NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

FACULTY OF INDUSTRIAL TECHNOLOGY
BACHELOR OF ENGINEERING (HONS) DEGREE
Part One Examination May 2014

TCE 1202 Materials and Containment 1B

Duration of Examination 3 Hours

Instructions to Candidates

1. Answer **Question One** and any other **Three** questions.
2. Show all your steps clearly in your calculations.
3. Start the answers for each question on a new page.

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1. a) Corrosion is known to have catastrophic results. Justify this statement using a relevant recent example. [5]

   b) With the aid of equations illustrate the processes of oxidation and reduction, clearly indicating at which electrode each process takes place in a corrosion cell. [5]

   c) Distinguish the Standard emf series from the Galvanic series. [5]

   d) Illustrate how the corrosion penetration rate (CPR) finds practical application in the field of materials engineering. [5]

   e) Compare and contrast activation polarization from concentration polarization. [5]

2. a) Consider a piece of iron being deformed with an elastic strain of 2%. The elastic modulus of iron is 200 GPa. What is the change in the standard electrode potential for the Fe/Fe^{2+} half-cell reaction under this condition? [7]

b) Corrosion control is achieved by two primary methods. Outline how each corrosion control technique is used. [6]

c) Some fuel cells operate by oxidizing hydrogen gas on an anode while reducing oxygen from ambient air in contact with a cathode. What would be the maximum voltage produced by such a cell running on pure hydrogen and air in an acidic environment? Would it be different if pure oxygen was used instead of ambient air? [5]

d) Evaluate the statement that some metals, such as titanium for example, which are relatively easy to oxidize, can still be found at the top of a galvanic series in seawater. [5]

e) Using standard potentials and molarity for ion concentrations, calculate the open circuit potential of the following electrochemical reaction (balance the equation with water related chemical species when necessary, i.e. H^+, OH^- and H_2O):

i. $H_2O_2 + Ni \rightarrow H_2O + Ni^{2+}$ [2]

3. a) Outline the six (6) common polymers and justify their suitability for their typical applications. [12]

b) 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 immersed in a Cd^{2+} solution.

i. If the cell is standard one, write the spontaneous overall reaction and calculate the voltage that is generated? [4]

ii. Compute the cell potential at 25°C if the Cd^{2+} and Ni^{2+} concentrations are 0.5 and 10^{-3}M, respectively. Is the spontaneous reaction direction still the same as for the standard cell? [3]

c) Explain in detail what hydrogen embrittlement is, highlighting how it occurs and the techniques used to reduce its occurrence. [6]

4. a) State and explain four new applications of ceramics. [4]

b) Summarize four (4) strategies for increasing the modulus and strength of polymers. [4]

c) A sheet of carbon steel one meter wide by three meter long has lost 40 g to corrosion over the past six months. Convert that mass loss to a penetration rate of the steel in mm units. What would be the total corrosion current associated with such a corrosion rate? (carbon steel density = 7.8 g/cm^3). [5]

d) Calculate the percentage crystallinity of a branched polyethylene that has a density of 0.925g/cm^3. The density for the totally amorphous material is 0.870g/cm^3 and the density of the perfectly crystalline polymer is 0.998g/cm^3. [5]

e) Discuss the properties and applications of glass-ceramics. [7]

5. a) The clear plastic bottles used for carbonated drinks (sometimes called soft drinks) are made from polyethylene terephthalate (PET). The fizz in pop results from dissolved carbon dioxide (CO_2) and because PET is permeable to CO_2, the soft drinks stored in PET bottles will eventually go flat (i.e lose its fizz). A 567gram bottle of soft drink has a CO_2 pressure of about 400 kPa inside the bottle and the CO_2 pressure outside the bottle is 0.4 kPa. Assume that each bottle has a surface area of 500cm^2 and a wall thickness of 0.05cm

   i. Assuming conditions of steady state, calculate the diffusion flux of CO_2 through the wall of the bottle? [5]

   ii. If the bottle must lose 750 cm^3(STP) of CO_2 before the soft drink tastes flat, what is the shelf-life for a bottle of soft drink in a PET bottle? [6]

b) Zinc experiences corrosion in an acid solution according to the reaction

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

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^2s) given the following polarization data: [6]

For Zn	For Hydrogen
$V_{(Zn/Zn^{2+})} = -0.763$ V	$V_{(H^+/H2)} = 0$ V
$i_0 = 10^{-7}$ A/cm^2	$i_0 = 10^{-10}$ A/cm^2
$\beta = +0.09$	$\beta = -0.08$

ii. Compute the value of the corrosion potential. [3]

c) Argue the use of polymers in lithium ion batteries and fuel cells. [5]

END OF EXAM