Chemistry 8155: Advanced Electroanalytical Chemistry

4 Credits

Syllabus and Course Information

The goal of this course is to familiarize students with electroanalytical techniques and their physicochemical background, such as the thermodynamics and kinetics of electron and ion transfer, the electric double layer, and mass transfer by diffusion and migration. Electrochemical methods that are presented in detail include ion-selective potentiometry, chronoamperometry, chronocoulometry, cyclic voltammetry, pulse voltammetry, ion-transfer voltammetry, and impedance spectroscopy, as well as some of their applications in bioelectroanalysis. Instrumentation that is discussed includes rotating disk electrodes, microelectrodes, chemically modified electrodes, scanning electrochemical microscopy (SECM), EC-STM, and the quartz crystal microbalance.

Instructor: Phil Buhlmann, 325 Smith Hall, 624-1431
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Web Page: Canvas

Lectures: Monday, Wednesday, Friday, 10:10 to 11:00 AM, Room 111, Smith Hall

Office Hours: Monday, 12:00–1:00 PM, 325 Smith Hall

Required Text: *Electrochemical Methods: Fundamentals and Applications*, 2nd ed.; Allen J. Bard, Larry R. Faulkner; Wiley Interscience, New York: 2001.

Other Useful Books:

Laboratory Techniques in Electroanalytical Chemistry, 2nd ed.; Peter T. Kissinger, William R. Heineman; Marcel Dekker, New York: 1996.

Ion-Selective Electrodes With Ionophore-Doped Sensing Membranes, Bühlmann, P.; Chen, L. D., in "Supramolecular Chemistry: From Molecules to Nanomaterials, Steed, J. W. and Gale, P. A., eds., Wiley, 2012.

Electrochemistry for Chemists, 2nd ed.; Donald T. Sawyer, Andrzej Sobkowiak, Julian L. Roberts, Jr.; Wiley Interscience, New York: 1995.

Structure of Electrified Interfaces, Jacek Lipkowski, Philip N. Ross; VCH, Weinheim: 1993.

Surface Electrochemistry: A Molecular Level Approach; John O'M. Bockris, Shahed U. M. Khan; Plenum, New York: 1923.

Electrode Kinetics for Chemists, Chemical Engineers, and Materials Scientists; Eliezer Gileadi; VCH, Weinheim: 1993.

Cyclic Voltammetry: Simulation and Analysis of Reaction Mechanisms; David K. Gosser, Jr.; VCH, Weinheim: 1993.

Analytical Electrochemistry; Joseph Wang; VCH, : Weinheim: 1994.

Impedance Spectroscopy, E. Barsoukov, J. Ross Macdonald; Wiley Interscience, New York: 2005.

Electrochemical Impedance Spectroscopy; M. E. Orazem, B. Tribollet; Wiley Interscience, New York: 2008.

Electroanalytical Methods for Biological Materials: Anna Brajter-Toth, James Q. Chambers; Marcel Dekker, New York: 2002.

Assignments: Each assignment will receive equal weighting in calculating the final grade. Assignments submitted late without a valid excuse will not be graded. The assignments will constitute **100 points** of the total grade.

Exams: Exams will be held in class on the dates indicated on the lecture schedule. There will be two exams during the semester. Each of these exams will last 50 minutes and will be worth **100 points**. The final exam is the finals week and will be comprehensive. It will last 2 hours and will be worth **200 points**.

No equations will be provided in any exam but you may summarize for each hour each exam and the final exam equations and notes that you wish to have available during exams. There is no limit to the number of pages that you prepare, but only notes prepared by yourself (handwritten or computer printouts) will be accepted; no books, photocopies, electronic storage media, internet connections, etc.

1-Min Papers: Each 1-minute paper should be brief and should not take a lot of time. Several lines at most. This is a good opportunity to ask any questions that may arise while reviewing the day's notes. Point out any important issues discussed in the lecture. Express in your own words what you learnt in the lecture and what you consider the essence of the lecture to be.

Each 1-minute paper submitted within 28 hours of a lecture will earn you 1 point. These 1-minute papers have two goals. (1) Numerous studies have shown that active review of the lecture content within the first 24 h and ideally on the same day drastically improves the learning process. Putting the course content in our own words allows you to identify what you understood and what you do not understand sufficiently yet. (2) Students in this class have very different backgrounds. The 1-minute papers very often reveal individual strengths and weaknesses, and help me to customize forthcoming lectures as necessary.

Other Feedback: Always **very** welcome. If you want to keep your comments anonymous, put them into mailbox C2 in front of the mailroom (139 Smith Hall).

Attendance: Attendance at all lectures is assumed. You are responsible for all material and announcements presented in class.

Zoom Recordings: Classes will be recorded on Zoom and made available to the class. You are not allowed to share recordings with anyone who is not registered for this class. If you are uncomfortable about the classes being recorded, please let me know.

Final Grades: Final grades for the course will be determined by the total number of points earned. The total points, divided as follows:

2 Exams @ 100 points each	200
Final exam	200
Assignments	100
1-Minute papers	30
Total Points Possible	530

Student Conduct Code
The University seeks an environment that promotes academic achievement and integrity, that is protective of free inquiry, and that serves the educational mission of the University. Similarly, the University seeks a community that is free from violence, threats, and intimidation; that is respectful of the rights, opportunities, and welfare of students, faculty, staff, and guests of the University; and that does not threaten the physical or mental health or safety of members of the University community.
As a student at the University you are expected to adhere to Board of Regents Policy: *Student Conduct Code*. To review the Student Conduct Code, please see: https://regents.umn.edu/sites/regents.umn.edu/files/2019-09/policy_student_conduct_code.pdf
Note that the conduct code specifically addresses disruptive classroom conduct, which means "engaging in behavior that substantially or repeatedly interrupts either the instructor's ability to teach and/or a student's ability to learn." The classroom extends to any setting where a student is engaged in work toward academic credit or satisfaction of program-based requirements or related activities.

Scholastic Dishonesty
You are expected to do your own academic work and cite sources as necessary. Failing to do so is scholastic dishonesty. Scholastic dishonesty means plagiarizing; cheating on assignments or examinations; engaging in unauthorized collaboration on academic work; taking, acquiring, or using test materials without faculty permission; submitting false or incomplete records of academic achievement; acting alone or in cooperation with another to falsify records or to obtain dishonestly grades, honors, awards, or professional endorsement; altering, forging, or misusing a University academic record; or fabricating or falsifying data, research procedures, or data analysis. (Student Conduct Code: https://regents.umn.edu/sites/regents.umn.edu/files/2019-09/policy_student_conduct_code.pdf) If it is determined that a student has cheated, the student may be given an "F" or an "N" for the course, and may face additional sanctions from the University. For additional information, please see:
https://policy.umn.edu/education/instructorresp.

The Office for Community Standards has compiled a useful list of Frequently Asked Questions pertaining to scholastic dishonesty: https://communitystandards.umn.edu/avoid-violations/avoiding-scholastic-dishonesty. If you have additional questions, please clarify with your instructor for the course. Your instructor can respond to your specific questions regarding what would constitute scholastic dishonesty in the context of a particular class, e.g., whether collaboration on assignments is permitted, requirements and methods for citing sources, if electronic aids are permitted or prohibited during an exam.

Makeup Work for Legitimate Absences
Students will not be penalized for absence during the semester due to unavoidable or legitimate circumstances. Such circumstances include verified illness, participation in intercollegiate athletic events, subpoenas, jury duty, military service, bereavement, and religious observances.

Such circumstances do not include voting in local, state, or national elections. For complete information, please see: *https://policy.umn.edu/education/makeupwork*.

Appropriate Student Use of Class Notes and Course Materials
Taking notes is a means of recording information but more importantly of personally absorbing and integrating the educational experience. However, broadly disseminating class notes beyond the classroom community or accepting compensation for taking and distributing classroom notes undermines instructor interests in their intellectual work product while not substantially furthering instructor and student interests in effective learning. Such actions violate shared norms and standards of the academic community. For additional information, please see: *https://policy.umn.edu/education/studentresp*.

Sexual harassment, sexual assault, stalking and relationship violence
The University prohibits sexual misconduct, and encourages anyone experiencing sexual misconduct to access resources for personal support and reporting. If you want to speak confidentially with someone about an experience of sexual misconduct, please contact your campus resources including the Aurora Center, Boynton Mental Health or Student Counseling Services (https://eoaa.umn.edu/report-misconduct). If you want to report sexual misconduct, or have questions about the University's policies and procedures related to sexual misconduct, please contact your campus Title IX office or relevant policy contacts.
Instructors are required to share information they learn about possible sexual misconduct with the campus Title IX office that addresses these concerns. This allows a Title IX staff member to reach out to those who have experienced sexual misconduct to provide information about personal support resources and options for investigation. You may talk to instructors about concerns related to sexual misconduct, and they will provide support and keep the information you share private to the extent possible given their University role.
https://regents.umn.edu/sites/regents.umn.edu/files/2019-09/policy_sexual_harassment_sexual_assault_stalking_and_relationship_violence.pdf

Equity, Diversity, Equal Opportunity, and Affirmative Action
The University provides equal access to and opportunity in its programs and facilities, without regard to race, color, creed, religion, national origin, gender, age, marital status, disability, public assistance status, membership or activity in a local commission created for the purpose of dealing with discrimination, veteran status, sexual orientation, gender identity, or gender expression. For more information, please consult Board of Regents Policy: *https://regents.umn.edu/sites/regents.umn.edu/files/2019-09/policy_equity_diversity_equal_opportunity_and_affirmative_action.pdf*.

Disability Accommodations
The University views disability as an important aspect of diversity, and is committed to providing equitable access to learning opportunities for all students. The Disability Resource Center (DRC) is the campus office that collaborates with students who have disabilities to provide and/or arrange reasonable accommodations.

- If you have, or think you have, a disability in any area such as, mental health, attention, learning, chronic health, sensory, or physical, please contact the DRC office on your campus (UM Twin Cities - *626.1333*) to arrange a confidential discussion regarding equitable access and reasonable accommodations.
- Students with short-term disabilities, such as a broken arm, can often work with instructors to **minimize** classroom barriers. In situations where additional assistance is needed, students should contact the DRC as noted above.

- If you are registered with the DRC and have a disability accommodation letter dated for this semester or this year, please contact your instructor early in the semester to review how the accommodations will be applied in the course.
- If you are registered with the DRC and have questions or concerns about your accommodations please contact your (access consultant/disability specialist).

Mental Health and Stress Management
As a student you may experience a range of issues that can cause barriers to learning, such as strained relationships, increased anxiety, alcohol/drug problems, feeling down, difficulty concentrating and/or lack of motivation. These mental health concerns or stressful events may lead to diminished academic performance and may reduce your ability to participate in daily activities. University services are available to assist you. You can learn more about the broad range of confidential mental health services available on campus via the Student Mental Health Website: *http://www.mentalhealth.umn.edu*.

COVID
The University requires all students and employees to be vaccinated or have a valid exemption; more information is at safe-campus website. On January 5, 2022 President Gabel announced an update on COVID-19 and campus operations which strongly encourages all community members to get a booster as soon as they are eligible. For information about getting a booster and how to schedule an appointment, please refer to **the University's Get the Vax 2.0 initiative.**

Stay at home if you experience any signs of illness or have a positive COVID-19 test result, and consult with your healthcare provider about an appropriate course of action. Absences related to illness, including COVID-19 symptoms, for yourself or your dependents, are **excused absences** and I will work with you to find the best course of action for missed work and course content. I will follow these same protocols and will let you know if the delivery of this course has to be temporarily changed as the result of my own circumstances.

With the high transmissibility of the recent variants it is strongly recommended that you use an enhanced mask— a surgical mask either alone or in combination with a cloth mask, or an N95, KN95, AirPop or similar mask. Surgical masks are widely available throughout campus, and you can get free high-quality masks by following the instructions at https://www.uhs.umn.edu/university-health-and-safety-mask-support-program.

Both the Center for Disease Control (**CDC**) and Minnesota Department of Health (**MDH**) recommend that we stay home and get tested if we are experiencing **COVID-19 symptoms,** even if we're already fully vaccinated. I commit to doing my part to keep you and your peers safe by doing this, and I expect that you will too. If you experience **COVID-19 symptoms** or symptoms of any potentially infectious respiratory or other illness, you should stay home or in your residence hall room and not come to class or to campus. Consult your healthcare provider about an appropriate course of action, and refer to the **M-test program** for COVID-19 testing resources. If you test positive for COVID-19 here are the guidelines for **what to do**.

Approximate Lecture and Exam Schedule

Month	Monday	Wednesday	Friday
January Week #1		**19** Introduction to Course & Electrochemical Concepts	**21** Phase Boundary Potentials & Solid-State Electrodes
Week #2	**24** Thermodynamics of Solid-State Ion-Selective Electrodes	**26** Thermodynamics of Solid-State Ion-Selective Electrodes	**28** Mathematica / SCAFT
February Week #3	**31** Thermodynamics of Ion-Exchanger Ion-Selective Electrodes	**2** Liquid Junction Potentials	**4** Reference Electrodes for the Advanced User
Week #4	**7** Activity Coefficients	**9** Using Activity Coefficients: Real Life Application	**11** Electrically Neutral and Electrically Charged Ionophores
Week #5	**14** Electrically Neutral and Electrically Charged Ionophores	**16** Mass Transfer Problems In Ion-Selective Potentiometry	**18** Electron Transfer Kinetics
Week #6	**21** Electron Transfer Kinetics	**23** Butler Vollmer Kinetics	**25** Mass Transfer Limitations
March Week #7	**28** Catch-up	**2** **Exam I**	**4** Mass Transfer Limitations
	7 **Spring Break**	**9** **Spring Break**	**11** **Spring Break**

Month	Monday	Wednesday	Friday
Week #8	**14** Mass Transfer Limitations	**16** A Potential Step	**18** Microelectrodes
Week #9	**21** Catch-up	**23** Cyclic Voltammetry of Redoxactive Monolayers	**25** Catch-up
April Week #10	**28** Charging Currents	**30** Cyclic Voltammetry of Dissolved Redoxactive Species	**1** Cyclic Voltammetry of Dissolved Redoxactive Species
Week #11	**4** Cyclic Voltammetry of Dissolved Redoxactive Species	**6** ITIES	**8** Electrical Double Layer Theory
Week #12	**11** Electrical Double Layer Theory	**13** Impedance Spectroscopy	**15** **Exam II**
Week #13	**18** Impedance Spectroscopy	**20** Impedance Spectroscopy	**22** Conductimetry
May Week #14	**25** Conductimetry and Oscillometry/ Dielectrometry	**27** EC-STM & SECM	**29** EC-STM & SECM
Week #15	**2** Coulometry & Stripping Techniques		
		Wednesday, May 11 **Final Examination** 8:00–10:00 PM **Smith 111**	