

CHM1150HF

ADVANCES IN ELECTROANALYTICAL CHEMISTRY AND ELECTROCHEMICAL SENSORS

WINTER 2022 SYLLABUS

Course Instructor

Kagan Kerman, e-mail: kagan.kerman@utoronto.ca

Office hours: Tuesdays 1-3 pm live on Zoom or by making an appointment for an alternate date by posting a request message in the Discussion Board. The Zoom links will be posted as Announcement emails on the course page. Students are encouraged to discuss about their assignments and practice for their oral presentations with Dr. Kerman during the office hours.

Course time: HYBRID Fridays in-person from 1 to 3 pm in room EV140 in Environmental Science and Chemistry building in UTSC (from March 4th to April 8th) & live on Zoom. The Zoom links are posted as an Announcement email on the course page. There is no attendance mark. **If you miss the live lectures, the video recordings will be posted in the Files section each week.**

Discussion Board: Students are encouraged to post their questions and inquiries on the Discussion Board so that the answers of Dr. Kerman can be read by all the students.

Reference Texts:

There is no individual textbook assigned for the course and students should rely on course notes, literature articles, and lectures for the topics covered. The following is a list of suggested texts you may use for extra reading on covered topics:

1. Electrochemical Methods, Fundamentals and Applications by Allen J. Bard, and Larry R. Faulkner, 2nd Edition, 2001, Wiley-VCH. (The 3rd edition will soon be available in Spring 2022 with Henry S. White as an additional author).

2. Quantitative Chemical Analysis by Daniel C. Harris, 8th edition, W. H. Freeman and Company. **Chapter 7:** Activity and the Systematic Treatment of Equilibrium, **Chapter 13:** Fundamentals of Electrochemistry, **Chapter 14:** Electrodes and Potentiometry, **Chapter 16:** Electroanalytical Techniques.

3. Bioelectrochemistry: Fundamentals, Experimental Techniques and Applications Edited by Philip Bartlett, 2008 John Wiley & Sons, Ltd.

4. Encyclopedia of Electrochemistry, Volume 9: Bioelectrochemistry
Volume editor: George S. Wilson, 2002, Wiley-VCH.

5. Analytical Electrochemistry by Joseph Wang, 3rd Edition, Wiley-VCH.

6. Understanding Voltammetry by Richard G. Compton and Craig E. Banks, World Scientific Books.

All textbooks can be found as digital-copy or hard-copy in the UTSC Library and Gerstein Science Library.

Course Objectives:

This course is meant to provide an overview of the field of bioelectrochemistry with a focus on the development of biosensors. It covers the principles, technologies, methods, and recent applications of electrochemical biosensors.

Course Topics

Jan. 14- Introduction to Syllabus & Fundamentals

Learning objectives: Fundamentals of biosensors and bioelectrochemistry

Jan 21- Electrodes

Learning objectives: Solid electrodes (Glassy carbon, carbon paste, metal electrodes), mercury electrodes, microelectrodes, screen-printed electrodes, reference electrodes, cyclic voltammetry-1

Jan. 28- Voltammetry & Amperometry

Learning objectives: Cyclic voltammetry-2, differential pulse voltammetry, square wave voltammetry, stripping voltammetry, amperometry

Feb. 04- Electrochemical Impedance Spectroscopy

Learning objectives: AC voltammetry, Nyquist plot, Bode plot, Equivalent circuits.

Recommended Reading: Electrochemical impedance spectroscopy: an overview of bioanalytical applications, Edward P. Randviir and Craig E. Banks, *Anal. Methods* **2013**, 5, 1098-1115.

Feb. 11- Potentiometry

Learning objectives: pH electrodes, membrane electrodes, chronopotentiometric stripping analysis.

Recommended Readings: Electroanalysis with membrane electrodes and liquid-liquid interfaces, Eric Bakker, *Anal. Chem.* **2016**, 88, 395-413.

Potentiometric sensing, Elena Zdrachek and Eric Bakker, *Anal. Chem.* **2021**, 93, 72-102.

Feb. 18- Oral presentations-1

Feb. 25- Reading Week

March 04- Electrochemical Biosensors-1

Learning objectives: Challenges and future of biosensors

Recommended Readings: Electrochemical sensing directions for next-generation healthcare: Trends, Challenges, and Frontiers, J. F. Hernandez-Rodriguez, D. Rojas, A. Escarpa, *Anal. Chem.* **2021**, 93, 167-183.

Nonspecific binding – Fundamental concepts and consequences for biosensing applications, A. Frutiger, A. Tanno, S. Hwu, R. F. Tiefnauer, J. Voros, N. Nakatsuka, *Chem. Rev.* **2021**, *121*, 8095-8160.

March 11- Electrochemical Biosensors-2

Learning objectives: Glucose biosensors

Recommended Readings: Electrochemical glucose biosensors, J. Wang, *Chem. Rev.* **2008**, *108*, 814-825.

Anchoring PQQ-glucose dehydrogenase with electropolymerized azines for the most efficient bioelectrocatalysis, A. A. Komkova, A. K. Orlov, A. A. Galushin, E. A. Andreev, A. A. Karyakin, *Anal. Chem.* **2021**, <https://doi.org/10.1021/acs.analchem.1c02664>

Printable nonenzymatic glucose biosensors using carbon nanotube-PtNP nanocomposites modified with AuRu for improved selectivity, T. N. H. Nguyen et al., *ACS Biomater. Sci. Eng.* **2020**, *6*, 5315-5325.

March 18- Electrochemical Biosensors-3

Learning objectives: DNA biosensors

Recommended Readings: DNA Biosensors and microarrays, A. Sassolas, B. D. Leca-Bouvier, L. J. Blum, *Chem. Rev.* **2008**, 109-139.

Das, J. et al. An ultrasensitive universal detector based on neutralizer displacement. *Nat. Chem.* **4**, 642–648 (2012).

J. Das, et al. Reagentless biomolecular analysis using a molecular pendulum, *Nat. Chem.* **2021**, *13*, 428-434.

Y. Wu and N. Aroyo-Curras, Advances in nucleic acid architectures for electrochemical sensing, *Curr. Opin. Electrochem.* **2021**, *27*, 100695.

March 25- Electrochemical Biosensors-4

Learning objectives: Immunosensors, Aptasensors, Wearable sensors

Recommended Readings: Molecular diagnosis of COVID-19: Challenges and research needs. W. Feng, et al., *Anal. Chem.* **2020**, *92*, 10196-10209.

Multiplexed immunosensors and immunoarrays, A. Jones, L. Dhanapala, R. N. T. Kankanamage, C. V. Kumar, J. F. Rusling, *Anal. Chem.* **2020**, *92*, 345-362.

Perspectives on the future role of aptamers in Analytical Chemistry, Y. Wu, I. Belmonte, K. S. Sykes, Y. Xiao, R. J. White, *Anal. Chem.* **2019**, *91*, 15335-15344.

Wearable chemical sensors: Emerging systems for on-body Analytical Chemistry, J. R. Sempionatto, I. Jeerapan, S. Krishnan, J. Wang, *Anal. Chem.* **2020**, *92*, 378-396.

Wearable and mobile sensors for personalized nutrition, J. R. Sempionatto, V. R.-V. Montiel, E. Vargas, H. Teymourian, J. Wang, *ACS Sens.* **2021**, *6*, 1745-1760.

Apr. 01- Electrochemical Biosensors-5

Learning objectives: Biosensors for neurodegenerative diseases

Recommended Reading: Electrochemical approaches for the detection of amyloid- β , tau, and α -synuclein, Q. Hassan, K. Kerman, *Curr Opin Electrochem*, **2019**, *14*, 89-95.

Electrochemical biosensors for biometal-protein interactions in neurodegenerative diseases, S. Li, K. Kerman, *Biosens. Bioelectron.* **2021**, *179*, 113035.

Electrochemical biosensors for the detection and study of α -synuclein related to Parkinson's disease – A review. Q. Hassan, S. Li, C. Ferrag, K. Kerman, *Anal. Chim. Acta* **2019**, 1089, 32-39.

Apr. 08- Oral presentations-2

Evaluation:

The grading scheme for the course is shown in the table below:

Take-home Mid-term	25%	<p><u>From February 28th, Monday 9 am to March 4th, Friday 5 pm (EST)</u></p> <p>Mid-term will contain reading articles and critically reviewing them as well as short-answer and multiple-choice questions. The mid-term questions will be posted in the Files folder of the course page. The students will submit the completed mid-term as a Word or PDF file through the Quercus Assignments page.</p>
Take-home Final Exam	40%	<p><u>From April 13th, Wednesday 9 am to April 20th, Wednesday 5 pm (EST)</u></p> <p>Final exam will contain reading articles and critically reviewing them as well as short-answer and multiple-choice questions. Entire course topics including the assignments and oral presentations will be included in the exam with more emphasis on the topics covered after the mid-term. The final exam questions will be posted in the Files folder of the course page. The students will submit the completed final exam as a Word or PDF file through the Quercus Assignments page.</p>
<p>Abstract assignment</p> <p><u>Submission deadline: February 11th</u></p>	5%	<p>The students will prepare an abstract that they can present about electrochemical biosensors at an international conference of their choice. This abstract may be about your own research if it is related to electrochemistry or a topic from published article(s). Each student will have to post their abstract title and choice of conference on the Discussion Board. For example, the students can prepare an abstract for the Canadian Chemistry Conference and Exhibition (CCCE 2022) which will be held in June 13-17 in Calgary. The abstract for this conference requires 500 words maximum with an option for uploading an image as graphical abstract. More details to be given in lectures. More information about the CSC CCCE 2022 can be found following the link below:</p> <p><u>https://www.cheminst.ca/conference/canadian-chemistry-conference-and-exhibition/</u></p>

<p>Oral presentations</p> <p><u>1st presentation date (15%):</u></p> <p><u>February 18th</u></p> <p><u>2nd presentation date (15%):</u></p> <p><u>April 8th</u></p>	<p>30%</p>	<p>The students will prepare a 15-min oral presentation about their submitted abstract. There will be a 5-10 min Question & Answer session following each presentation. Since we have a small class, each student will present individually, not in teams. The students will present live the same presentation in the course for the first time on Feb. 18th and for the second time on April 8th. On these dates, the courses can continue longer than 2 hours. In this way, the students will have a chance to improve their presentations based on the feedback that they will get in the first presentation and course learnings.</p> <p>I have been notified that some of our students have time conflicts and will not be able to join the live presentations of their assignments. I would request those students that will not be able to join the live class to record their presentations following the instructions below:</p> <p>Please, record your 15-min presentation about your assignment topic and post the video on Quercus. You can use the recording software of your choice to record your presentation. Many students opt to use the recording features found within PowerPoint, Keynote, Zoom or Teams and upload their presentation directly to the Quercus course Assignments page as an mp4. Students will have the option to include a video of themselves. Prior to the start of your screen recording, we recommend that you close all unrelated applications, and windows with any personal or private information.</p> <p>Please upload your presentations to the Quercus Assignment platform here by the deadline of your presentation date. Please, don't hesitate to contact me, if you have exceptional circumstances.</p>

Course Policies and General Information:

Course Announcements: Announcements, updates to readings, assignment topics, requirements, and evaluation, etc. will be emailed and posted to the course site. Students are responsible for

checking the course website regularly. **Please, arrange your UTORONTO emails to accept the course announcements.**

Office Hours: Students are welcome to ask questions or resolve course-related problems by contacting the Course Instructor either by joining Zoom during scheduled office hours or by making an appointment by posting a request message on the Discussion Board. Students are responsible for work missed as a result of absence; the

Course Instructors will not re-teach material covered in the lectures and lab sessions

e-mail Communication: The Course Instructors may be contacted via the course email addresses to get clarification on course-related issues, or to ask brief questions. The Course Instructor will endeavour to provide responses to emails within 48 h. Urgent issues must be communicated in person or by telephone (with a follow up email message).

Missed Mid-term Test: The exact dates of the mid-term tests are provided in the Course Topics schedule. Students who miss the term test will be assigned a mark of zero for the test unless they can document a compelling reason for missing it. Students in that position must submit a written request to the Course Instructor with appropriate documentation as listed below:

<https://www.utoronto.ca/physsci/self-declaration-absence-form-0>

For the **Winter 2022** term, missed term tests due to medical illness will require *ALL* of the following:

1. Completed [Student Absence form](#)
2. Self-Declaration on [ACORN](#)

All items must be submitted **within three (3) business days** of the term test date. If a request is accepted for the mid-term test, the weighting of the mid-term will be in an extra-assignment. **There will be no make-up mid-term tests.**

AccessAbility: Students with diverse learning styles and needs are welcome in this course. In particular, if you have a disability/health consideration that may require accommodations, please feel free to approach me and/or the AccessAbility Services Office as soon as possible. The sooner you let us know your needs the quicker, we can assist you in achieving your learning goals in this course.

Cell Phones: During lectures and labs please put your cell phones in silent mode to avoid disruption of the class. If circumstances warrant use of your cell phone and you must receive an emergency call, please inform the Course Instructor at the beginning of the session in advance and then excuse yourself from the session to respond to the call outside the lecture hall or laboratory.

Academic Calendar: Further information about academic regulations and course withdrawal deadlines can be found in the UT Calendar. You are encouraged to read this material.

Academic Integrity: Honesty and fairness are considered fundamental to the University's mission, and, as a result, all those who violate those principles are dealt with as if they were damaging the integrity of the University itself. When students are suspected of cheating or a similar academic offence, they are typically surprised at how formally and seriously the matter is dealt with - and how severe the consequences can be if it is determined that cheating did occur. The University of Toronto treats cases of cheating and plagiarism

very seriously.

Examples of offences for which you will be penalized include (but are not limited to):

- Using any unauthorized aids on an exam or test (e.g., "cheat sheets")
- Representing someone else's work or words as your own - plagiarism (see web document "How not to plagiarize" available online at <http://www.utoronto.ca/writing/plagsep.html>)
- Falsifying documents or grades
- Purchasing an essay
- Submitting someone else's work as your own
- Submitting the same essay or report in more than one course (without permission)
- Looking at someone else's answers during an exam or test
- Impersonating another person at an exam or test or having someone else impersonate you
- Making up sources or facts for an essay or report.

As a student it is your responsibility to ensure the integrity of your work and to understand what constitutes an academic offence. If you have any concerns that you may be crossing the line, please, read from the website

<http://www.utoronto.ca/academicintegrity/resourcesforstudents.html>

and always consult your instructor. Your instructor can explain, for example, the nuances of plagiarism and how to use secondary sources appropriately; he or she will also tell you what kinds of aids - calculators, dictionaries, etc. - are permitted in a test or exam. Ignorance of the rules does not excuse cheating or plagiarism.

This information is taken from the brochure, "*Academic Integrity*" and website, part of a series of UT publications to help students understand the University's rules and decision making structures. For copies, visit the Office of the Registrar at UT. All of the policies and procedures surrounding academic offences are dealt with in one policy: "*The Code of Behaviour on Academic Matters*". The full text is located in the back of the UT Calendar.