GWANDA STATE UNIVERSITY

FACULTY OF ENGINEERING AND THE ENVIRONMENT

DEPARTMENT OF METALLURGICAL ENGINEERING

CORROSION AND WEAR EMR 5203

CORROSION ENGINEERING EMR 3207

Part III & V Second Semester Examination Paper

MAY / JUNE 2023

This examination paper consists of 7 printed pages

Time Allowed: **3 hours**

Total Marks: **100**

Mr. Tinashe Mabikire

<u>**INSTRUCTIONS**</u>

1. Answer any 4 questions from the 5 questions.
2. Each question carries 25 marks
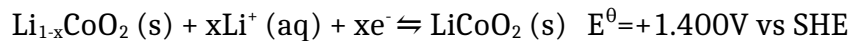3. Use of calculators is permissible.

Question 1

Zimbabwe is looking into the beneficiation of lithium into batteries. The principle of operation of lithium battery is electrochemistry or controlled corrosion. A small backyard firm want to manufacture lithium rechargeable batteries to power watches. The batteries should run at 3.75V and have a capacity of 300mAH. Internal voltage drop for the battery in operation is 1.00V.

The battery anodic discharge reaction is :

Li_xC_6 (s) $\rightleftharpoons$ 6C (s) + xLi^+ (aq) + xe^- $\qquad$ E^θ=+3.045V vs SHE
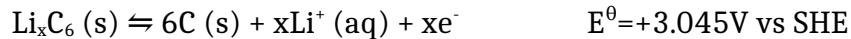
The cathodic discharge reaction is :

$Li_{1-x}CoO_2$ (s) + xLi^+ (aq) + $xe^- \rightleftharpoons LiCoO_2$ (s) $\quad$ E^θ=+1.400V vs SHE

Electrolyte

$LiPF_6$ in solvent Ethylene Carbonate

Li atomic mass is 6.941g/mol, Faraday Constant is 96,485 Coulomb/mole and Avogadro's Constant is 6.02E23

a) Write a balanced equation for the overall discharge reaction for this battery and calculate its cell potential. [4]
b) State any five factors that affect the overall battery potential to be lower than the theoretically calculated cell potential. [5]
c) Calculate the mass of lithium per battery, if each battery contains thrice the minimum mass required to store 300mAH. [5]
d) The design electrolyte volume for the battery is 2.35ml what is the approximate activity of Li^+ when a third of the lithium mass is in the electrolyte as Li^+. [3]
e) Calculate the battery open circuit voltage with non-standard conditions. [4]
f) State any two disadvantages that will come from using a solid based electrolyte in this battery compared to liquid based. [4]

Question 2

A steel tank is hot dipped in a de-aerated acid solution containing 5E-4mol/cm^3 molarity of zinc chloride ($ZnCl_2$) so that a 0.15mm zinc coating is deposited on the steel surface. This process produces a galvanised steel tank.
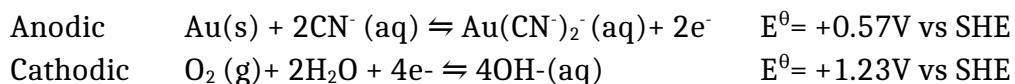
Reduction Potential for Zn^{2+}(aq) + 2e$^- \rightleftharpoons$ Zn(s) $\qquad$ E^θ = -0.76V vs SHE

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Standard Condition Equilibrium Current Density for Zn Electrode i_{oZn} = 10µA/cm², Standard Condition Equilibrium Current Density for H_2 Electrode i_{oH} = 10^{-3}µA/cm², Anodic polarisation constant β_a=0.08V, Cathodic polarisation constant β_c=0.12V, Temperature = 25°C, zinc atomic weight is 65.38g/mol, zinc density is 7.13 g/cm³.

a. Calculate the time it will takes for the zinc coating to completely corrode, at a pH of 4.
[10]

b. It is known that the standard electrode potential (E°) for pure crystalline zinc is equal to –0.763 V. Will this value change by cold working and impurities? Explain this change or zero difference.
[5]

c. Why does a pearlitic steel corrode rapidly in an acidic solution?
[4]

d. Why would the tip and the head of an iron nail behave as anodes relative to the cathodic shank?
[4]

e. What is the significant differences between the over-potential and the Ohmic potential (E)?
[2]

Question 3

A local mine intent to use iron tanks for the leaching of gold. The gold is leached at pH 10.5. The leaching reactions for gold is according to the Elsner's equation with the following half reaction and potentials.

Anodic	$Au(s) + 2CN^- (aq) \leftrightharpoons Au(CN^-)_2^- (aq) + 2e^-$	E^θ= +0.57V vs SHE
Cathodic	$O_2 (g) + 2H_2O + 4e- \leftrightharpoons 4OH-(aq)$	E^θ= +1.23V vs SHE

NaCN (Mr = 49g/mol) is added at 1kg per 1000L of water, dissolved O_2 (Mr = 32g/mol) at 10ppm in solution

Use the Fe Pourbaix diagram shown in Figure Q3.

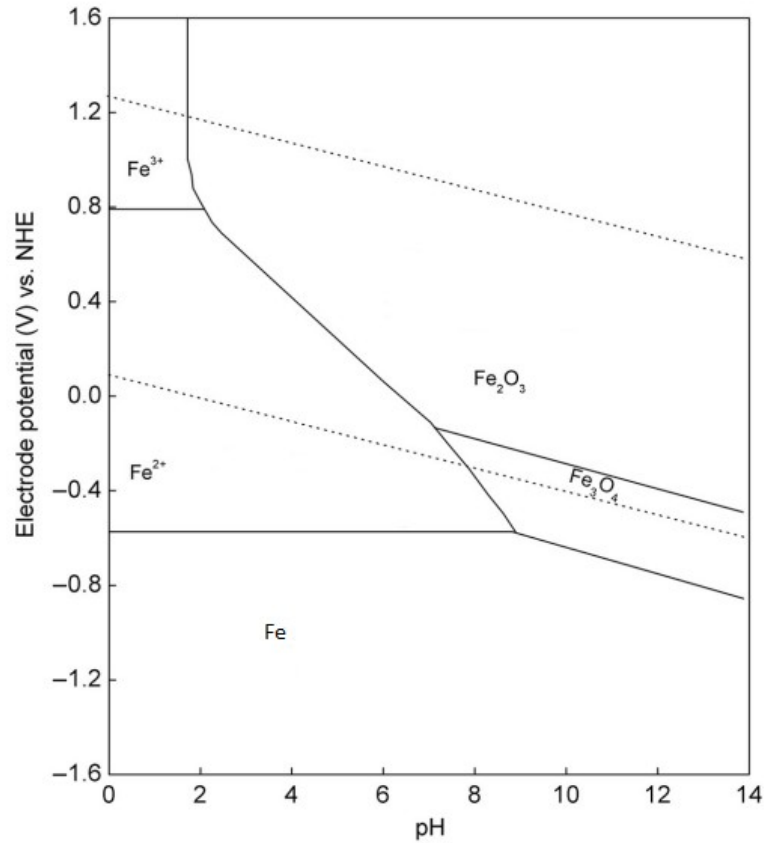EMR 5203 Corrosion and Wear & EMR 3207 Corrosion Engineering

Figure Q3: Fe Pourbaix diagram

a) On a sketch of the diagram above show area you expect iron to show immunity, passivity to corrosion and where you expect it to corrode. [5]

b) Where you expect corrosion write down the balanced chemical reaction equations. [2]

c) Where you expect passivity write down the balanced chemical reaction equation and explain the basis of the passivity. [2]

d) Under the conditions for gold leaching in mechanically agitated tanks will iron corrode? [4]

e) Show in your sketch by an "X" mark the point that corresponds to the pH and potential stating their values. [8]

f) What way can the mine prevent corrosion of its iron tanks in gold leaching. [4]

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Question 4

With power shortages current being persistent in Zimbabwe the community has turned to use of camping LPG gas burners. The cooker top shown in Figure Q4 fails after some time in use.

In uses the LPG adiabatic temperature reaches 1700°C but the pan and cooker top temperatures averages 220°C. A loading stress of 30N can be experienced in cooking cycles, and when not in use, it is at room temperature and zero stress. The material used is a high output stainless steel fully chrome plated.

Figure Q4: Cooker top

a. Write down a balanced reaction that you predict to happen during corrosion of the support stand. [3]

b. What type(s) of corrosion do you suspect leads to failure of these support stands and why? [4]

c. Design an experiment that you can carry out to estimate the effect of corrosion and failure of these support stands and predict their use life span. [10]

d. What condition in uses may cause accelerate premature failure of the stand? Explain how the failure is accelerated. [4]

e. Propose a way to prolong the life span of these support stands. Explain how it prolong the use time span. [4]

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Question 5

Corrosion prevention can be achieved in numerous ways and one of the techniques is alloying. Consider figure Q5 for alloying experiments, Anodic Polarization curves for Fe-Cr-Ni alloys with different contents of Cr and Ni.
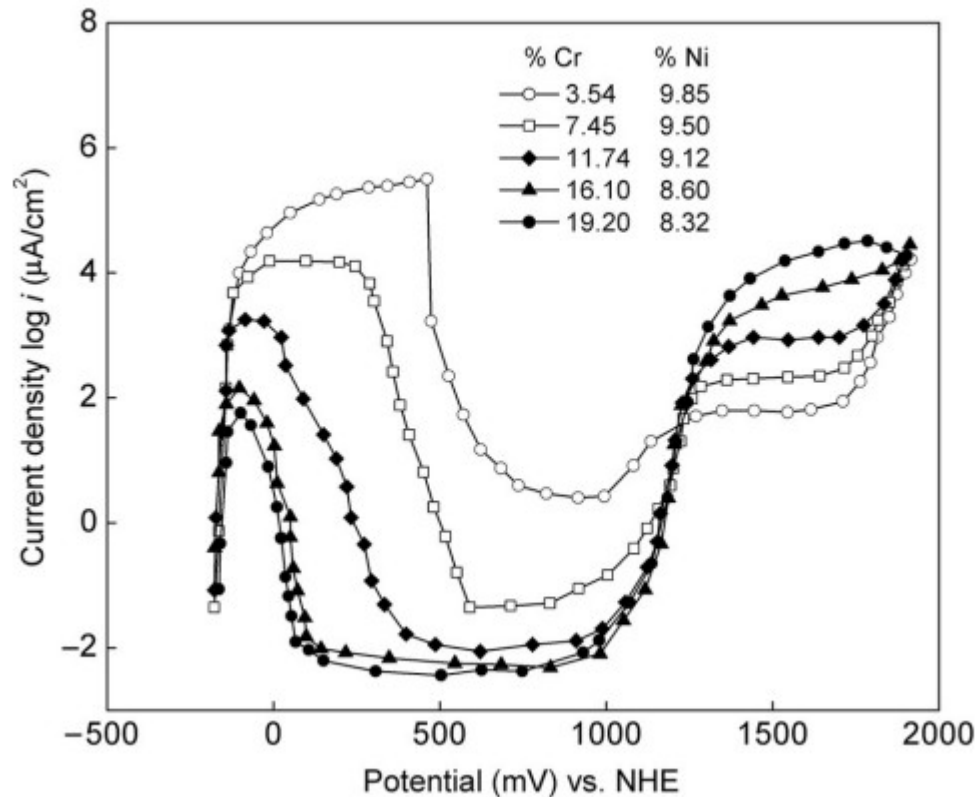

Figure Q5: Anodic Polarization curves for Fe-Cr-Ni alloys with different contents of Cr and Ni.

   a. Of the five alloys which one possess superior anodic polarisation corrosion resistance? Justify your selection. [3]

b. Explain the principle of operation of anodic polarisation corrosion resistance shown in the graph above [6]

c. In what potential range is the passivity obtained by the alloy with 16.10% Chromium? [2]

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d. Why does the alloy have lower corrosion resistance above this range stated in (c)? [3]

e. Why does the alloy have lower corrosion resistance below this range stated in (c)? [3]

f. If the metal is brought to the corrosion resistance potential range in treatment and then later used in lower potential range what happens to its corrosion resistance and why? [4]

g. Why does the order of current densities switch inverse between potentials 500mV and 1500mV? [2]

h. What is the impact of alloying with Ni to the corrosion resistance of Fe? [2]

END OF QUESTION PAPER

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