Strathmore
UNIVERSITY

SCHOOL OF COMPUTING AND ENGINEERING SCIENCES

BSC (ELECTRICAL AND ELECTRONIC ENGINEERING)

END OF SEMESTER EXAMINATION

CHE 1101 CHEMISTRY I

DATE: 13th October 2023 Time: 2.5 Hours

Instructions

1. This examination consists of **FIVE** questions.
2. Your answers should be a minimum of four decimal places
3. Answer **Question ONE (COMPULSORY)** and any other **TWO** questions.

Question One

a) Obtain the electron configuration for (i) Nb, element number 41; (ii) Pr, element number 59. **(4mrks)**

b) According to Bohr's theory, two of the allowed orbits in the hydrogen atom have radii of 62.918 and 121.67 pm. Calculate the energy, the frequency, and the wavelength of the photon emitted when the electron moves from the outer to the inner of these two orbits. **(4mrks)**

c) A 0.4550 grams solid mixture containing $CaSO_4$ is dissolved in water and treated with an excess of $Ba(NO_3)_2$, resulting in the precipitation of 0.6168 grams of $BaSO_4$.

$$CaSO_{4\,(aq)} + Ba(NO_3)_2\,(aq) \longrightarrow BaSO_{4(s)} + Ca(NO_3)_{2\,(aq)}$$

What is the concentration (percent) of $CaSO_4$ in the mixture? **(4mrks)**

d) Measurements of the conductivities of acetic acid solutions indicate that the fraction of acetic acid molecules converted to acetate and hydronium ions is

0.0296 at a concentration of 0.02 mol dm^{-3}. Calculate the equilibrium constant for this concentration given the reaction below; **(4mrks)**

$$CH_3COOH(aq) + H_2O(l) \rightleftharpoons CH_3COO^-(aq) + H_3O^+(aq)$$

e) Use the data in Table 1 on the Internal Energy of the system to find ΔH for the reaction below, at 25°C, 1 bar. **(4mrks)**

$$2O_3\,(g) \longrightarrow 3O_2\,(g)$$

TABLE 1 Detailed Balance Sheet of the Energy Changes Occurring in the Reaction $2O_3(g) \rightarrow 3O_2(g)$ 25°C, constant volume

Type of Energy	Initial Value/kJ	Final Value/kJ	Change*in Energy/kJ
Electronic	x†	x – 290.70	–290.70
Translational	7.43	11.15	+3.72
Rotational and vibrational	8.32	7.44	– 0.88
Total	**x + 15.75**	**x – 272.11**	**–287.86**

f) Compute the vapor pressure of an ideal solution containing 92.1g of glycerine, $C_3H_5(OH)_3$, and 184.4g of ethanol, C_2H_5OH, at 40^0C. The vapor pressure of pure ethanol is 0.178 atm at 40^0C. Glycerine is essentially non-volatile at this temperature. **(4mrks)**

g) Consider a general reaction in which the reactants "A" and "B" form products "C" and "D" according to the equation given below. Assuming "k_f" and "k_b" have comparable values, and supposing that "a" is the initial concentration of both the reactants "A" and "B" and "x" is the decrease in the concentrations of both reactants after "t" time, derive and explain the rate law depending upon both constants "k_f" and "k_b" noting that the second order reaction, is opposed by a second order reaction **(4mrks)**

$$A + B \underset{k_b}{\overset{k_f}{\rightleftharpoons}} C + D$$

h) State and explain, using equations, the second law and third law of chemical thermodynamics **(2mrks)**

Question Two (15mrks)

a) A 0.5L sample of an aqueous solution containing 10g of haemoglobin has an osmotic pressure of 5.9 torr at 22^0C. Assuming ideal solution behaviour, what is the molar mass of haemoglobin? **(7mrks)**

b) Write a balanced equation for the reaction hydrogen peroxide and iron (II) to yield iron (III) and water in acidic solution, providing all the seven steps of your ionic equation balancing process and justify/ confirm that the final equation is actually balanced **(8mrks)**

$$H_2O_2(aq) + Fe^{2+} \longrightarrow H_2O(l) + Fe^{3+}$$

Question Three (15mrks)

a) The Equilibrium constant K_c for the dissociation of dinitrogen tetroxide according to the equation shown below, changes from a very small to a very large value as the temperature is increased, as shown in the table. Calculate the fraction of N_2O_4 dissociated at each temperature, if 1.5 mol N_2O_4 is sealed in a container of volume 5.0 dm^3. **(9mrks)**

$$N_2O_4(g) \rightleftharpoons 2NO_2(g)$$

Temperature in Kelvin	K_c in (mol x dm^{-3})
250	$1.5x10^{-6}$
450	1.6
650	$1.775x10^{3}$

b) Consider the decomposition of yellow mercury (II) oxide, shown in the following equation. Calculate the standard free energy change at room temperature, ΔG°, using;

i. Standard free energies of formation **(2mrks)**

ii. Standard enthalpies of formation and standard entropies **(3mrks)**

iii. Do the results indicate the reaction to be spontaneous or nonspontaneous under standard conditions? **(1mrks)**

$$HgO(s,\ \text{yellow}) \longrightarrow Hg(l) + \frac{1}{2}O_2(g)$$

Compound	ΔG_f° (kJ/mol)	ΔH_f° (kJ/mol)	S° (J/K·mol)
HgO (*s*, yellow)	−58.43	−90.46	71.13
Hg(*l*)	0	0	75.9
$O_2(g)$	0	0	205.2

Question Four (15mrks)

Derive the Schrodinger Wave Equation from either the postulates of quantum mechanics or from the classical wave equation, and explain the significance of the derived equation in solving problems that concern spectrochemistry/ dual particle – wave nature of matter. **(15mrks)**

Question Five (15mrks)

a) Acetate buffers are used in biochemical studies of enzymes and other chemical components of cells to prevent pH changes that might affect the biochemical activity of these compounds

i. Calculate the pH of an acetate buffer that is a mixture with 0.15M acetic acid and 0.15M sodium acetate.
(3mrks)

ii. Determine the pH after 1.5 mL of 0.15 NaOH is added to 110 mL of this buffer. **(3mrks)**

iii. For comparison, calculate the pH after 1.5 mL of 0.15M NaOH is added to 110 mL of a solution of an unbuffered solution with a pH of 4.74 **(3mrks)**

b) Consider a general reaction in which the reactant "A" forms product "B" according to the equation given below. Assuming "k_f" and "k_b" have comparable values, and supposing that "a" is the initial concentration of the reactant A and "x" is the decrease in the concentration of A after "t" time, derive and explain the rate law depending upon both constants "k_f" and "k_b" noting that the first order reaction, is opposed by a first order reaction **(6mrks)**

$$A \underset{k_b}{\overset{k_f}{\rightleftharpoons}} B$$