

CHEN 4838/5838 Electrochemical Engineering

Course Summary:

This course will introduce fundamentals and applications of electrochemical systems from an engineering perspective. Aspects of thermodynamics, reaction kinetics, and transport phenomena relevant to the description of conductive phases and their interfaces will be covered. An optimistic list of topics includes: equilibrium and cell potentials, reactions rates within Butler-Volmer kinetics and Marcus theory, electrochemical double layer structure, ion transport (Poisson-Nernst-Planck equation), and the influence of coupled kinetic/transport phenomena on potential and current distributions in cells. A number of electroanalytical techniques including potentiometry/coulometry, voltammetry/ amperometry, AC impedance, and hydrodynamic methods will also be discussed. Examples will be drawn from applications spanning energy conversion and storage (fuel cells, electrolyzers, batteries, supercapacitors), as well as applications in electrochemical separations, sensors, surface modification, and corrosion. Time permitting, semiconducting electrodes and photo-electrochemistry may be covered.

Learning Objectives:

- Ability to apply chemical engineering principles from thermodynamics, transport, and reaction kinetics to analyze and design electrochemical systems such as batteries, fuel cells, or electrochemical sensors
- Qualitative and quantitative understanding of major experimental methods used to characterize electrochemical systems
- Critical evaluation of primary research literature for development of ideas on novel methods and applications

Instructor: Prof. Adam Holewinski, SEEC N332, adam.holewinski@colorado.edu

Class time: Spring 2022, MWF 3:00 – 3:50pm, JSCBB A104

Office Hours: JSCBB A104, Weds 4-5pm (*Please arrive during first half*)
SEEC N360B: Thurs 4-5pm, only in weeks HW is due. Must notify of intent to attend.

Textbook: *Electrochemical Methods: Fundamentals and Applications*. Bard & Faulkner 2nd edition

Prerequisites: CHEN 3210/20, 3320, 4330; APPM 2350, 2360; PHYS 1120
Background knowledge will be assumed in:

- Core ChemE: Thermodynamics (laws 1-3, phase equilibria, cycles, activity); Transport phenomena (continuity equations, driving forces); Kinetics (rate laws, material/energy balances for reactors)
- Math & Physics: multivariable calculus, differential equations, electrostatics and basic circuits.

Logistics: Announcements, supplemental readings, homework assignments, and other communication will be run through CANVAS (canvas.colorado.edu). Feel free to email the instructor but include "CHEN 4838" in the subject line.

<u>Grading:</u>	Participation:	10%
	Homework:	25%
	Project:	15%
	Midterms (in class): 2 x 15%	30%
	Final exam:	20%

Participation: Attendance will be recorded by 'iClicker' questions. You will need to set up an iClicker student account and participate through the mobile phone app. Full credit will be given for > 90% attendance rate and actively participating at least 3 times (answering a question or posing a substantive question)

Homework: There will be 5 - 7 assignments, due select days (usually Fridays) at the beginning of class (3:00 sharp). You may work together on the homework, but you must submit separate work! One problem per set (unannounced) will be graded fully, and the assignment will be checked for completion. Solutions will be posted. *It is your responsibility to check posted solutions.*

Exams/Quizzes: You will be allowed to bring a scientific calculator, a one-sided note sheet, and writing implements, so please plan accordingly!

Project: A critical literature review of research articles pertaining to electrochemistry will be written and presented to the class as well as undergo 'peer review'. More details will be provided around the time of the first midterm.

4838 Credit: Groups will select an article (approved by instructor) and prepare a 10 minute critique presentation (everyone must speak) with 1-page written summary

5838 Credit: Each individual or group will select a topic (approved by instructor) on which to write a 3-page 'journal-format' review article and give a 15 minute presentation. The article must contain at least 15 references.

TENTATIVE SCHEDULE (updates will be announced and posted to Canvas)

(i) **Bolded** dates tentatively have HW due. [**Bracketed**] dates will have midterm quizzes

(ii) We will generally follow the textbook but will supplement notes in some places and focus on some sections more than others. This is reflected in the reading selections below insofar as practical. The book will provide a helpful perspective and more descriptive accounts of most topics, but class notes should guide study priorities.

Week	Dates	Reading	Topic
1	Jan. 10, 12, 14	Ch. 1.1-1.4	Overview of Echem; Circuit analysis and electrostatics
2	Jan. 17 , 19, 21 (<i>MLK day</i>)	Ch. 2.1-2.2	EC Thermo: Equilibrium, Nernst Eqn
3	Jan. 24, 26, 28	Supplemental (Canvas)	EC Thermo: complex equilibria, Pourbaix diagrams, Solid EC materials
4	Jan. 31; Feb 2, 4 *	Ch 3.1-3.5; Supplemental	EC Thermo: activity coefficients, EC Kinetics: BV-model;
5	Feb. 7 *, 9, 11	Ch 3.6 (stop p124)	EC Kinetics: electrocatalysis; Marcus theory
6	Feb. 14, [16], 18	Supplemental (Canvas)	Catch-up/review MIDTERM
7	Feb. 21, 23, 25	Supplemental (Canvas) Ch 2.3-2.4, Ch 4	Experiments I: Uncompensated resistance; current/potential distribution; steady state.
8	Feb. 28; Mar 2, 4	Ch 4	EC Transport: Conductivity, Transference number, junction potential
9	Mar. 7, 9, 11	Ch 4	EC Transport: Migration and diffusion; Poisson-Nernst-Planck equations. Solid state transport
10	Mar. 14, 16, 18 <i>Sp. Break Mar 21-25</i>	Ch 9.1-9.4; Ch. 5-6 Supplemental (Canvas)	Experiments II: Step transients, cyclic voltammetry
11	Mar. 28, [30], 31	Ch. 13.1-13.3;	Double layer structure/effects
12	Apr. 4, 6, 8	Ch 10	Experiments III: AC Impedance
13	Apr. 11, 13, 15	Ch 14	Semiconductors and photoelectrochemistry
14	Apr. 18, 20, 22		Project presentations
15	Apr. 25 , 27, 29 (<i>Reading day</i>)		Catch up / Review
	May 1 1:30-4pm,		Final Exam

CLASSROOM BEHAVIOR

Both students and faculty are responsible for maintaining an appropriate learning environment in all instructional settings, whether in person, remote or online. Those who fail to adhere to such behavioral standards may be subject to discipline. Professional courtesy and sensitivity are especially important with respect to individuals and topics dealing with race, color, national origin, sex, pregnancy, age, disability, creed, religion, sexual orientation, gender identity, gender expression, veteran status, political affiliation or political philosophy. For more information, see the policies on [classroom behavior](#) and the [Student Conduct & Conflict Resolution policies](#).

REQUIREMENTS FOR COVID-19

As a matter of public health and safety due to the pandemic, all members of the CU Boulder community and all visitors to campus must follow university, department and building requirements and all public health orders in place to reduce the risk of spreading infectious disease. Students who fail to adhere to these requirements will be asked to leave class, and students who do not leave class when asked or who refuse to comply with these requirements will be referred to [Student Conduct and Conflict Resolution](#). For more information, see the policy on [classroom behavior](#) and the [Student Code of Conduct](#). If you require accommodation because a disability prevents you from fulfilling these safety measures, please follow the steps in the “Accommodation for Disabilities” statement on this syllabus.

As of Aug. 13, 2021, CU Boulder has returned to requiring masks in classrooms and laboratories regardless of vaccination status. This requirement is a temporary precaution during the delta surge to supplement CU Boulder’s COVID-19 vaccine requirement. Exemptions include individuals who cannot medically tolerate a face covering, as well as those who are hearing-impaired or otherwise disabled or who are communicating with someone who is hearing-impaired or otherwise disabled and where the ability to see the mouth is essential to communication. If you qualify for a mask-related accommodation, please follow the steps in the “Accommodation for Disabilities” statement on this syllabus. In addition, vaccinated instructional faculty who are engaged in an indoor instructional activity and are separated by at least 6 feet from the nearest person are exempt from wearing masks if they so choose.

Students who have tested positive for COVID-19, have symptoms of COVID-19, or have had close contact with someone who has tested positive for or had symptoms of COVID-19 must stay home. In this class, if you are sick or quarantined, please notify the instructional staff of your absence as soon as possible so that arrangements can be made.

ACCOMMODATION FOR DISABILITIES

If you qualify for accommodations because of a disability, please submit your accommodation letter from Disability Services to your faculty member in a timely manner so that your needs can be addressed. Disability Services determines accommodations based on documented disabilities in the academic environment. Information on requesting accommodations is located on the [Disability Services website](#). Contact Disability Services at 303-492-8671 or dsinfo@colorado.edu for further assistance. If you have a temporary medical condition, see [Temporary Medical Conditions](#) on the Disability Services website.

PREFERRED STUDENT NAMES AND PRONOUNS

CU Boulder recognizes that students' legal information doesn't always align with how they identify. Students may update their preferred names and pronouns via the student portal; those preferred names and pronouns are listed on instructors' class rosters. In the absence of such updates, the name that appears on the class roster is the student's legal name.

HONOR CODE

All students enrolled in a University of Colorado Boulder course are responsible for knowing and adhering to the Honor Code academic integrity policy. Violations of the Honor Code may include, but are not limited to: plagiarism, cheating, fabrication, lying, bribery, threat, unauthorized access to academic materials, clicker fraud, submitting the same or similar work in more than one course without permission from all course instructors involved, and aiding academic dishonesty. All incidents of academic misconduct will be reported to the Honor Code (honor@colorado.edu); 303-492-5550). Students found responsible for violating the academic integrity policy will be subject to nonacademic sanctions from the Honor Code as well as academic sanctions from the faculty member. Additional information regarding the Honor Code academic integrity policy can be found on the [Honor Code website](#).

SEXUAL MISCONDUCT, DISCRIMINATION, HARASSMENT AND/OR RELATED RETALIATION

The University of Colorado Boulder (CU Boulder) is committed to fostering an inclusive and welcoming learning, working, and living environment. CU Boulder will not tolerate acts of sexual misconduct (harassment, exploitation, and assault), intimate partner violence (dating or domestic violence), stalking, or protected-class discrimination or harassment by or against members of our community. Individuals who believe they have been subject to misconduct or retaliatory actions for reporting a concern should contact the Office of Institutional Equity and Compliance (OIEC) at 303-492-2127 or email cureport@colorado.edu. Information about OIEC, university policies, [reporting options](#), and the campus resources can be found on the [OIEC website](#).

Please know that faculty and graduate instructors have a responsibility to inform OIEC when made aware of incidents of sexual misconduct, dating and domestic violence, stalking, discrimination, harassment and/or related retaliation, to ensure that individuals impacted receive information about their rights, support resources, and reporting options.

RELIGIOUS HOLIDAYS

Campus policy regarding religious observances requires that faculty make every effort to deal reasonably and fairly with all students who, because of religious obligations, have conflicts with scheduled exams, assignments or required attendance. In this class, please bring any relevant scheduling concerns to the instructor at least two weeks before the conflicting date. See the [campus policy regarding religious observances](#) for full details.