



UNIVERSITY OF GHANA

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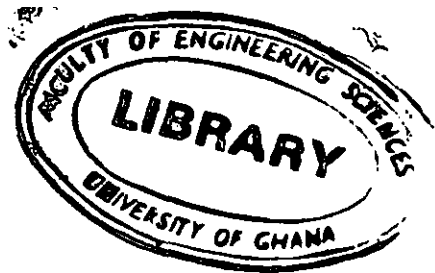
BSC. MATERIALS SCIENCE AND ENGINEERING

SECOND SEMESTER EXAMINATIONS: 2015/2016

SCHOOL OF ENGINEERING SCIENCES

DEPARTMENT OF MATERIALS SCIENCE AND ENGINEERING

MTEN 416: CORROSION AND CORROSION CONTROL (2 CREDITS)



INSTRUCTIONS:

ANSWER ALL QUESTIONS IN BOTH SECTIONS A AND B. ANSWER BOTH SECTIONS IN THE BOOKLET PROVIDED. FOR SECTION A WRITE THE APPROPRIATE LETTER OF CHOICE IN THE ANSWER BOOKLET.

TIME ALLOWED: TWO (2) HOURS

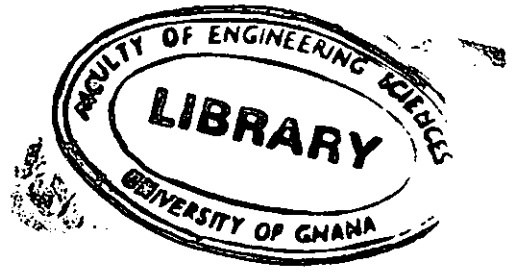
SECTION A

ANSWER ALL QUESTIONS IN ANSWER BOOKLET. THIS SECTION CARRIES 40 MARKS.

1. Which of the following is a valid cathodic reaction for corrosion of a metal in an acid solution with dissolved oxygen?
 - (a) $2H^+ + 2e^- \rightarrow H_2$;
 - (b) $O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$;
 - (c) $O_2 + 2H_2O + 4e^- \rightarrow 4(OH^-)$;
 - (d) $O_2 + 2H_2O \rightarrow 4(OH^-)$.
2. For a metal dissolving into ions upon corrosion in a solution, which of the following can be expected?
 - (a) Transpassive corrosion;
 - (b) Passive corrosion;
 - (c) Active corrosion;
 - (d) Polarization corrosion.
3. According to the standard emf series which of the following metals have the highest anodic behavior?
 - (a) Fe;
 - (b) Au;
 - (c) Zn;

(d) Ni.

4. One-half of an electrochemical cell consists of a pure nickel electrode in a solution of Ni^{2+} ions; the other half is a cadmium electrode inserted in a Cd^{2+} solution. For a standard cell, calculate the voltage that is generated if the standard half-cell potential for cadmium and nickel are -0.403 V and -0.250 V, respectively.
- (a) +0.153 V;
 - (b) -0.153 V;
 - (c) +0.135 V;
 - (d) -0.135 V.
5. For a zinc electrode connected to a platinum electrode, a potential of -0.621 V is measured. If the equilibrium zinc electrode potential is -0.763 V, calculate the overpotential.
- (a) -0.142 V;
 - (b) +0.142 V;
 - (c) -0.124 V;
 - (d) +0.124 V.
6. The condition where the electrochemical reaction rate is controlled by one step in the series that occurs at the slowest rate is known as
- (a) Activation polarization;
 - (b) Concentration polarization;
 - (c) Over potential;
 - (d) Passivation.
7. Which of the following is not a step in the reduction of H^+ ions to form hydrogen gas bubbles on a zinc electrode?
- (a) Adsorption of H^+ ions from the solution unto the surface of zinc;
 - (b) Electron transfer from hydrogen to the zinc surface;
 - (c) Electron transfer from the zinc to form a hydrogen atom;
 - (d) Combination of two hydrogen atoms to form a molecule of hydrogen gas.
8. The current density measured at equilibrium between oxidation and reduction reactions is known as
- (a) Redox current density;
 - (b) Equilibrium corrosion rate;
 - (c) Exchange current density;
 - (d) Polarization current density.
9. The line with a negative slope on a Tafel plot represents
- (a) Polarization;
 - (b) Overpotential;
 - (c) Oxidation;



- (d) Reduction.
10. When a reaction rate is limited by diffusion,
- (a) Activation overpotential exists;
 - (b) Concentration overpotential exists;
 - (c) Inert polarization has occurred.
 - (d) Passivation polarization exists.
11. The Tafel lines for hydrogen gas evolution and Zn oxidation intersects at $i = 10^{-4} \text{ A/cm}^2$. Determine the rate of oxidation of zinc.
- (a) $5.2 \times 10^{-6} \text{ mol/m}^2\text{-s}$;
 - (b) $2.5 \times 10^{-6} \text{ mol/m}^2\text{-s}$;
 - (c) $7.2 \times 10^{-6} \text{ mol/m}^2\text{-s}$;
 - (d) $2.7 \times 10^{-6} \text{ mol/m}^2\text{-s}$.
12. Which of the following measures will not help to control galvanic corrosion?
- (a) Couple two metals that are close together on the galvanic series;
 - (b) Electrically insulate dissimilar metals from each other;
 - (c) Use of a large cathode and small anode;
 - (d) Electrically connecting a third anodic metal to the other two.
13. The application of a layer of zinc to the surface of steel is known as galvanizing. Which of the following corrosion prevention techniques best describe galvanizing?
- (a) Sacrificial anode,
 - (b) Rectifier protection;
 - (c) Inhibitor protection;
 - (d) Anodic protection.
14. Which of the following can be done by hot dipping?
- (a) Rectifier protection;
 - (b) Anodic protection;
 - (c) Galvanizing;
 - (d) Impressed current cathodic protection.
15. Which of the following systems may corrosion inhibitors not be applied?
- (a) Automobile radiator;
 - (b) Outside a pipeline;
 - (c) Steam boilers;
 - (d) Cooling water stream in a heat exchanger.
16. All the following are ways by which weld decay of stainless steel may be prevented except
- (a) Subjecting the sensitized material to high temperature heat treatment to redissolve particles;

- (b) Lowering the carbon content below 0.03 wt% C;
 - (c) Increasing the carbon content above 0.03 wt% C;
 - (d) Alloying the steel with another metal such as niobium or titanium.
17. Which of the following will enhance the resistance of a metal to pitting corrosion?
- (a) Polishing the metal's surface;
 - (b) The presence of surface flaws;
 - (c) Reducing the molybdenum content of stainless steels below 2%;
 - (d) Using the metal nearby the ocean.
18. Which of the following corrosion monitoring technique cannot detect pitting?
- (a) Magnetic flux leakage;
 - (b) Electric field mapping;
 - (c) Inductive resistance;
 - (d) Coupon testing.
19. Which of the following methods of corrosion protection can be implemented in a remote location?
- (a) Rectifier cathodic protection;
 - (b) Sacrificial anode cathodic protection;
 - (c) Anodic protection;
 - (d) Passivation.
20. Which of the following assumes a $pH = 0$?
- (a) Galvanic corrosion;
 - (b) Galvanic series;
 - (c) Emf series;
 - (d) Corrosion potential.

SECTION B

ANSWER ALL QUESTIONS IN THIS SECTION

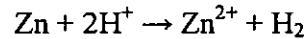
1.
 - a. With the help of a labeled schematic polarization curve(s), explain why aluminum is more corrosion resistant than iron even though iron has a higher reduction potential than aluminum.
 - b. Briefly explain why concentration polarization is not normally rate controlling for oxidation reaction.
 - c. Plot a schematic graph each of overvoltage versus log of current density for activation polarization and concentration polarization, then schematically graph a combined activation-concentration polarization curve. Label the parts of these three schematic graphs.

- d. Briefly differentiate anodic and cathodic protection against corrosion explaining types where applicable with the aid of appropriate schematic diagram.

(30 marks).

2.

- a. One-half of an electrochemical cell consists of a pure nickel electrode in a solution of Ni^{2+} ions; the other half is cadmium electrode immersed in a Cd^{2+} solution.
- If the cell is a standard one, write the spontaneous overall reaction and calculate the voltage that is generated.
 - Compute the cell potential at 25 °C if the Cd^{2+} and Ni^{2+} concentrations are 0.5 M and 10^{-3} M, respectively. Is the spontaneous reaction direction still the same as for the standard cell?
- b. Zinc experiences corrosion in an acid solution according to the reaction



The rates of both oxidation and reduction half-reactions are controlled by activation polarization.

- Compute the rate of oxidation of Zn (in $\text{mol}/\text{cm}^2\text{-s}$) given the following activation polarization data:

For Zn: $V_{(\text{Zn}/\text{Zn}^{2+})} = -0.763 \text{ V}$; $i_0 = 10^{-7} \text{ A}/\text{cm}^2$; $\beta = +0.09$

For Hydrogen: $V_{(\text{H}^+/\text{H}_2)} = 0 \text{ V}$; $i_0 = 10^{-10} \text{ A}/\text{cm}^2$; $\beta = -0.08$

- Compute the value of the corrosion potential.

(30 marks).

