CH EN 5308/6308 Fall 2025

Battery Technology and Electrochemical Engineering

Instructor	Professor Tao Gao
Class Description	Batteries are one of the most important types of electrochemical energy technologies. They are helping our society to reduce the CO_2 emissions in the transportation and electricity generation sectors, therefore combating the climate change challenge. More broadly, the knowledge in electrochemistry can be applied to many other emerging topics in chemical engineering and material science, such as energy conversion, CO_2 capture and reduction, electro-synthesis, green metallurgy, critical material extraction, biosensing, etc. This course will cover fundamental knowledge and state-of-the-art progress in the field of electrochemical energy storage technologies. It is suitable for students interested in battery technology, or students planning to pursue a career in the battery, electric vehicle, and renewable energy industry, or more broadly the electrochemical industry. In the first part of this course, we introduce the basics of electrochemical systems, including their structure and principle, thermodynamics, mass transport, kinetics, and interface. In the second part of this course, we will cover the principles of electrochemical energy storage technology, including Li-ion batteries, redox flow batteries, etc. Then we will introduce the frontier of these technologies, including electrode materials, electrolytes, supply chain and manufacturing, etc. This is a cross-listed course, in which undergraduate and graduate students can register at the same time. The course contents will be the same, albeit the requirement for undergraduate students will be different from that of graduate students.
Learning Objectives	1. Apply basic concepts of electrochemical systems to analyze and solve problems in electrochemical engineering. 2. Develop preliminary designs of battery technologies including specification of materials for different energy storage needs. 3. Apply the knowledge to understand other emerging electrochemical technologies
Reference books	Electrochemical methods: fundamentals and applications. Allen J. Bard, Larry R. Faulkner, 2nd edition, John Wiley & Sons, Inc. 2001 (Hard copy available from Marriot Library)

	Electrochemical Systems, John Newman, Karen E. Thomas-Alyea, 3rd edition, John Wiley & Sons, Inc. 2004 (Electronic copy available from Marriot Library) Contact TA if need help to find the reference book.
Other reference materials	Review papers and book chapters will be provided as reference materials during the course. Reading the reference materials and books is recommended but not required.
Course Structure	**Lectures:** Students and the instructor will meet twice per week in the classroom, where lectures will be given by the instructor. **Homework:** There will be four homework assignments. These assignments are designed to help students gain a quantitative understanding of some important concepts in this course. Homework will be assigned after the corresponding lectures are done. Undergraduate students can finish the optional problems for bonus points. **Exams:** There are two exams during the course and no final exam. The two exams cover different contents of the course. Exam 1 examines student's understanding of basic concepts of electrochemical systems. Exam 2 examines students' understanding of current battery technologies. The exams will be take-home exam. **Labs:** Students will need to finish two labs, in which they will use the knowledge they learn in the lectures to analyze the experiment results. Students need to form a team of 2-3 for the lab. Lab 1: make an electrochemical cell. Lab 2: make a Li-ion battery.

Week	Date	Format	Content	Assignment	Reading
1	Aug 18	Lecture	1. Introduction. Importance of electrochemical systems		Bard Ch1
	Aug 20		Electrochemical cells, electrolyte, electrode, potential, redox reaction.		
2	Aug 25	Lecture	2. Thermodynamics. Gibbs energy		Bard Ch2 Atkins Ch 5
	Aug 27		Electromotive force, Nernst Equation		
3	Sept 1	No Class	Labor Day		
	Sep 3		Equilibrium, reversibility, electrochemical potential		

4	Sep 8		Half reactions and standard electrode potential, Inner potential, interfacial potential difference Pourbaix Diagrams		
	Sep 10		Thermodynamics of electrolyte solutions		
5	Sep 15	Lecture	3. Electrolyte and Mass transport. Electrolyte conductivity	HW1 due	Bard Ch4 Newman Ch11,12 Atkins Ch 21
	Sep 17		Steady-state mass transport Nernst-Plank equation, Mass flux, mass balance, charge neutrality and current, Conservation of charge		
6	Sep 22		Diffusion potential, Binary electrolyte Supporting electrolyte, Concentrated electrolyte		
	Sep 24	Lecture	4. Kinetics. Homogeneous kinetics vs heterogeneous kinetics. Arrhenius equation, Transition state theory		Bard Ch3
7	Sep 29		Current-overpotential equation, B-V equation, Multi-step mechanism, Microscopic theory of electron transfer reaction, Different types of overpotential		
	Oct 1	Lecture	5. Interface and interphase. Surface, interface and interphase, On-faradic process, Electric double layer (EDL)	HW2 due	Bard Ch1.2, Ch13
8		No Class	Fall Break. October 6-12		
9	Oct 13	Lab	Lab 1. Electrochemical cell		
	Oct 15				
10	Oct 20	Lecture	6. Electrochemical Methods. Controlled current methods, Controlled potential methods, Impedance based methods		Bard Ch5,6,8,10
	Oct 22		Exam 1		
11	Oct 27	Lecture	7. Li-ion batteries. Basic concepts of batteries, History of Li-ion batteries Energy density of Li-ion batteries	Lab 1 report due	
	Oct 29		Cathode materials, Anode materials, Electrolyte		
12	Nov 3	Lab	Lab 2. Li-ion battery		
	Nov 5				
13	Nov 10		8. Li metal batteries. Li-S battery, Li-air (oxygen) battery		

	Nov 12		Li-NMC battery, Li metal anode		
14	Nov 17	Lecture	10. aqueous and flow batteries. Flow batteries	Lab 2 report due	
	Nov 19		Hybrid flow batteries, Zn battery, Fe battery		
15	Nov 24	Lecture	11. Manufacturing and supply chain. Cell Manufacturing, wet process, dry process	HW 3 due	
	Nov 26		Cathode, anode and electrolyte manufacturing, mining and recycling		
16	Dec 1		12. Current topics in electrochemical engineering	HW 4 due	
	Dec 3	Exam	Exam 2		