*DEPARTMENT OF MATERIALS SCIENCE AND ENGINEERING*
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# 3.53 ELECTROCHEMICAL PROCESSING OF MATERIALS

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staff: Donald R. Sadoway, lecturer

Hilary Sheldon, administrative assistant, ×3.3279, hsheldon@mit.edu, Room 8-201

lectures: Monday, January 14 through Friday, January 25, (no lecture January 21)

2:00 - 5:00, Room 5-217 (1/14 – 1/18); Room 5-134 (1/22 -1/25)

credits: 3-0-6 H-LEVEL Grad Credit

G(IAP)

prerequisite: 3.044 or 3.185 (applies only to undergraduates)

grading: take-home exam

text: A.J. Bard and L.R. Faulkner, *Electrochemical Methods*, 2nd edition, Wiley, New York, 2001.

sign-up on filecards:

NAME:
COURSE & YEAR:
REGISTRATION STATUS: credit, listener, or visitor
OFFICE, TELEPHONE, & EMAIL:
ADVISOR OR RESEARCH SUPERVISOR:
PREVIOUS DEGREES, SCHOOLS, & MAJOR:
COMMENTS & EXPECTATIONS:

what is the purpose of 3.53?

* to teach the elements of electrochemical processing as they derive from electrochemical fundamentals

* to interpret contemporary industrial practice in terms of the relevant thermodynamics and kinetics

## Outline

***unit 1 -- equilibrium electrochemistry or "ions in solution"***

thermodynamic and transport properties of electrolytes; electrode potentials (the underlying physics, i.e., electron excess or electron deficiency on the electrode); emf series (aqueous and molten salts); reference electrodes (thermodynamics [establishing the value of the potential] and kinetics [their *iE* characteristic]). For this part of the subject I draw on notes of my own that I have prepared from various sources.

***unit 2 -- electrochemical kinetics or rate processes in electrochemistry***

electrode-electrolyte interface, nature of the double layer; kinetics of electrode processes, competition between processes involving mass transport and interfacial processes such as charge transfer at the electrode/electrolyte interface; laboratory techniques to determine rate and mechanism: controlled *E*, controlled *i*, a.c. methods, i.e., a.c. voltammetry and electrochemical impedance spectroscopy, including the underlying electrical engineering -- namely construction of the equivalent circuit. We get into phasors and impedance plots in the complex plane, but in a manner that has some practical value -- data interpretation for process optimization, maybe even on-line control; stationary and rotating electrodes. This entire unit pretty much follows the text. We cover reasonably thoroughly almost everything in Chapters 3 through 10, skipping 8.

***unit 3 -- electrochemical processing***

winning, refining, plating, synthesis; current efficiency, voltage efficiency, power efficiency; energy balances; materials issues and environmental issues; case studies on Hall cell electrolysis to produce aluminum and electrolytic production of magnesium by both the Dow process and the I.G. Farben process. In studying aluminum and electrolytic magnesium technologies we try to rationalize contemporary industrial practice in the light of what we have learned earlier in the semester. Includes consideration of the environmental issues as, for example, in the case of the quest for the carbon-free anode for the Hall process.

***omissions***

I do not have time to do everything. In the past, these topics were not covered directly, although much of what I teach supports the study of these as well: corrosion; solid electrolytes. This year, depending upon the particular interests of the students in the class, I'm hoping to say something about batteries and fuel cells.

# 3.53 Schedule of Topics with Readings*

1. Monday, January 14, 2008.
   Introduction
   What is electrochemistry: intro to electrochemical cells at equilibrium?
   Applied electrochemistry :
   - batteries and fuel cells
   - electrolytic production of metals

2. Tuesday, January 15, 2008. Ch. 3.1 -3.4
   Elements of electron transfer reactions
   Kinetic of electrode processes
   Reference electrodes and such

3. Wednesday, January 16, 2008. Ch. 1.4, 4; 5.1, 5.2, 5.4
   Mass transport in electrochemical systems
   Potential-step methods

4. Thursday, January 17, 2008. Ch. 5.1, 5.2, 5.4 – 5.8
   Potential-step methods (continued)

5. Friday, January 18, 2008. Ch. 6.1 – 6.6
   Potential-sweep methods

6. Tuesday, January 22, 2008. Ch. 7.1, 7.2, 8.
   Polarography with the dropping mercury electrode
   Controlled-current methods

7. Wednesday, January 23, 2008. Ch. 10
   Review of ac circuits
   Equivalent circuit of an electrochemical cell
   Electrochemical impedance spectroscopy
   AC voltammetry

8. Thursday, January 24, 2008. Ch. 10
   continuation of previous day's lesson

9. Friday, January 25, 2008. Ch. 9.1 – 9.4
   Rotating-disk electrode & variations of same
   Summary

readings are referenced to the textbook: ***Electrochemical Methods***, 2nd ed., A.J. Bard & L.R. Faulkner, Wiley, New York, 2001.