, and visitors are required to wear face coverings in classrooms and university spaces. This is in accordance with CDC guidance and University policy and expected in this class.