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BSC. MATERIALS SCIENCE AND ENGINEERING
SECOND SEMESTER EXAMINATIONS: 2015/2016
SCHOOL OF ENGINEERING SCIENCES
DEPARTMENT OF MATERIALS SCIENCE AND ENGINEEINRG
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;

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(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 in 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.

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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 $i = 10^{-4}$ A/cm^2. Determine the rate of oxidation of zinc.
    (a) 5.2×10^{-6} mol/m^2-s;
    (b) 2.5×10^{-6} mol/m^2-s;
    (c) 7.2×10^{-6} mol/m^2-s;
    (d) 2.7×10^{-6} mol/m^2-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.

   i. If the cell is a standard one, write the spontaneous overall reaction and calculate the voltage that is generated.

   ii. 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

$$Zn + 2H^{+} \rightarrow Zn^{2+} + H_2$$

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

   i. Compute the rate of oxidation of Zn (in mol/cm^2-s) given the following activation polarization data:
   For Zn: $V_{(Zn/Zn^{2+})} = -0.763$ V; $i_0 = 10^{-7}$ A/cm^2; $\beta = +0.09$
   For Hydrogen: $V_{(H^{+}/H2)} = 0$ V; $i_0 = 10^{-10}$A/cm^2; $\beta = -0.08$

   ii. Compute the value of the corrosion potential.

(30 marks).

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