February 7, 2011

3.53 ELECTROCHEMICAL PROCESSING OF MATERIALS

staff: Donald R. Sadoway, lecturer

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lectures: Monday, Wednesday, Friday -- 1:00 - 3:00, Room 8-119 (see separate schedule)

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

G(spring)

prerequisite: 3.044 (applies only to undergraduates)

grading: take-home exam


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 term 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 9.

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.
3.53 Tentative Schedule of Topics + Readings*

   Introduction
   What is electrochemistry: intro to electrochemical cells at
   equilibrium?
   Applied electrochemistry:
   - batteries and fuel cells
   - electrolytic production of metals

2. Wednesday, February 9, 2011. Ch. 3.1 -3.4
   Elements of electron transfer reactions
   Kinetic of electrode processes
   Reference electrodes and such

3. Friday, February 11, 2011. NO LECTURE.

3. Monday, February 14, 2011. Ch. 1.4, 4; 5.1, 5.2, 5.4
   Mass transport in electrochemical systems
   Potential-step methods

4. Wednesday, February 16, 2011. Ch. 5.1, 5.2, 5.4 - 5.8
   Potential-step methods (continued)

5. Friday, February 18, 2011. Ch. 6.1 - 6.6
   Potential-sweep methods

   Polarography with the dropping mercury electrode
   Controlled-current methods

7. Wednesday, February 23, 2011. Ch. 10
   Review of ac circuits
   Equivalent circuit of an electrochemical cell

8. Friday, February 25, 2011. Ch. 10
   Electrochemical impedance spectroscopy
   AC voltammetry

   Summary

If needed, lectures will continue March 14, 16, and 18.

Readings are referenced to the textbook: *Electrochemical Methods,*