

**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

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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<sup>2+</sup> 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  $H_2O$ ):



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  $25^\circ C$  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<sup>3</sup>). [5]

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

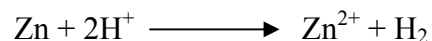
e) Discuss the properties and applications of glass-ceramics. [7]

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<sub>2</sub>) and because PET is permeable to CO<sub>2</sub>, 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<sub>2</sub> pressure of about 400 kPa inside the bottle and the CO<sub>2</sub> pressure outside the bottle is 0.4 kPa. Assume that each bottle has a surface area of 500cm<sup>2</sup> and a wall thickness of 0.05cm

i. Assuming conditions of steady state, calculate the diffusion flux of CO<sub>2</sub> through the wall of the bottle? [5]

ii. If the bottle must lose 750 cm<sup>3</sup>(STP) of CO<sub>2</sub> 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



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<sup>2</sup>s) given the following polarization data: [6]

For Zn	For Hydrogen
$V_{(Zn/Zn^{2+})} = -0.763 \text{ V}$	$V_{(H^+/H_2)} = 0 \text{ V}$
$i_0 = 10^{-7} \text{ A/cm}^2$	$i_0 = 10^{-10} \text{ A/cm}^2$
$\beta = +0.09$	$\beta = -0.08$

- 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