MACHAKOS UNIVERSITY

University Examinations 2022/2023 Academic year

SCHOOL OF PURE AND APPLIED SCIENCES

DEPARTMENT OF PHYSICAL SCIENCES

FIRST YEAR SECOND SEMESTER EXAMINATION FOR

BACHELOR OF SCIENCE (ELECTRICAL AND ELECTRONICS ENGINEERING)

BACHELOR OF SCIENCE (MECHANICAL ENGINEERING)

BACHELOR OF SCIENCE (CIVIL ENGINEERING)

ECU 102/123: CHEMISTRY FOR ENGINEERS II

DATE: 13/4/2023 **TIME: 8:30 – 10:30 AM**

INSTRUCTIONS:

- The paper consists of **two** sections.
- Section **A** is **compulsory** (30 marks).
- Answer any **two** questions from section **B** (each 20 marks).

SECTION A

QUESTION ONE (30 MARKS)

a) Write the rate laws for the following elementary reactions.

i) $CH_3CN_{(g)} \rightarrow CH_3CN_{(g)}$ (1 mark)

ii) $O_{3(g)} + NO_{(g)} \rightarrow O_{2(g)} + NO_2(g)$ (1 mark)

b) Calculate the boiling point elevation for a 0.750 m solution of $C_6H_{12}O_6$ in water assuming that fructose is non-volatile and non-ionic. The boiling point elevation constant for water is 0.582°C/m. (3 marks)

c) The rate constant of a zero order reaction is $1.2 \times 10^{-3} mol\ l^{-1} s^{-1}$. Calculate the half-life of the reaction if the initial concentration of the reactant is $1.2 \times 10^{-2} mol\ l.^{-1}$ (4 marks)

d) Explain the following.

i) Why is the probability of a reaction with molecularity higher than three rare? (1 mark)

ii) Why does the rate of any reaction generally decrease during the course of the reaction? (1 mark)

e) Most gases obey Henry's law with a few exceptions. Highlight two such exceptions. . (2 marks)

f) The equilibrium concentrations for the reaction between carbon (II) oxide and molecular chlorine to form $COCl_2$ gas at 74°C are [CO] =0.012 M, $[Cl_2]$=0.054 M and $[COCl_2]$=0.14 M. Calculate the equilibrium constants K_c and K_p for the following reaction (4 marks)

$CO_{(g)} + Cl_{2\,(g)} \leftrightharpoons COCl_{2\,(g)}$

g) The following elementary steps are proposed for a reaction mechanism.

Step 1: $\boldsymbol{NO_2Cl_{(g)} \rightarrow NO_{2(g)} + Cl_{(g)}}$

Step 2: $\boldsymbol{NO_2Cl_{(g)} + Cl_{(g)} \rightarrow NO_{2(g)} + Cl_{2(g)}}$

i) Write the overall balanced equation. (1 mark)

ii) Determine the molecularity of each step. (2 marks)

h) The solubility of pure nitrogen gas at 25°C and 1 atm pressure is 6.5×10^{-4} mol/L. The partial pressure of nitrogen gas in the atmosphere is 0.78 atmospheres. Calculate the concentration of nitrogen dissolved in water under these atmospheric conditions? (3 marks)

i) The volume of oxygen gas generated by the decomposition of potassium chlorate at 24°C ,762 mmHg is 124 mL . Calculate the mass (in grams) of oxygen gas obtained given that the pressure of water vapour at 24°C is 22.4 mmHg. (4 marks)

j) Calculate the pH of 0.02 M barium hydroxide solution. (3 marks)

SECTION B

QUESTION TWO (20 MARKS)

a) A solution containing 6.64 g of non-ionic solute in 171 grams of water freezes at -1.204°C. Calculate the molar mass of the solute given the freezing point depression constant of water is 1.86°C/m. (6 marks)

b) The equilibrium constant for the reaction given below is 178 at 1000 k.

$2NO_{2\,(g)} \rightleftharpoons 2NO_{(g)} + O_{2(g)}$. Calculate the equilibrium pressure of oxygen if P_{NO}=0.420 atm and PNO_2=0.280 atm? (4 marks)

c) The initial concentrations of H_2, I_2 and HI in a 1.0 L stainless-steel flask at 430°C were 0.00623 M, 0.00414 M and 0.0224 M respectively. The equilibrium constant K_c for the reaction $H_{2(g)} + I_{2(g)} \rightleftharpoons 2HI_{(g)}$ is 54.3 at this temperature. Calculate the concentrations of H_2, I_2 and HI at equilibrium. (6 marks)

d) Explain how a weak base and its conjugate acid form a buffer solution. (4 marks)

QUESTION THREE (20 MARKS)

a) Consider the following equilibrium process

$N_2F_{4(g)} \rightleftharpoons 2NF_{2(g)} \qquad \Delta H^O = +38.5\ kJ$

Predict the changes in equilibrium if

i. The reacting mixture is heated at constant volume. (2 marks)

ii. NF_2 is removed from reacting mixture at constant temperature and volume. (2 marks)

iii. Helium is added to the reacting mixture at constant temperature and volume. (2 marks)

b) The solubility of CuBr is 2.0×10^{-4} mol/L at 25°C. Calculate the K_{sp} value of CuBr. (5 marks)

c) The vapor pressure of ethyl alcohol at a certain temperature is 97.3 torr. Calculate;

i) The vapor pressure of the ethyl alcohol in solution at constant temperature if 0.185 moles of glucose is dissolved in 0.929 moles of ethyl alcohol. (3 marks)

ii) The vapor pressure lowering of alcohol. (2 marks)

d) Discuss why vapor pressure of a solution is less than that of a pure solvent. (4 marks)

QUESTION FOUR (20 MARKS)

a) At 60°C the following reaction was observed to be first order and proceeds to completion. $A_{(g)} \rightarrow B_{(g)} + 2C_{(g)}$. When a pure compound, A is decomposed into an empty vessel, it is found that at the end of 10 minutes, the total pressure of the system is 180 torr and 300 torr after a very long time. Calculate

i) The initial pressure of A. (5 marks)

ii) Pressure of A after 10 minutes. (3 marks)

iii) Rate constant. (3 marks)

iv) Half-life of the reaction. (1 mark)

b) Given the following mechanism

Step 1	$2NO \rightarrow N_2O_2$	
Step 2	$N_2O_2 + H_2 \rightarrow N_2O + H_2O$	slow
Step 3	$N_2O + H_2 \rightarrow N_2 + H_2O$	

i) Determine the equation for the overall reaction. (2 marks)

ii) Identify the intermediates in this reaction. (2 marks)

iii) Determine the rate law using pre-equilibrium approach. (3 marks)

iv) State the overall order of the reaction. (1 mark)

QUESTION FIVE (20 MARKS)

a) Given that 3.80 moles of ammonia occupy 5.40 L at 47°C. Calculate the pressure of the gas in atmosphere using

i) The ideal gas equation. (2 marks)

ii) The van der waals equation. (van der waals constants for ammonia, a=4.17 atm.L^2/mol^2 and b=0.0371 L/mol) (4 marks)

b) Under what conditions will real gas exhibit non-ideal behaviour. Provide a test for ideal gas behaviour (3 marks)

c) Iodine atoms combine to form molecular iodine in the gas phase according to the equation, $I_{(g)} + I_{(g)} \longrightarrow I_2$. The reaction follows second order kinetics and has a high-rate constant of $7.0 \times \frac{10^9}{m.s}$ at 23^0 C.

i) If the initial concentration of iodine was 0.086 M, calculate the concentration after three minutes. (3 marks)

ii) Calculate the half-life of the reaction if the initial concentration of iodine is 0.600 M. (2 marks)

d) Calculate the pH after 0.0300 mol of solid NaOH is added to 1.000 L of a solution containing 0.150 mol of $HC_2H_3O_2$ and 0.195 mol of $NaC_2H_3O_2$. Assume that the volume of the solution does not change. (6 marks)