National Exams May 2015

10-Met-A7: Corrosion and Oxidation

3 hours duration

Notes:

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper, a clear statement of any assumptions made.
2. Approved Casio or Sharp calculator is permitted. This is a closed book exam.
3. Answer 5 out of 6 questions.
4. Each question is of equal value (5×20 marks each for a total of 100 marks).
5. Some questions require descriptions of types of corrosion and engineering solutions. Clarity and organization of the answers are important.

1. Basic Corrosion Theory (20 marks)

The rusting of iron in neutral, pH = 7, aerated solutions, $pO_2 = 0.2$, produces solid ferrous hydroxide. Given the following half-cell reactions and corresponding standard reduction potentials:

$$O_2 + 4e^- + 4H^+ \rightarrow 2H_2O \qquad E^\circ_{O_2/H_2O} = 1.229V$$

$$Fe(OH)_2 + 2e^- + 2H^+ \rightarrow Fe + 2H_2O \qquad E^\circ_{Fe(OH)_2/Fe} = -0.048V$$

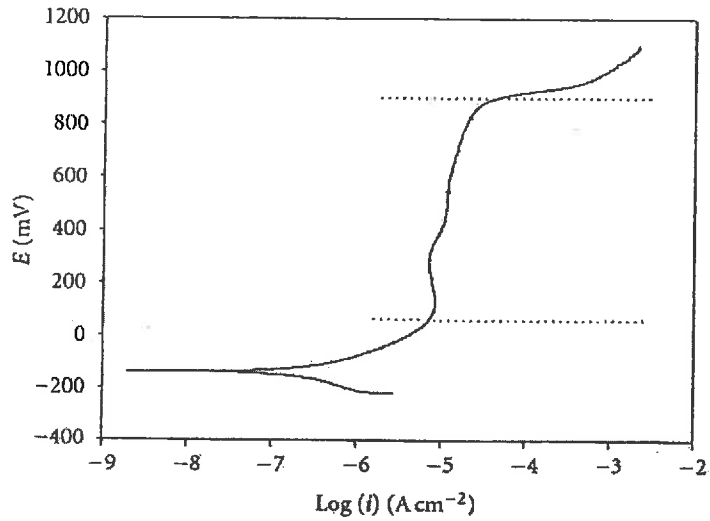
a) Use the Nernst equation to calculate the electrode potentials, E, for each half-cell reaction. Recall also that $pH = \log\frac{1}{[H^+]}$

$$E = E^\circ - \frac{0.0592}{n}\log\frac{[red]}{[ox]}$$

b) Combine the half-cell reactions to produce the overall corrosion reaction and estimate the corresponding corrosion cell potential, E_{cell}. Given the value of E_{cell}, is the corrosion reaction spontaneous or not? Justify your answer.

2. Electrochemical Corrosion Theory (20 marks)

The following figure is a polarization curve for ANSI 321 stainless steel in 0.5 M H_2SO_4.



a) Label the regions of active, passive and transpassive corrosion and estimate the corrosion potential, E_{corr}, and corrosion current density, i_{corr}. Describe what occurs as the corrosion behavior of a metal transitions from active corrosion to passive corrosion, i.e. describe passivation.

b) Assuming the active corrosion reaction is principally oxidation of iron, Fe, to produce ferrous ions, Fe^{2+}, use the corrosion current estimated in part a) to calculate the corrosion rate in µm/yr, given, M_{Fe} = 55.85 g/mol.Fe, δ_{Fe} = 7.86 g/cm^3. Recall that an ampere is a coulomb per second, A = C/s, and Faraday's constant, F = 96490 C/mol.e$^-$.

3. Metallurgical Cells (20 marks)

a) Describe the conditions that lead to galvanic corrosion, its mechanism, as well as commonly employed engineering solutions to prevent this type of corrosion.

b) Describe how stainless steels become sensitized to weld decay, the mechanism of corrosion at such welds, as well as some common engineering solutions to prevent this type of corrosion.

4. Environmental Cells (20 marks)

a) Describe the conditions that lead to crevice corrosion, its mechanism, as well as some common engineering solutions to prevent this type of corrosion.

b) Describe the conditions that lead to pitting, its mechanism, as well as some common engineering solutions to preventing this type of corrosion.

5. Stress Assisted Corrosion (20 marks)

a) Describe the conditions that lead to stress cracking corrosion, its mechanism, as well as some common engineering solutions to prevent this type of corrosion.

b) Describe the conditions that lead to corrosion fatigue, its mechanism, as well as some common engineering solutions to prevent this type of corrosion.

6. Corrosion Control (20 marks)

a) Describe the main way in which each of following types of coatings mitigates corrosion:

i. Ceramic (glass or cement) coatings:

ii. Zinc on steel:

iii. Tin on steel:

iv. Inhibitors:

v. Organic paints:

b) Describe the common features of cathodic protection systems. Compare sacrificial anode versus impressed-current systems with particular emphasis on justifying the selection one technology over the other for protection of a remotely located buried pipeline versus protection of a concrete/rebar structure located in an urban centre.