BINDURA UNIVERSITY OF SCIENCE EDUCATION

FACULTY OF SCIENCE AND ENGINEERING

CHEMISTRY DEPARTMENT

PROGRAM: MASTER OF SCIENCE EDUCATION DEGREE JAN 2025

COURSE: **MCH 501 PHYSICAL CHEMISTRY 5**

DURATION: **3HRS**

ANSWER ANY FOUR (4) QUESTIONS. EACH QUESTIONS CARRIES 25 MARKS.

1. (a) What are **extensive** and **intensive** properties, also give one example of each? **4 marks**

   (b) Classify the following processes as spontaneous or non-spontaneous and explain your answer.
   (i) The reversible isothermal expansion of an ideal gas.
   (ii) The vaporization of superheated water at 102ºC and 1 bar.
   (iii) The constant pressure melting of ice at its normal freezing point by the addition of an infinitesimal quantity of heat.
   (iv) The adiabatic expansion of a gas into a vacuum. **4 marks**

   (c) Derive the Michaelis Menten equation. **10 marks**

   (d) In the unimolecular isomerization of cyclobutane to butylene, the following values for k_{uni} as a function of cyclobutane pressure were measured:

P_0 (Torr)	110	210	390	760
k_{uni} (s^{-1})	9.58	10.3	10.8	11.1

   Assuming that the Lindemann mechanism accurately describes this reaction, determine k_1 and the ratio k_{-1}/k_2. **7 marks**

2. (a) Derive the work done in an isothermal process **10 marks.**

   (b) Determine the half-cell reactions and the overall cell reaction, calculate the cell potential, and determine the equilibrium constant at 298.15 K for the cell

$$\mathrm{Cu}(s)\left|\mathrm{Cu}^{2+}\left(aq, a_{Cu^{2+}}=0.0150\right)\right\|\mathrm{H}^{+}\left(aq, a_{H^{+}}=0.100\right)\left|\mathrm{H}_2(g)\right|\mathrm{Pt}(s).$$

   Is the cell reaction spontaneous as written? **15 marks**

3. (a) One mole of N_2 at 20.5ºC and 6.00 bar undergoes a transformation to the state described by 145ºC and 2.75 bar. Calculate ΔS if

$$\frac{C_{P,m}}{\mathrm{J\,mol^{-1}\,K^{-1}}} = 30.81 - 11.87\times10^{-3}\frac{T}{\mathrm{K}} + 2.3968\times10^{-5}\frac{T^2}{\mathrm{K^2}} - 1.0176\times10^{-8}\frac{T^3}{\mathrm{K^3}}.$$

15 marks

(b) Calculate ΔS if the temperature of 1 mol of an ideal gas with $C_V = 3/2R$ is increased from 150 to 350 K under conditions of (i) constant pressure and (ii) constant volume. **10 marks**

4. (a) Define the terms "entropy" and "enthalpy" and explain their relationship to the second law of thermodynamics. **4 marks**

(b) A chemical reaction has a ΔH° of -150 kJ and a ΔS° of 200 J/K. Calculate the temperature at which the reaction becomes spontaneous. **3 marks**

(c) The rate of consumption of B in the reaction A +3B →C+2D is 1.0 mol dm^{-3} s^{-1}. State the reaction rate, and the rates of formation or consumption of A, C, and D. **4 marks**

(d) Write brief notes on the Steady-state approximation. **4 marks**

(e) Define the following terms:

(i) Isocratic conditions
(ii) State-function
(iii) Junction-potential
(iv) Exergonic reactions
(v) Endergonic reaction. **10 marks**

5. (a) In a branching reaction in which two products can be formed from the same reactant, what determines the extent to which one product will be formed over another? **3 marks**

(b) What is the overall order of the reaction corresponding to the following rate constants: **2 marks**

(c) The growth of a bacterial colony can be modeled as a first-order process in which the probability of cell division is linear with respect to time such that, $\frac{dN}{N} = \zeta dt$, where dN is the number of cells that divide in the time interval dt, and ζ is a constant.

(i) Use the preceding expression to show that the number of cells in the colony is given by $N = N_0 e^{\zeta t}$, where N is the number of cell colonies and N_0 is the number of colonies present at $t = 0$. **5 marks**

(ii) The generation time is the amount of time it takes for the number of cells to double. Using the answer to part (i), derive an expression for the generation time.

5 marks

(iii) In milk at 37°C, the bacteria lactobacillus acidophilus has a generation time of about 75 min.

Construct a plot of the acidophilus concentration as a function of time for time intervals of 15, 30, 45, 60, 90, 120, and 150 minutes after a colony of size N_0 is introduced to a container of milk.

10 marks

END OF PAPER