GWANDA STATE UNIVERSITY

FACULTY OF ENGINEERING AND THE ENVIRONMENT

DEPARTMENT OF METALLURGICAL ENGINEERING

CHEMISTRY FOR METALLURGICAL ENGINEERS

EMG 2103

PART II EXAMINATION PAPER

SEPTEMBER 2024

This examination paper consists of 4 printed pages

Time Allowed: 3 hours

Total Marks: 100

Examiner : Mrs Siqiniselo Maphosa

INSTRUCTIONS

1. Answer any 4 questions

2. Each question carries 25 marks

3. Use of calculators is permissible

QUESTION 1

a) Explain using instrumentation diagram the principles, advantages and disadvantages of the XRF analytical technique in characterising metallurgical samples. [10]

b) Compare and contrast the, principle, advantages and disadvantages of ICP-OES over ICP-AES. [15]

QUESTION 2

a) An engineer is assigned to design an electrochemical cell that will deliver a potential of exactly 1.52 V. Design and sketch a cell to provide this voltage, detailing the solutions, their concentrations, and the electrodes you will need. Write equations for all possible reactions. [10]

b) If alkaline batteries were not alkaline but rather acidic (as in the older dry cell batteries), what extra difficulties could you envision with corrosion, based on reactions that are part of the table of standard reduction potentials? [6]

c) Tin-plated steel is used for "tin" cans. Suppose that in the production of sheets of tin-plated steel, a line at a factory operates at a current of 100.0 A for exactly 8 hours on a continuously fed sheet of unplated steel. If the electrolyte contains tin(II) ions, what is the total mass of tin that has plated out in this operation? [4]

d) Zinc is used as a coating for galvanized steel, where it helps prevent corrosion. Explain using electrochemical data why zinc would also make an acceptable sacrificial anode for a steel pipeline. [5]

QUESTION 3

a) Rank the following in order of increasing strength of intermolecular forces in the pure substances. Which exists as a gas at 25°C and 1 atm? I) $CH_3CH_2CH_2CH_3$ (butane), II) CH_3OH (methanol), III)He [3]

b) Explain from a molecular perspective why graphite has properties that are useful for lubrication. [5]

c) Which member of each of the following pairs of compounds has the higher boiling point? Give a brief explanantion I) O_2 or N_2, II) SO_2 or CO_2, III) HF or HI, IV) SiH_4 or GeH_4 [8]

d) Describe hydrogen bonding giving examples [5]

e) What properties of diamond lead to the most engineering applications? Which types of applications would benefit from these properties? [4]

QUESTION 4

a) Use the kinetic-molecular theory to explain the effect of these factors on the rate of a reaction
   i) Temperature
   ii) Pressure
   iii) Surface area
   iv) Catalyst [12]

b) The reaction of $NO_2(g)$ and $CO(g)$ is thought to occur in two steps:

Step 1: $NO_2(g) + NO_2(g) \rightarrow NO(g) + NO_3(g)$ (slow)

Step 2: $NO_3(g) + CO(g) \rightarrow NO_2(g) + CO_2(g)$ (fast)

   i) Show that the elementary steps add up to give the overall stoichiometric equation. [4]
   ii) What is the molecularity of each step? [3]

c) The label on a bottle of 3% (by volume) hydrogen peroxide, H_2O_2, purchased at a grocery store, states that the solution should be stored in a cool, dark place. H_2O_2 decomposes slowly over time, and the rate of decomposition increases with an increase in temperature and in the presence of light. However, the rate of decomposition increases dramatically if a small amount of powdered MnO_2 is added to the solution. The decomposition products are H_2O and O_2. MnO_2 is not consumed in the reaction.

i) Write the equation for the decomposition of H_2O_2. [2]

ii) What role does MnO_2 play? [1]

iii) In the chemistry lab, a student substituted a chunk of MnO_2 for the powdered compound. The reaction rate was not appreciably increased. What is one possible explanation for this observation? [3]

QUESTION 5

a) Give the electronic arrangement of the Co^{2+} ion. [1]

ii) Explain why complex ions with partially filled d sub-levels are usually coloured.

iii) What is meant by the term co-ordinate bond? [2]

iv) Explain why co-ordinate bonds can be formed between transition metal ions and water molecules.

[3]

v) What name is given to any ligand that can form two co-ordinate bonds to one metal ion? Give an example of such a ligand

[3]

b) When cobalt (II) chloride is treated, under certain conditions, with the bidentate ligand, $NH_2CH_2CH_2NH_2$, (which can be represented by the symbol "en"), the compound **$[CoC1_2(en)_2]Cl$** is formed.

i) What is the oxidation state of cobalt in the compound formed? [2]

ii) What is meant by the term bidentate as applied to a ligand? [2]

iii) What is the co-ordination number of cobalt in this compound? [2]

iv) When this compound is treated with aqueous silver nitrate, only one mole of silver chloride is produced per mole of compound. Explain this observation

[3]

v) When titanium dissolves in concentrated hydrochloric acid, the violet **$[Ti(H_2O)_4Cl_2]^+$** ion is formed. Deduce the oxidation state and co-ordination number of titanium in this ion. [5]

c) Give the name of a naturally-occurring complex compound which contains iron [2]