

1997 December 16

**CHE 5824**

**CORROSION PROCESSES**

**Final Examination**

- Three hours, closed book.
- Attempt all questions.
- Hand calculators may be used for computation - NOT for storage of information pertinent to this course.
- You MUST provide CLEAR diagrams of ADEQUATE SIZE for illustration.

- Data:

Gas constant;  $R = 8.31 \text{ J.K}^{-1}.\text{mol}^{-1}$   
Faraday;  $F = 96,500 \text{ coulomb.mol}^{-1}$   
At.wt.; Fe = 55.9  
At.wt.; O = 16.0

1. The accompanying figure is a simplified Pourbaix diagram for the iron-water system at 25°C. For the lines denoted (a), (b) and i to x write balanced chemical equations to explain the respective equilibria. If the standard redox potential for the Fe - Fe<sup>2+</sup> equilibrium is -0.440 V (vs. SHE), calculate an approximate concentration pertinent to the boundary of the ferrous ion region in the diagram. Use the diagram to estimate as narrow a potential range as possible within which the potential of iron falls when it is corroding in:

- a de-aerated acid solution of ferrous ions at unit activity and pH 2;
- the same solution only aerated.

(10 marks)

2. A carbon steel pipe contains flowing water at 300°C. Measurements with an ultrasonic probe indicate that after 1.2 month exposure the pipe inside wall has corroded 28.5 μm, and after 6.0 month it has corroded 35.8 μm. Deduce a simple power law to describe the corrosion penetration as a function of time. At one year exposure, what will be the instantaneous and average penetration rates and the oxide (assumed to be magnetite) film thickness (assume metal and oxide densities of 7.9 g/cm<sup>3</sup> and 5.2 g/cm<sup>3</sup> respectively, and an oxide porosity of 10%)?

(10 marks)

3. Describe the various mechanisms by which hydrogen can degrade metals. What metals are particularly susceptible to the degradation and what environments are particularly damaging? How can the degradation be counteracted?

(7 marks)

4. What metals/alloys are susceptible to crevice corrosion, and what sub-group of metals/alloys is particularly vulnerable? Why?

Describe how crevice corrosion may occur in a flanged joint in a copper alloy pipe carrying aerated, brackish water. How would you counteract the corrosion?

(7 marks)

5. The Butler-Volmer (B-V) equation for a redox reaction can be written in the form:

$$i = i_0 \{ \exp (b_A \cdot \eta) - \exp (-b_C \cdot \eta) \}.$$

Referring to a qualitative diagram, explain the meaning of the equation and the significance of the terms therein.

Again on a qualitative B-V diagram, show how a metal oxidation reaction can couple with another redox reaction to describe corrosion of the metal. How is the diagram transformed into an Evans diagram?

Construct (an) Evans diagram(s) to illustrate qualitatively the active corrosion of a passivating metal in de-aerated acid solution, and the influence of the exchange current density for the hydrogen evolution reaction on the corrosion rate. Indicate the conditions required for the corrosion to occur in the passive regime.

(10 marks)

6. Citing examples, describe the corrosion phenomenon called “selective leaching”. How can it be counteracted?

(6 marks)

