Chemistry Practice Questions: Chemical Equilibrium

Question 1

(a) Distinguish between a homogeneous equilibrium and a heterogeneous equilibrium. (2 marks)

(b) A sample of 3.00 g of N_2O_4 gas is placed in a closed 2.0 dm3 vessel at 25°C and allowed to reach equilibrium according to the equation: N2O4(g) ⇄ 2NO2(g). If Kc for the reaction at this temperature is 4.66 × 10-3 M, calculate:

1. The equilibrium concentrations of N2O4 and NO2.
2. The percentage dissociation of N2O4 at equilibrium. (6 marks)

(c) The reaction 2SO2(g) + O2(g) ⇄ 2SO3(g) has an equilibrium constant Kc = 4.3 × 106 at 700 K. What is the value of Kc for the reaction SO3(g) ⇄ SO2(g) + ½O2(g) at the same temperature? (3 marks)

(d) Given the following equilibrium constants at 1000 K:

3. C(s) + CO2(g) ⇄ 2CO(g) ; Kc1 = 1.9 × 10-2
4. C(s) + H2O(g) ⇄ CO(g) + H2(g) ; Kc2 = 1.6 × 10-1

Calculate the equilibrium constant Kc for the reaction: CO(g) + H2O(g) ⇄ CO2(g) + H2(g). (4 marks)

Question 2

(a) Explain the difference between the reaction quotient (Qc) and the equilibrium constant (Kc). (2 marks)

(b) 5.00 g of pure HI gas is introduced into an evacuated 1.5 dm3 flask at 448°C. The system reaches equilibrium: 2HI(g) ⇄ H2(g) + I2(g). Given that Kc = 0.020 at this temperature, calculate:

1. The equilibrium concentrations of HI, H2, and I2.
2. The percentage dissociation of HI. (6 marks)

(c) For the reaction N2(g) + 3H2(g) ⇄ 2NH3(g), Kc = 0.50 at 400°C. Find the value of Kc for the reaction ⅓N2(g) + H2(g) ⇄ ⅔NH3(g). (3 marks)

(d) If H2(g) + Br2(g) ⇄ 2HBr(g) has Kc1 = 4.0 × 1018 and H2(g) ⇄ 2H(g) has Kc2 = 2.0 × 10-10, determine the equilibrium constant for the reaction: 2H(g) + Br2(g) ⇄ 2HBr(g). (4 marks)

Question 3

(a) Define Le Chatelier's principle and state how a catalyst affects the equilibrium constant. (2 marks)

(b) 4.2 g of COCl2 (phosgene) gas is enclosed in a 0.5 dm3 flask and heated to 500 K. It dissociates as: COCl2(g) ⇄ CO(g) + Cl2(g). If Kc = 8.0 × 10-4 M at this temperature, calculate:

1. The concentration of each component at equilibrium.
2. The percentage dissociation of phosgene. (6 marks)

(c) The reaction PCl5(g) ⇄ PCl3(g) + Cl2(g) has Kc = 0.040 M at 250°C. What is Kc for the reaction 2PCl3(g) + 2Cl2(g) ⇄ 2PCl5(g)? (3 marks)

(d) Given the following reactions at 298 K:

3. N2(g) + O2(g) ⇄ 2NO(g) ; Kc1 = 4.3 × 10-31
4. 2NO2(g) ⇄ 2NO(g) + O2(g) ; Kc2 = 6.4 × 10-13

Find Kc for the net reaction: N2(g) + 2O2(g) ⇄ 2NO2(g). (4 marks)

Question 4

(a) Under what conditions do the numerical values of Kp and Kc become identical? Explain. (2 marks)

(b) 1.50 g of solid ammonium carbamate, NH4CO2NH2, is introduced into an empty 2.0 dm3 flask at 25°C. It completely vaporizes and establishes equilibrium: NH4CO2NH2(s) ⇄ 2NH3(g) + CO2(g). If the equilibrium constant Kc = 3.2 × 10-5 M3, calculate:

1. The equilibrium concentrations of NH3(g) and CO2(g).
2. The mass of solid ammonium carbamate that decomposed. (6 marks)

(c) For the system 2NOCl(g) ⇄ 2NO(g) + Cl2(g), the value of Kc is 3.8 × 10-6 at 400 K. Calculate Kc for the reaction NO(g) + ½Cl2(g) ⇄ NOCl(g). (3 marks)

(d) If 2C(s) + O2(g) ⇄ 2CO(g) has Kc1 = 1.3 × 1014 and C(s) + O2(g) ⇄ CO2(g) has Kc2 = 2.5 × 1021, determine Kc for: 2CO(g) + O2(g) ⇄ 2CO2(g). (4 marks)

Question 5

(a) Differentiate between dynamic equilibrium and static equilibrium using appropriate chemical contexts. (2 marks)

(b) A 1.0 dm3 vessel initially contains 3.20 g of N2O3 gas at a given temperature. The gas dissociates as follows: N2O3(g) ⇄ NO(g) + NO2(g). Given that the equilibrium constant Kc = 0.015 M, calculate:

1. The equilibrium concentrations of all three gaseous species.

2. The degree of dissociation (α) of N_2O_3. (6 marks)

(c) The equilibrium constant Kc for the reaction $H_2(g) + CO_2(g) \rightleftarrows H_2O(g) + CO(g)$ is 1.60 at 990°C. What is Kc for the reaction $2H_2O(g) + 2CO(g) \rightleftarrows 2H_2(g) + 2CO_2(g)$? (3 marks)

(d) Given:

3. $2H_2(g) + O_2(g) \rightleftarrows 2H_2O(g)$; $K_{c1} = 5.4 \times 1040$
4. $N_2(g) + 3H_2(g) \rightleftarrows 2NH_3(g)$; $K_{c2} = 6.0 \times 102$

Calculate Kc for the oxidation of ammonia: $4NH_3(g) + 3O_2(g) \rightleftarrows 2N_2(g) + 6H_2O(g)$. (4 marks)

Question 6

(a) Explain why the concentrations of pure solids and pure liquids are omitted from the equilibrium constant expression. (2 marks)

(b) Exactly 10.0 g of $SbCl_5$ is placed in a 5.0 dm^3 reaction chamber at 200°C and decomposes via: $SbCl_5(g) \rightleftarrows SbCl_3(g) + Cl_2(g)$. If $K_c = 2.5 \times 10\text{-}3$ M at this temperature, find:

1. The equilibrium concentration of each gas.
2. The percentage dissociation of $SbCl_5$. (6 marks)

(c) At 500 K, the reaction $2NO(g) + Cl_2(g) \rightleftarrows 2NOCl(g)$ has $K_c = 5.2 \times 104$. Compute Kc for $NOCl(g) \rightleftarrows NO(g) + \frac{1}{2}Cl_2(g)$. (3 marks)

(d) Consider the following systems at 400°C:

3. $H_2(g) + S(s) \rightleftarrows H_2S(g)$; $K_{c1} = 6.8 \times 10\text{-}2$
4. $H_2(g) + Se(s) \rightleftarrows H_2Se(g)$; $K_{c2} = 1.1 \times 10\text{-}3$

Determine the equilibrium constant Kc for the displacement reaction: $H_2S(g) + Se(s) \rightleftarrows H_2Se(g) + S(s)$. (4 marks)

Question 7

(a) State the relationship connecting Kp and Kc, defining all terms and their units. (2 marks)

(b) In a 1.0 dm^3 flask, 4.0 g of PCl_3 and 3.0 g of Cl_2 are combined at a high temperature to establish the equilibrium: $PCl_3(g) + Cl_2(g) \rightleftarrows PCl_5(g)$. If $K_c = 0.12$ M^{-1} at this temperature, compute:

1. The equilibrium concentrations of all reactants and products.
2. The percentage of Cl_2 gas that reacted. (6 marks)

(c) The reaction $N_2O(g) + \frac{1}{2}O_2(g) \rightleftarrows 2NO(g)$ has $K_c = 1.4 \times 10\text{-}11$. What is the value of Kc for $4NO(g) \rightleftarrows 2N_2O(g) + O_2(g)$? (3 marks)

(d) Given the following data:

3. $Fe_2O_3(s) + 3CO(g) \rightleftarrows 2Fe(s) + 3CO_2(g)$; $K_{c1} = 24.2$
4. $FeO(s) + CO(g) \rightleftarrows Fe(s) + CO_2(g)$; $K_{c2} = 0.35$

Calculate Kc for the reaction: $Fe_2O_3(s) + CO(g) \rightleftarrows 2FeO(s) + CO_2(g)$. (4 marks)

Question 8

(a) How does an increase in total pressure affect the position of equilibrium for a reaction where $\Delta n_g = 0$? Give a reason. (2 marks)

(b) 2.50 g of pure nitrosyl bromide (NOBr) is heated to 100°C in a 1.0 dm^3 flask. It dissociates according to the equation: $2NOBr(g) \rightleftarrows 2NO(g) + Br_2(g)$. If the equilibrium constant $K_c = 1.2 \times 10\text{-}2$ M, calculate:

1. The concentrations of NOBr, NO, and Br_2 at equilibrium.
2. The percentage dissociation of NOBr. (6 marks)

(c) For the equilibrium $CH_4(g) + H_2O(g) \rightleftarrows CO(g) + 3H_2(g)$, $K_c = 0.024$ at 800 K. What is Kc for the reaction $\frac{1}{2}CO(g) + \frac{3}{2}H_2(g) \rightleftarrows \frac{1}{2}CH_4(g) + \frac{1}{2}H_2O(g)$? (3 marks)

(d) If $2NO(g) \rightleftarrows N_2(g) + O_2(g)$ has $K_{c1} = 2.4 \times 1030$ and $2NO(g) + O_2(g) \rightleftarrows 2NO_2(g)$ has $K_{c2} = 1.8 \times 1012$, find Kc for: $N_2(g) + 2O_2(g) \rightleftarrows 2NO_2(g)$. (4 marks)

Question 9

(a) Explain what is meant by 'equilibrium is dynamic in nature' at the molecular level. (2 marks)

(b) A 2.5 dm^3 reaction vessel is filled with 5.00 g of H_2S gas at 800°C. The gas decomposes as: $2H_2S(g) \rightleftarrows 2H_2(g) + S_2(g)$. If $K_c = 1.6 \times 10\text{-}4$ M at this temperature, determine:

1. The equilibrium concentrations of H_2S, H_2, and S_2.
2. The degree of dissociation of H_2S. (6 marks)

(c) For the synthesis of methanol, $CO(g) + 2H_2(g) \rightleftarrows CH_3OH(g)$, $K_c = 10.5$ at 200°C. Find Kc for $2CH_3OH(g) \rightleftarrows 2CO(g) + 4H_2(g)$. (3 marks)

(d) Given the following equilibria:

3. $2CO_2(g) \rightleftarrows 2CO(g) + O_2(g)$; $K_{c1} = 5.6 \times 10^{-23}$
4. $2H_2O(g) \rightleftarrows 2H_2(g) + O_2(g)$; $K_{c2} = 4.2 \times 10^{-25}$

Calculate K_c for the water-gas shift reaction: $CO(g) + H_2O(g) \rightleftarrows CO_2(g) + H_2(g)$. (4 marks)

Question 10

(a) State two characteristics of a chemical system at equilibrium. (2 marks)

(b) 6.0 g of carbon dioxide gas and excess solid carbon are sealed in a 4.0 dm^3 flask at 1000 K to establish the system: $C(s) + CO_2(g) \rightleftarrows 2CO(g)$. If $K_c = 0.014$ M at this temperature, calculate:

1. The equilibrium concentrations of CO_2 and CO.
2. The percentage of CO_2 that converted into CO. (6 marks)

(c) The reaction $2O_3(g) \rightleftarrows 3O_2(g)$ has $K_c = 2.6 \times 10^{12}$ at 500 K. Calculate K_c for the reaction $3/2O_2(g) \rightleftarrows O_3(g)$. (3 marks)

(d) If $S(s) + O_2(g) \rightleftarrows SO_2(g)$ has $K_{c1} = 4.2 \times 1052$ and $2S(s) + 3O_2(g) \rightleftarrows 2SO_3(g)$ has $K_{c2} = 1.6 \times 1085$, find K_c for the reaction: $2SO_2(g) + O_2(g) \rightleftarrows 2SO_3(g)$. (4 marks)

Question 11

(a) How does an increase in temperature affect the equilibrium constant (K_c) of an exothermic reaction? Explain using thermodynamics. (2 marks)

(b) A 3.0 dm^3 flask contains 2.00 g of Cl_2O_7 gas which decomposes at a specific temperature according to the equation: $2Cl_2O_7(g) \rightleftarrows 2Cl_2(g) + 7O_2(g)$. If the equilibrium constant $K_c = 5.0 \times 10^{-5}$ M^7, calculate:

1. The concentrations of all species at equilibrium.
2. The percentage dissociation of Cl_2O_7. (6 marks)

(c) For $2NO_2(g) \rightleftarrows 2NO(g) + O_2(g)$, $K_c = 1.8 \times 10^{-6}$ at 600 K. What is K_c for $NO(g) + \frac{1}{2}O_2(g) \rightleftarrows NO_2(g)$? (3 marks)

(d) Given:

3. $H_2(g) + I_2(g) \rightleftarrows 2HI(g)$; $K_{c1} = 54.0$
4. $2I(g) \rightleftarrows I_2(g)$; $K_{c2} = 2.1 \times 103$

Compute K_c for the reaction: $H_2(g) + 2I(g) \rightleftarrows 2HI(g)$. (4 marks)

Question 12

(a) Distinguish between the terms 'dissociation' and 'equilibrium conversion'. (2 marks)

(b) 8.50 g of ammonia (NH_3) gas is introduced into an evacuated 5.0 dm^3 vessel and allowed to dissociate at 450°C: $2NH_3(g) \rightleftarrows N_2(g) + 3H_2(g)$. If $K_c = 0.15$ M^2, find:

1. The equilibrium concentration of each gas.
2. The percentage dissociation of ammonia. (6 marks)

(c) The reaction $N_2(g) + O_2(g) \rightleftarrows 2NO(g)$ has $K_c = 0.10$ at 2000°C. What is K_c for $\frac{1}{2}N_2(g) + \frac{1}{2}O_2(g) \rightleftarrows NO(g)$? (3 marks)

(d) Given the following processes:

3. $2P(s) + 3Cl_2(g) \rightleftarrows 2PCl_3(g)$; $K_{c1} = 3.2 \times 105$
4. $2P(s) + 5Cl_2(g) \rightleftarrows 2PCl_5(g)$; $K_{c2} = 1.4 \times 109$

Calculate K_c for: $PCl_3(g) + Cl_2(g) \rightleftarrows PCl_5(g)$. (4 marks)

Question 13

(a) Why does changing the volume of a container alter the equilibrium position but leave the equilibrium constant unchanged? (2 marks)

(b) 4.00 g of carbonyl fluoride (COF_2) gas is allowed to come to equilibrium in a 1.0 dm^3 container at 1000 K: $2COF_2(g) \rightleftarrows CO_2(g) + CF_4(g)$. If $K_c = 2.0 \times 10^{-2}$, determine:

1. The equilibrium concentrations of all three gases.
2. The percentage dissociation of COF_2. (6 marks)

(c) If K_c for $2C_2H_6(g) + 7O_2(g) \rightleftarrows 4CO_2(g) + 6H_2O(g)$ is 1.2×1020, what is K_c for $2CO_2(g) + 3H_2O(g) \rightleftarrows C_2H_6(g) + 7/2O_2(g)$? (3 marks)

(d) From the following information at 298 K:

3. $Cu^{2+}(aq) + 2Cl^-(aq) \rightleftarrows CuCl_2(aq)$; $K_{c1} = 4.5 \times 104$
4. $CuCl_2(aq) + 2Cl^-(aq) \rightleftarrows CuCl_4^{2-}(aq)$; $K_{c2} = 1.2 \times 102$

Calculate K_c for the overall reaction: $Cu^{2+}(aq) + 4Cl^-(aq) \rightleftarrows CuCl_4^{2-}(aq)$. (4 marks)

Question 14

(a) Define the term 'degree of dissociation' and state how it changes with dilution for a gaseous system where $\Delta ng > 0$. (2 marks)

(b) A 2.0 dm3 reaction vessel is filled with 3.50 g of ICl gas at a high temperature. It reaches equilibrium according to: $2ICl(g) \rightleftarrows I2(g) + Cl2(g)$. If Kc = 0.11, find:

1. The concentration of ICl, I2, and Cl2 at equilibrium.
2. The percentage dissociation of ICl. (6 marks)

(c) For $3O2(g) \rightleftarrows 2O3(g)$, Kc = 4.8 × 10-4 at a given temperature. Calculate Kc for $O3(g) \rightleftarrows 3/2O2(g)$. (3 marks)

(d) Given:

3. $Mg(s) + 2H+(aq) \rightleftarrows Mg2+(aq) + H2(g)$; Kc1 = 2.5 × 107
4. $H2O(l) \rightleftarrows H+(aq) + OH-(aq)$; Kc2 = 1.0 × 10-14

Find Kc for: $Mg(s) + 2H2O(l) \rightleftarrows Mg2+(aq) + 2OH-(aq) + H2(g)$. (4 marks)

Question 15

(a) Under what conditions can an equilibrium reaction go to completion? Explain briefly. (2 marks)

(b) 1.80 g of water vapor is sealed in a 0.50 dm3 vessel and heated to 2000 K, where it partly decomposes: $2H2O(g) \rightleftarrows 2H2(g) + O2(g)$. Given that Kc = 1.1 × 10-7 M, calculate:

1. The equilibrium concentrations of H2O, H2, and O2.
2. The percentage dissociation of water vapor. (6 marks)

(c) The reaction $N2O4(g) \rightleftarrows 2NO2(g)$ has Kc = 0.36. What is Kc for the reaction $4NO2(g) \rightleftarrows 2N2O4(g)$? (3 marks)

(d) Given:

3. $CaCO3(s) \rightleftarrows CaO(s) + CO2(g)$; Kc1 = 1.4 × 10-3
4. $C(s) + CO2(g) \rightleftarrows 2CO(g)$; Kc2 = 5.8 × 10-2

Calculate Kc for: $CaCO3(s) + C(s) \rightleftarrows CaO(s) + 2CO(g)$. (4 marks)

Question 16

(a) Explain how the introduction of an inert gas at constant volume affects a chemical equilibrium. (2 marks)

(b) 5.50 g of hydrogen iodide gas (HI) is sealed in a 1.2 dm3 container and allowed to dissociate at 500°C: $2HI(g) \rightleftarrows H2(g) + I2(g)$. If Kc = 0.025, calculate:

1. The equilibrium concentrations of all chemical entities.
2. The percentage dissociation of HI. (6 marks)

(c) The reaction $CO(g) + Cl2(g) \rightleftarrows COCl2(g)$ has Kc = 1.5 × 103. Find Kc for $½COCl2(g) \rightleftarrows ½CO(g) + ½Cl2(g)$. (3 marks)

(d) If $N2(g) + O2(g) \rightleftarrows 2NO(g)$ has Kc1 = 1.0 × 10-30 and $N2(g) + 2O2(g) \rightleftarrows 2NO2(g)$ has Kc2 = 3.0 × 10-17, determine Kc for the reaction: $2NO(g) + O2(g) \rightleftarrows 2NO2(g)$. (4 marks)

Question 17

(a) Differentiate between physical equilibrium and chemical equilibrium, providing one example of each. (2 marks)

(b) 2.00 g of sulfur trioxide (SO3) gas is heated in an empty 1.5 dm3 flask to 900 K and breaks down as follows: $2SO3(g) \rightleftarrows 2SO2(g) + O2(g)$. If Kc = 1.8 × 10-3 M, calculate:

1. The equilibrium concentration of each gas.
2. The percentage dissociation of SO3. (6 marks)

(c) For $PCl5(g) \rightleftarrows PCl3(g) + Cl2(g)$, Kc = 0.050. Compute Kc for $3PCl3(g) + 3Cl2(g) \rightleftarrows 3PCl5(g)$. (3 marks)

(d) Given the following parameters:

3. $2NO2(g) \rightleftarrows 2NO(g) + O2(g)$; Kc1 = 4.5 × 10-5
4. $2SO2(g) + O2(g) \rightleftarrows 2SO3(g)$; Kc2 = 2.3 × 104

Calculate Kc for the reaction: $NO2(g) + SO2(g) \rightleftarrows NO(g) + SO3(g)$. (4 marks)

Question 18

(a) State the law of mass action. (2 marks)

(b) 6.40 g of anhydrous PCl5 is vaporized into a closed 2.0 dm3 vessel at 200°C establishing the system: $PCl5(g) \rightleftarrows PCl3(g) + Cl2(g)$. If Kc = 0.0050 M, find:

1. The equilibrium concentrations of PCl5, PCl3, and Cl2.
2. The percentage dissociation of PCl5. (6 marks)

(c) The equilibrium constant for $N2(g) + 3H2(g) \rightleftarrows 2NH3(g)$ is 0.065. What is Kc for $NH3(g) \rightleftarrows ½N2(g) + 3/2H2(g)$? (3 marks)

(d) If $C(s) + O_2(g) \rightleftarrows CO_2(g)$ has $K_{c1} = 2.0 \times 1021$ and $2CO(g) + O_2(g) \rightleftarrows 2CO_2(g)$ has $K_{c2} = 1.5 \times 1010$, find K_c for the reaction: $2C(s) + O_2(g) \rightleftarrows 2CO(g)$. (4 marks)

Question 19

(a) State Le Chatelier's principle and explain how decreasing temperature affects an endothermic system. (2 marks)

(b) 1.20 g of pure hydrogen metaphosphate (HPO_3) gas is heated in a 0.80 dm^3 container to form a dimer: $2HPO_3(g) \rightleftarrows (HPO_3)_2(g)$. If $K_c = 15.0\ M^{-1}$, calculate:

1. The equilibrium concentrations of the monomer and dimer.
2. The percentage conversion of the monomer into the dimer. (6 marks)

(c) For $2H_2S(g) \rightleftarrows 2H_2(g) + S_2(g)$, $K_c = 2.4 \times 10^{-4}$. What is K_c for $\frac{1}{2}S_2(g) + H_2(g) \rightleftarrows H_2S(g)$? (3 marks)

(d) Given the following data:

3. $2H_2(g) + O_2(g) \rightleftarrows 2H_2O(g)$; $K_{c1} = 4.0 \times 1040$
4. $Cl_2(g) + H_2(g) \rightleftarrows 2HCl(g)$; $K_{c2} = 2.5 \times 1033$

Calculate K_c for the reaction: $4HCl(g) + O_2(g) \rightleftarrows 2Cl_2(g) + 2H_2O(g)$. (4 marks)

Question 20

(a) Under what condition does the reaction quotient Q_c equal the equilibrium constant K_c? (2 marks)

(b) 3.00 g of pure dinitrogen trioxide gas (N_2O_3) is placed in a 1.0 dm^3 vessel at room temperature. It decomposes to form: $N_2O_3(g) \rightleftarrows NO(g) + NO_2(g)$. Given that $K_c = 0.022$ M, calculate:

1. The equilibrium concentrations of all three gaseous entities.
2. The percentage dissociation of N_2O_3 at equilibrium. (6 marks)

(c) The reaction $CH_4(g) + H_2O(g) \rightleftarrows CO(g) + 3H_2(g)$ has $K_c = 0.054$. What is K_c for the reaction $2CO(g) + 6H_2(g) \rightleftarrows 2CH_4(g) + 2H_2O(g)$? (3 marks)

(d) If $2NO(g) + O_2(g) \rightleftarrows 2NO_2(g)$ has $K_{c1} = 1.2 \times 1012$ and $N_2(g) + O_2(g) \rightleftarrows 2NO(g)$ has $K_{c2} = 4.0 \times 10^{-31}$, calculate the net equilibrium constant K_c for the reaction: $N_2(g) + 2O_2(g) \rightleftarrows 2NO_2(g)$. (4 marks)

CHEMISTRY 2 - CHEMICAL KINETICS PRACTICE QUESTIONS

QUESTION 1

(a) Briefly explain the following terms:

1. Activation energy
2. Order of a reaction
3. Rate-determining step
4. Initial rate of reaction. **(04 marks)**

(b) The thermal decomposition of dinitrogen pentoxide (2N2O5(g) -> 4NO2(g) + O2(g)) is a first-order reaction with a rate constant of 4.8 x 10^-4 s^-1 at 45°C.

1. If the initial concentration of N2O5 is 0.40 M, what will be its concentration after 15.0 minutes? (02 marks)
2. How long will it take for the concentration of N2O5 to decrease from 0.40 M to 0.10 M? (02 marks)
3. How long will it take to decompose 85% of the starting material? (02 marks)

(c) For the reaction A + B -> C, the following initial rates data were collected at 298 K:

[A] (M)	[B] (M)	Rate (M·s^-1)
0.20	0.10	3.50 x 10^-3
0.20	0.20	7.00 x 10^-3
0.40	0.20	2.80 x 10^-2

1. What is the order of reaction with respect to each reactant and the overall order of reaction? (03 marks)
2. What is the rate constant at 298 K? (02 marks)
3. If the rate constant for this reaction at 340 K is 1.52 M^-2s^-1, what is the activation energy of the reaction? (03 marks)
4. What is the rate constant at 315 K? (02 marks)

QUESTION 2

(a) Briefly explain the following terms:

1. Collision frequency
2. Half-life of a reaction
3. Elementary reaction
4. Catalysis. **(04 marks)**

(b) The rearrangement of methyl isocyanide (CH3NC(g) -> CH3CN(g)) is a first-order reaction with a rate constant of 5.1 x 10^-5 s^-1 at 215°C.

1. If the initial concentration of CH3NC is 0.15 M, what will be its concentration after 60.0 minutes? (02 marks)
2. How long will it take for the concentration to fall from 0.15 M to 0.05 M? (02 marks)
3. How long will it take to isomerize 60% of the initial sample? (02 marks)

(c) For the reaction 2NO(g) + O2(g) -> 2NO2(g), the following kinetics data were recorded at 300 K:

[NO] (M)	[O2] (M)	Rate (M·s^-1)
0.01	0.01	1.20 x 10^-4
0.02	0.01	4.80 x 10^-4
0.02	0.02	9.60 x 10^-4

1. What is the order of reaction with respect to each reactant and the overall order of reaction? (03 marks)
2. What is the rate constant at 300 K? (02 marks)

3. If the rate constant at 360 K is 8.40 x 10^3 M^-2s^-1, find the activation energy of the reaction. (03 marks)
4. What is the value of the rate constant at 320 K? (02 marks)

QUESTION 3

(a) Briefly explain the following terms:

1. Effective collisions
2. Zero-order reaction
3. Reaction mechanism
4. Homogeneous catalyst. **(04 marks)**

(b) The decomposition of hydrogen peroxide in aqueous solution (2H2O2(aq) -> 2H2O(l) + O2(g)) is a first-order process with a rate constant of 7.3 x 10^-4 s^-1 at 25°C.

1. If the starting concentration of H2O2 is 0.80 M, determine its concentration after 12.5 minutes. (02 marks)
2. How long will it take for the concentration to decrease from 0.80 M to 0.25 M? (02 marks)
3. How long will it take to decompose 90% of the H2O2? (02 marks)

(c) For the reaction X + 2Y -> Z, the following initial rates parameters were studied at 295 K:

[X] (M)	[Y] (M)	Rate (M·s^-1)
0.15	0.15	2.40 x 10^-5
0.30	0.15	2.40 x 10^-5
0.30	0.30	9.60 x 10^-5

1. Find the order with respect to X, Y, and the overall reaction order. (03 marks)
2. Calculate the rate constant at 295 K? (02 marks)
3. If the rate constant rises to 4.27 x 10^-3 M^-1s^-1 at 335 K, calculate the activation energy. (03 marks)
4. Determine the rate constant at 310 K. (02 marks)

QUESTION 4

(a) Briefly explain the following terms:

1. Intermediate
2. Integrated rate law
3. Heterogeneous catalyst
4. Temperature coefficient of a reaction. **(04 marks)**

(b) The radioactive decay of a certain isotope follows a first-order kinetic pathway with a rate constant of 0.035 day^-1.

1. If an initial sample concentration is 0.60 M, what concentration remains after 20.0 days? (02 marks)
2. How many days will it take for the sample concentration to drop from 0.60 M to 0.15 M? (02 marks)
3. How long will it take to convert 78% of the original isotope sample? (02 marks)

(c) For the reaction CH3CHO(g) -> CH4(g) + CO(g), experimental numbers were obtained at 800 K:

[CH3CHO] (M)	Rate (M·s^-1)
0.10	9.0 x 10^-5
0.20	3.6 x 10^-4
0.30	8.1 x 10^-4

1. Deduce the order of the reaction with respect to acetaldehyde and its overall order. (03 marks)
2. Compute the rate constant at 800 K. (02 marks)
3. If the rate constant at 900 K increases to 0.18 M^-1s^-1, calculate the activation energy. (03 marks)
4. Compute the rate constant at 850 K. (02 marks)

QUESTION 5

(a) Briefly explain the following terms:

1. Specific reaction rate
2. Maxwell-Boltzmann distribution
3. Molecularity of a rate-determining step
4. Steric factor. **(04 marks)**

(b) The first-order gas-phase decomposition of sulfuryl chloride (SO2Cl2(g) -> SO2(g) + Cl2(g)) exhibits a rate constant of 2.2 x 10^-5 s^-1 at 320°C.

1. Given an initial concentration of 0.50 M, what is the concentration after 4.0 hours? (02 marks)
2. How long will it take for the SO2Cl2 concentration to fall from 0.50 M to 0.20 M? (02 marks)
3. How long will it take to achieve 65% decomposition of the starting material? (02 marks)

(c) The reaction 2A + B2 -> 2AB was evaluated at 310 K, yielding the data below:

[A] (M)	[B2] (M)	Rate (M·s^-1)
0.05	0.05	6.25 x 10^-5
0.10	0.05	1.25 x 10^-4
0.10	0.10	1.25 x 10^-4

1. Find the order with respect to A, B2, and the overall process. (03 marks)
2. Calculate the rate constant at 310 K. (02 marks)
3. If the rate constant at 350 K matches 8.50 x 10^-3 s^-1, determine the activation energy. (03 marks)
4. Predict the value of the rate constant at 330 K. (02 marks)

QUESTION 6

(a) A certain first-order reaction has a rate constant of 9.0 x 10^-3 s^-1 at 300 K.

1. Calculate the remaining concentration after 10 minutes if initial concentration is 1.0 M. (02 marks)
2. Find the time required to reduce the concentration to half of its initial value. (02 marks)
3. Determine the time required to convert 75% of the starting reactant. (02 marks)

(b) The initial rates data for a reaction under standard conditions are modeled as follows:

[Reactant A] (M)	[Reactant B] (M)	Rate (M·s^-1)
0.10	0.10	12.0 x 10^-4
0.20	0.10	24.0 x 10^-4
0.20	0.20	96.0 x 10^-4

1. Determine individual reaction orders and the total overall order. (03 marks)
2. Find the numerical value of the rate constant. (02 marks)
3. Calculate the activation energy if the rate doubles at a higher temperature. (03 marks)
4. Find the rate constant at a 15K higher temperature. (02 marks)

QUESTION 7

(a) A certain first-order reaction has a rate constant of 10.5 x 10^-3 s^-1 at 300 K.

1. Calculate the remaining concentration after 10 minutes if initial concentration is 1.0 M. (02 marks)
2. Find the time required to reduce the concentration to half of its initial value. (02 marks)
3. Determine the time required to convert 75% of the starting reactant. (02 marks)

(b) The initial rates data for a reaction under standard conditions are modeled as follows:

[Reactant A] (M)	[Reactant B] (M)	Rate (M·s^-1)

0.10	0.10	14.0 x 10^-4
0.20	0.10	28.0 x 10^-4
0.20	0.20	112.0 x 10^-4

1. Determine individual reaction orders and the total overall order. (03 marks)
2. Find the numerical value of the rate constant. (02 marks)
3. Calculate the activation energy if the rate doubles at a higher temperature. (03 marks)

4. Find the rate constant at a 15K higher temperature. (02 marks)

_QUESTION 8

(a) A certain first-order reaction has a rate constant of 12.0 x 10^-3 s^-1 at 300 K.

1. Calculate the remaining concentration after 10 minutes if initial concentration is 1.0 M. (02 marks)
2. Find the time required to reduce the concentration to half of its initial value. (02 marks)

3. Determine the time required to convert 75% of the starting reactant. (02 marks)

(b) The initial rates data for a reaction under standard conditions are modeled as follows:

[Reactant A] (M)	[Reactant B] (M)	Rate (M·s^-1)
0.10	0.10	16.0 x 10^-4
0.20	0.10	32.0 x 10^-4
0.20	0.20	128.0 x 10^-4

1. Determine individual reaction orders and the total overall order. (03 marks)
2. Find the numerical value of the rate constant. (02 marks)
3. Calculate the activation energy if the rate doubles at a higher temperature. (03 marks)

4. Find the rate constant at a 15K higher temperature. (02 marks)

QUESTION 9

(a) A certain first-order reaction has a rate constant of 13.5 x 10^-3 s^-1 at 300 K.

1. Calculate the remaining concentration after 10 minutes if initial concentration is 1.0 M. (02 marks)
2. Find the time required to reduce the concentration to half of its initial value. (02 marks)

3. Determine the time required to convert 75% of the starting reactant. (02 marks)

(b) The initial rates data for a reaction under standard conditions are modeled as follows:

[Reactant A] (M)	[Reactant B] (M)	Rate (M·s^-1)
0.10	0.10	18.0 x 10^-4
0.20	0.10	36.0 x 10^-4
0.20	0.20	144.0 x 10^-4

1. Determine individual reaction orders and the total overall order. (03 marks)
2. Find the numerical value of the rate constant. (02 marks)
3. Calculate the activation energy if the rate doubles at a higher temperature. (03 marks)

4. Find the rate constant at a 15K higher temperature. (02 marks)

QUESTION 10

(a) A certain first-order reaction has a rate constant of 15.0 x 10^-3 s^-1 at 300 K.

1. Calculate the remaining concentration after 10 minutes if initial concentration is 1.0 M. (02 marks)

2. Find the time required to reduce the concentration to half of its initial value. (02 marks)

3. Determine the time required to convert 75% of the starting reactant. (02 marks)

(b) The initial rates data for a reaction under standard conditions are modeled as follows:

[Reactant A] (M)	[Reactant B] (M)	Rate (M·s^-1)
0.10	0.10	20.0 x 10^-4
0.20	0.10	40.0 x 10^-4
0.20	0.20	160.0 x 10^-4

1. Determine individual reaction orders and the total overall order. (03 marks)
2. Find the numerical value of the rate constant. (02 marks)
3. Calculate the activation energy if the rate doubles at a higher temperature. (03 marks)

4. Find the rate constant at a 15K higher temperature. (02 marks)

QUESTION 11

(a) A certain first-order reaction has a rate constant of 16.5 x 10^-3 s^-1 at 300 K.

1. Calculate the remaining concentration after 10 minutes if initial concentration is 1.0 M. (02 marks)
2. Find the time required to reduce the concentration to half of its initial value. (02 marks)

3. Determine the time required to convert 75% of the starting reactant. (02 marks)

(b The initial rates data for a reaction under standard conditions are modeled as follows:

[Reactant A] (M)	[Reactant B] (M)	Rate (M·s^-1)
0.10	0.10	22.0 x 10^-4
0.20	0.10	44.0 x 10^-4
0.20	0.20	176.0 x 10^-4

1. Determine individual reaction orders and the total overall order. (03 marks)
2. Find the numerical value of the rate constant. (02 marks)
3. Calculate the activation energy if the rate doubles at a higher temperature. (03 marks)

4. Find the rate constant at a 15K higher temperature. (02 marks)

QUESTION 12

(a) A certain first-order reaction has a rate constant of 18.0 x 10^-3 s^-1 at 300 K.

1. Calculate the remaining concentration after 10 minutes if initial concentration is 1.0 M. (02 marks)
2. Find the time required to reduce the concentration to half of its initial value. (02 marks)

3. Determine the time required to convert 75% of the starting reactant. (02 marks)

(b) The initial rates data for a reaction under standard conditions are modeled as follows:

[Reactant A] (M)	[Reactant B] (M)	Rate (M·s^-1)
0.10	0.10	24.0 x 10^-4
0.20	0.10	48.0 x 10^-4
0.20	0.20	192.0 x 10^-4

1. Determine individual reaction orders and the total overall order. (03 marks)
2. Find the numerical value of the rate constant. (02 marks)

3. Calculate the activation energy if the rate doubles at a higher temperature. (03 marks)

4. Find the rate constant at a 15K higher temperature. (02 marks)

QUESTION 13

(a) A certain first-order reaction has a rate constant of 19.5 x 10^-3 s^-1 at 300 K.

1. Calculate the remaining concentration after 10 minutes if initial concentration is 1.0 M. (02 marks)
2. Find the time required to reduce the concentration to half of its initial value. (02 marks)
3. Determine the time required to convert 75% of the starting reactant. (02 marks)

(b) The initial rates data for a reaction under standard conditions are modeled as follows:

[Reactant A] (M)	[Reactant B] (M)	Rate (M·s^-1)
0.10	0.10	26.0 x 10^-4
0.20	0.10	52.0 x 10^-4
0.20	0.20	208.0 x 10^-4

1. Determine individual reaction orders and the total overall order. (03 marks)
2. Find the numerical value of the rate constant. (02 marks)
3. Calculate the activation energy if the rate doubles at a higher temperature. (03 marks)
4. Find the rate constant at a 15K higher temperature. (02 marks)

QUESTION 14

(a) A certain first-order reaction has a rate constant of 21.0 x 10^-3 s^-1 at 300 K.

1. Calculate the remaining concentration after 10 minutes if initial concentration is 1.0 M. (02 marks)
2. Find the time required to reduce the concentration to half of its initial value. (02 marks)
3. Determine the time required to convert 75% of the starting reactant. (02 marks)

(b) The initial rates data for a reaction under standard conditions are modeled as follows:

[Reactant A] (M)	[Reactant B] (M)	Rate (M·s^-1)
0.10	0.10	28.0 x 10^-4
0.20	0.10	56.0 x 10^-4
0.20	0.20	224.0 x 10^-4

1. Determine individual reaction orders and the total overall order. (03 marks)
2. Find the numerical value of the rate constant. (02 marks)
3. Calculate the activation energy if the rate doubles at a higher temperature. (03 marks)
4. Find the rate constant at a 15K higher temperature. (02 marks)

QUESTION 15

(a) A certain first-order reaction has a rate constant of 22.5 x 10^-3 s^-1 at 300 K.

1. Calculate the remaining concentration after 10 minutes if initial concentration is 1.0 M. (02 marks)
2. Find the time required to reduce the concentration to half of its initial value. (02 marks)
3. Determine the time required to convert 75% of the starting reactant. (02 marks)

(b) The initial rates data for a reaction under standard conditions are modeled as follows:

[Reactant A] (M)	[Reactant B] (M)	Rate (M·s^-1)
0.10	0.10	30.0 x 10^-4
0.20	0.10	60.0 x 10^-4

0.20	0.20	240.0 x 10^-4

1. Determine individual reaction orders and the total overall order. (03 marks)
2. Find the numerical value of the rate constant. (02 marks)
3. Calculate the activation energy if the rate doubles at a higher temperature. (03 marks)

4. Find the rate constant at a 15K higher temperature. (02 marks)

QUESTION 16

(a) A certain first-order reaction has a rate constant of 24.0 x 10^-3 s^-1 at 300 K.

1. Calculate the remaining concentration after 10 minutes if initial concentration is 1.0 M. (02 marks)
2. Find the time required to reduce the concentration to half of its initial value. (02 marks)

3. Determine the time required to convert 75% of the starting reactant. (02 marks)

(b) The initial rates data for a reaction under standard conditions are modeled as follows:

[Reactant A] (M)	[Reactant B] (M)	Rate (M·s^-1)
0.10	0.10	32.0 x 10^-4
0.20	0.10	64.0 x 10^-4
0.20	0.20	256.0 x 10^-4

1. Determine individual reaction orders and the total overall order. (03 marks)
2. Find the numerical value of the rate constant. (02 marks)
3. Calculate the activation energy if the rate doubles at a higher temperature. (03 marks)

4. Find the rate constant at a 15K higher temperature. (02 marks)

QUESTION 17

(a) A certain first-order reaction has a rate constant of 25.5 x 10^-3 s^-1 at 300 K.

1. Calculate the remaining concentration after 10 minutes if initial concentration is 1.0 M. (02 marks)
2. Find the time required to reduce the concentration to half of its initial value. (02 marks)

3. Determine the time required to convert 75% of the starting reactant. (02 marks)

(b) The initial rates data for a reaction under standard conditions are modeled as follows:

[Reactant A] (M)	[Reactant B] (M)	Rate (M·s^-1)
0.10	0.10	34.0 x 10^-4
0.20	0.10	68.0 x 10^-4
0.20	0.20	272.0 x 10^-4

1. Determine individual reaction orders and the total overall order. (03 marks)
2. Find the numerical value of the rate constant. (02 marks)
3. Calculate the activation energy if the rate doubles at a higher temperature. (03 marks)

4. Find the rate constant at a 15K higher temperature. (02 marks)

QUESTION 18

(a) A certain first-order reaction has a rate constant of 27.0 x 10^-3 s^-1 at 300 K.

1. Calculate the remaining concentration after 10 minutes if initial concentration is 1.0 M. (02 marks)
2. Find the time required to reduce the concentration to half of its initial value. (02 marks)

3. Determine the time required to convert 75% of the starting reactant. (02 marks)

(b) The initial rates data for a reaction under standard conditions are modeled as follows:

[Reactant A] (M)	[Reactant B] (M)	Rate (M·s^-1)
0.10	0.10	36.0 x 10^-4
0.20	0.10	72.0 x 10^-4
0.20	0.20	288.0 x 10^-4

1. Determine individual reaction orders and the total overall order. (03 marks)
2. Find the numerical value of the rate constant. (02 marks)
3. Calculate the activation energy if the rate doubles at a higher temperature. (03 marks)

4. Find the rate constant at a 15K higher temperature. (02 marks)

QUESTION 19

(a) A certain first-order reaction has a rate constant of 28.5 x 10^-3 s^-1 at 300 K.

1. Calculate the remaining concentration after 10 minutes if initial concentration is 1.0 M. (02 marks)
2. Find the time required to reduce the concentration to half of its initial value. (02 marks)

3. Determine the time required to convert 75% of the starting reactant. (02 marks)

(b) The initial rates data for a reaction under standard conditions are modeled as follows:

[Reactant A] (M)	[Reactant B] (M)	Rate (M·s^-1)
0.10	0.10	38.0 x 10^-4
0.20	0.10	76.0 x 10^-4
0.20	0.20	304.0 x 10^-4

1. Determine individual reaction orders and the total overall order. (03 marks)
2. Find the numerical value of the rate constant. (02 marks)
3. Calculate the activation energy if the rate doubles at a higher temperature. (03 marks)

4. Find the rate constant at a 15K higher temperature. (02 marks)

QUESTION 20

(a) A certain first-order reaction has a rate constant of 30.0 x 10^-3 s^-1 at 300 K.

1. Calculate the remaining concentration after 10 minutes if initial concentration is 1.0 M. (02 marks)
2. Find the time required to reduce the concentration to half of its initial value. (02 marks)

3. Determine the time required to convert 75% of the starting reactant. (02 marks)

(b) The initial rates data for a reaction under standard conditions are modeled as follows:

[Reactant A] (M)	[Reactant B] (M)	Rate (M·s^-1)
0.10	0.10	40.0 x 10^-4
0.20	0.10	80.0 x 10^-4
0.20	0.20	320.0 x 10^-4

1. Determine individual reaction orders and the total overall order. (03 marks)
2. Find the numerical value of the rate constant. (02 marks)
3. Calculate the activation energy if the rate doubles at a higher temperature. (03 marks)

4. Find the rate constant at a 15K higher temperature. (02 marks)

END

Topic: Colligative Properties and Solutions

Question 1

(a) Briefly explain the following phenomena:

(i) Adding salt to water increases its boiling point.

(ii) Antifreeze (ethylene glycol) is added to car radiators both in winter and summer.

(b) Distinguish between an ideal solution and a non-ideal solution.

(c) A solution is prepared by dissolving 1.50 g of a non-volatile polymer in 100.0 g of water. The osmotic pressure of this solution is found to be 0.035 atm at 25°C. Calculate the molar mass of the polymer.

(d) A 0.05 M aqueous solution of potassium ferricyanide, K3[Fe(CN)6], exhibits an osmotic pressure of 3.90 atm at 27°C. Compare the expected and experimental values for the van 't Hoff factor (i).

Question 2

(a) Briefly explain the following phenomena:

(i) Liquid-liquid mixtures showing positive deviation from Raoult's law form minimum-boiling azeotropes.

(ii) Purified water can be obtained from seawater via reverse osmosis.

(b) Distinguish between osmosis and diffusion.

(c) When 2.45 g of an unknown organic compound is dissolved in 25.0 g of chloroform, the boiling point of the solution increases by 0.84°C. Calculate the molar mass of the compound. (Given Kb for chloroform = 3.63°C kg/mol).

(d) A 0.2 M aqueous solution of NaCl has an observed osmotic pressure of 9.2 atm at 25°C. Calculate the experimental van 't Hoff factor (i) and determine the percentage dissociation of NaCl.

Question 3

(a) Briefly explain the following phenomena:

(i) Equimolar solutions of glucose and sodium chloride do not freeze at the same temperature.

(ii) Seawater does not freeze at 0°C.

(b) Distinguish between molality and molarity, and explain why molality is preferred in colligative property calculations.

(c) An aqueous solution containing 4.50 g of a non-volatile non-electrolyte in 125.0 g of water boils at 100.15°C. Calculate the molecular mass of the solute. (Given Kb for water = 0.512°C kg/mol).

(d) The freezing point of a 0.10 m aqueous solution of BaCl2 is -0.51°C. Compare the expected van 't Hoff factor with the experimental value. (Given Kf for water = 1.86°C kg/mol).

Question 4

(a) Briefly explain the following phenomena:

(i) A mixture of acetone and chloroform shows a negative deviation from Raoult's law.

(ii) The vapor pressure of a solvent decreases when a non-volatile solute is added.

(b) Distinguish between a volatile solvent and a non-volatile solute.

(c) A 1.20 g sample of an unknown covalent hydrocarbon is dissolved in 20.0 g of cyclohexane. The freezing point of the mixture drops by 2.55°C. Find the molar mass of the hydrocarbon. (Given Kf for cyclohexane = 20.0°C kg/mol).

(d) The osmotic pressure of a 0.02 M solution of K2SO4 at 298 K is 1.32 atm. Find the experimental van 't Hoff factor (i) and comment on how it compares to the theoretical value.

Question 5

(a) Briefly explain the following phenomena:

(i) Raw mangoes shrivel when kept in a concentrated salt solution.

(ii) Intravenous injections must be isotonic with human blood cells.

(b) Distinguish between semi-permeable membranes and porous membranes.

(c) A solution of 0.85 g of an organic substance in 50.0 g of benzene freezes at 4.90°C. If pure benzene freezes at 5.50°C, determine the molar mass of the substance. (Use Kf for benzene = 5.12°C kg/mol).

(d) A 0.01 M solution of Al2(SO4)3 has an osmotic pressure of 0.98 atm at 25°C. Compare the expected and experimental values for i.

Question 6

(a) Briefly explain the following phenomena:

(i) Vapor pressure lowering is not a colligative property, but relative lowering of vapor pressure is.

(ii) Ice melts faster when calcium chloride ($CaCl_2$) is scattered over icy roads.

(b) Distinguish between hypertonic and hypotonic solutions.

(c) At 300 K, the vapor pressure of pure water is 31.8 mmHg. A solution is prepared by dissolving 15.0 g of a non-volatile carbohydrate in 90.0 g of water. If the vapor pressure of the solution is 31.2 mmHg, calculate the molar mass of the carbohydrate.

(d) The boiling point of a 0.15 m aqueous solution of $MgSO_4$ is 100.095°C. Compare the expected and experimental values for the van 't Hoff factor (i). (Given Kb for water = 0.512°C kg/mol).

Question 7

(a) Briefly explain the following phenomena:

(i) Acetic acid shows a lower osmotic pressure when dissolved in benzene compared to when it is dissolved in water.

(ii) A maximum-boiling azeotrope is formed by a solution showing negative deviation from Raoult's law.

(b) Distinguish between association and dissociation of solute particles in a solution.

(c) 0.500 g of an unknown protein sample is dissolved in enough water to make 100 cm^3 of solution. The solution exerts an osmotic pressure of 2.60 mmHg at 25°C. Calculate the molar mass of the protein.

(d) A 0.04 m solution of $K_4[Fe(CN)_6]$ turns out to freeze at -0.26°C. Deduce the experimental van 't Hoff factor and determine the degree of ionization. (Given Kf for water = 1.86°C kg/mol).

Question 8

(a) Briefly explain the following phenomena:

(i) Colligative properties can be used to determine the molecular weight of proteins but not polymers of extremely high mass using freezing point depression.

(ii) The boiling point elevation of a solution is directly related to the concentration of solute particles.

(b) State Raoult's Law for solutions containing non-volatile solutes.

(c) 3.10 g of an unknown non-volatile compound is dissolved in 45.0 g of carbon tetrachloride (CCl_4). The boiling point of the solution is 78.2°C, while pure CCl_4 boils at 76.8°C. Find the molar mass of the compound. (Given Kb for CCl_4 = 5.03°C kg/mol).

(d) A 0.1 M solution of $FeCl_3$ shows an osmotic pressure of 8.54 atm at 27°C. Compare its expected van 't Hoff factor with its experimental value.

Question 9

(a) Briefly explain the following phenomena:

(i) When a person consumes excessively salty food, they experience tissue swelling (edema).

(ii) The enthalpy of mixing (ΔH_{mix}) for an ideal solution is zero.

(b) Distinguish between the cryoscopic constant (Kf) and the ebullioscopic constant (Kb).

(c) A solution containing 1.10 g of an unknown hormone in 22.0 g of benzene lowers the freezing point by 0.78°C. Find the molecular mass of the hormone. (Use Kf for benzene = 5.12°C kg/mol).

(d) A 0.05 m aqueous solution of KNO_3 freezes at -0.172°C. Calculate the experimental van 't Hoff factor (i) and evaluate the degree of dissociation. (Given Kf for water = 1.86°C kg/mol).

Question 10

(a) Briefly explain the following phenomena:

(i) The vapor pressure of an aqueous solution of glucose is higher than that of an aqueous solution of aluminum chloride of the same molarity.

(ii) Wilted flowers revive when placed in fresh water.

(b) State the condition under which the van 't Hoff factor (i) is equal to 1, less than 1, and greater than 1.

(c) 0.422 g of a organic compound dissolved in 18.5 g of ethanol elevates the boiling point by 0.18°C. Calculate the molar mass of the compound. (Given Kb for ethanol = 1.22°C kg/mol).

(d) The osmotic pressure of a 0.1 M solution of CH_3COOH is 2.65 atm at 25°C. Compare the expected value of i (assuming complete dissociation) with the experimental value.

Question 11

(a) Briefly explain the following phenomena:

(i) Liquid-liquid mixtures showing negative deviation from Raoult's law result in a decrease in total volume ($\Delta V_{mix} < 0$).

(ii) Preservation of meat by salting protects it from bacterial action.

(b) Distinguish between reverse osmosis and normal osmosis.

(c) A 0.60 g sample of an organic non-electrolyte is dissolved in 30.0 g of acetone. The boiling point rises by 0.32°C. Find the molar mass of the solute. (Given Kb for acetone = 1.71°C kg/mol).

(d) A 0.02 M aqueous solution of $K_3[Fe(CN)_6]$ has an observed osmotic pressure of 1.65 atm at 25°C. Compare the expected and experimental values for i.

Question 12

(a) Briefly explain the following phenomena:

(i) Molecular weight values determined via colligative properties for benzoic acid in benzene are nearly double the actual atomic formula mass.

(ii) Aquatic animals are more comfortable in cold water than in warm water.

(b) Distinguish between isotonic solutions and azeotropic mixtures.

(c) The vapor pressure of pure ethanol at 20°C is 44.5 mmHg. A solution is made by dissolving 2.50 g of an organic drug in 50.0 g of ethanol. If the solution's vapor pressure is 43.9 mmHg, find the molar mass of the drug.

(d) The freezing point of a 0.05 m solution of $Ca(NO_3)_2$ is -0.24°C. Compare the expected value of i with the experimental value. (Given Kf for water = 1.86°C kg/mol).

Question 13

(a) Briefly explain the following phenomena:

(i) Solutions of ethanol and water show a positive deviation from Raoult's law.

(ii) Red blood cells burst when placed in distilled water.

(b) Describe the relationship between vapor pressure and temperature for a pure solvent and a solution to illustrate boiling point elevation.

(c) A 1.50 g sample of a vitamin compound is dissolved in 25.0 g of camphor. The freezing point of the mixture decreases by 7.80°C. Calculate the molar mass of the vitamin. (Given Kf for camphor = 39.7°C kg/mol).

(d) A 0.1 M aqueous solution of Na_2SO_4 exerts an osmotic pressure of 6.85 atm at 27°C. Calculate the experimental van 't Hoff factor and determine the degree of dissociation.

Question 14

(a) Briefly explain the following phenomena:

(i) Phenol associates into dimers when dissolved in benzene.

(ii) Osmotic pressure measurement is preferred over boiling point elevation for determining the molecular weight of biomolecules.

(b) Distinguish between ideal behavior and real behavior of solutions with respect to intermolecular forces.

(c) What is the molecular mass of a compound if 0.90 g of it dissolved in 60.0 g of water increases the boiling point to 100.064°C? (Given Kb for water = 0.512°C kg/mol).

(d) A 0.15 m aqueous solution of an electrolyte AB_2 freezes at -0.72°C. Compare the theoretical and experimental values of i. (Given Kf for water = 1.86°C kg/mol).

Question 15

(a) Briefly explain the following phenomena:

(i) Nitric acid and water form a maximum-boiling azeotrope.

(ii) Adding volatile liquids to water shifts its boiling point downwards instead of upwards.

(b) Distinguish between colligative properties and constitutive properties of solutions.

(c) 0.750 g of an unknown steroid is dissolved in 20.0 g of benzene, giving a freezing point depression of 0.640°C. Calculate the molar mass of the steroid. (Use Kf for benzene = 5.12°C kg/mol).

(d) The osmotic pressure of a 0.05 M solution of K_2CO_3 at 25°C is 3.15 atm. Find the experimental van 't Hoff factor (i) and comment on its variation from the expected state.

Question 16

(a) Briefly explain the following phenomena:

(i) When NaCl is added to ice, a freezing mixture reaching -21°C can be achieved.

(ii) Concentrated sugar solutions act as excellent food preservatives.

(b) Define the term osmotic pressure and write its mathematical equation according to the van 't Hoff theory.

(c) A 2.10 g mass of an antibiotic dissolved in 150 cm3 of water produces an osmotic pressure of 0.045 atm at 300 K. Find the molar mass of the antibiotic.

(d) The boiling point of a 0.1 m solution of HCl is 100.098°C. Compare the expected value and experimental values for i. (Given Kb for water = 0.512°C kg/mol).

Question 17

(a) Briefly explain the following phenomena:

(i) Hexane and heptane form a nearly ideal solution when mixed together.

(ii) At high altitudes, liquid water boils at temperatures below 100°C.

(b) Explain why the relative lowering of vapor pressure is equal to the mole fraction of the solute.

(c) A solution of 0.322 g of a organic non-volatile substance in 15.5 g of chloroform raises the boiling point by 0.45°C. Compute the molecular weight of the substance. (Given Kb for chloroform = 3.63°C kg/mol).

(d) A 0.025 M solution of K4[Fe(CN)6] at 25°C has an experimental osmotic pressure of 2.45 atm. Compare the expected and experimental values for i.

Question 18

(a) Briefly explain the following phenomena:

(i) Hydrochloric acid (HCl) when dissolved in water behaves as a strong electrolyte, but when dissolved in benzene, it behaves as a non-electrolyte.

(ii) Plasmolysis occurs when a plant cell is placed in a concentrated hypertonic sugar solution.

(b) Distinguish between fractional distillation and azeotropic distillation.

(c) The vapor pressure of pure diethyl ether is 442 mmHg at 293 K. A solution containing 3.50 g of a solute in 50.0 g of diethyl ether has a vapor pressure of 426 mmHg. Compute the molar mass of the solute. (Molar mass of diethyl ether = 74 g/mol).

(d) A 0.1 m aqueous solution of NH4Cl freezes at -0.345°C. Calculate the experimental van 't Hoff factor (i) and determine the percentage dissociation. (Given Kf for water = 1.86°C kg/mol).

Question 19

(a) Briefly explain the following phenomena:

(i) Equimolar solutions of urea and sodium chloride are not isotonic.

(ii) Mixing equal volumes of ethanol and water results in a solution where the total volume is less than the sum of individual volumes ($\Delta V_{mix} < 0$).

(b) Distinguish between ideal gas equations and van 't Hoff osmotic pressure equations.

(c) A solution of 0.50 g of an unknown covalent molecular compound in 20.0 g of benzene gives a freezing point lowering of 0.415°C. Calculate the molar mass of the compound. (Use Kf for benzene = 5.12°C kg/mol).

(d) A 0.05 M solution of K2SO4 shows an observed osmotic pressure of 3.25 atm at 27°C. Compare the expected and experimental values for i.

Question 20

(a) Briefly explain the following phenomena:

(i) Carbon disulfide and acetone show a highly positive deviation from Raoult's law.

(ii) Sprinkling salt on snails causes them to perish due to dehydration.

(b) Distinguish between normal molecular mass and abnormal molecular mass.

(c) When 0.455 g of an unknown drug sample is dissolved in 12.0 g of cyclohexane, the boiling point increases by 0.540°C. Calculate the molar mass of the drug. (Given Kb for cyclohexane = 2.79°C kg/mol).

(d) A 0.1 m solution of a weak monobasic acid (HA) has an observed freezing point of -0.210°C. Compare the expected value (if completely non-ionized) and the experimental value for i, and calculate the acid dissociation constant (Ka). (Given Kf for water = 1.86°C kg/mol).

END

FORM FIVE CHEMISTRY 01 – PRACTICE QUESTIONS

Constants: Rydberg constant $R_H = 1.09678 \times 10^7\ m^{-1}$

Quantum Numbers & Electron Configurations

1. Give the values of the quantum numbers *n*, *l*, and *m* for the electron with the highest energy in a potassium atom (Z = 19).

2. State the possible values of *n*, *l*, and *m* for the outermost valence electron in a chlorine atom (Z = 17).

3. Determine the set of four quantum numbers (n, l, m, m_s) for the last entering electron in a scandium atom (Z = 21).

4. Explain the extra stability associated with half-filled (p^3, d^5) and completely filled (p^6, d^{10}) orbitals in terms of symmetry and exchange energy.

5. Using the concept of half-filled and completely filled subshells, explain why the ground-state electronic configuration of chromium (Z = 24) is [Ar] $3d^5\ 4s^1$ rather than [Ar] $3d^4\ 4s^2$.

6. Account for the anomalous electronic configuration of copper (Z = 29) being [Ar] $3d^{10}\ 4s^1$ instead of [Ar] $3d^9\ 4s^2$.

7. How many electrons in a single atom can possess the following quantum numbers:

a) $n = 3$, $m_s = +1/2$

b) $n = 4$, $l = 2$, $m_s = -1/2$

c) $n = 2$, $m_s = 0$

8. Determine the maximum number of electrons in an atom that can have the quantum numbers:

a) $n = 5$, $m_s = -1/2$

b) $n = 3$, $l = 1$, $m = 0$

Orbital Energies & Degeneracy (9–12)

9. Between the following sets of quantum numbers for orbitals in a multi-electron atom, identify which has higher energy and state why:

i) $n = 4$, $l = 0$, $m = 0$

ii) $n = 3$, $l = 2$, $m = +2$

10. Compare the energies of the following two orbitals in an isolated atom in the absence of a magnetic field:

i) $n = 4$, $l = 1$, $m = +1$

ii) $n = 4$, $l = 1$, $m = -1$

11. Arrange the following sets of orbital quantum numbers in order of increasing energy:

A: $n = 4$, $l = 2$, $m = 0$

B: $n = 5$, $l = 0$, $m = 0$

C: $n = 4$, $l = 1$, $m = -1$

12. Explain why the orbitals represented by ($n = 3$, $l = 2$, $m = +1$) and ($n = 3$, $l = 2$, $m = -1$) have equal energy in a free atom.

13. Calculate the energy emitted (in Joules) when an electron in a hydrogen atom undergoes a transition giving the spectral line of the lowest energy in the Lyman (ultraviolet) series ($R_H = 1.09678 \times 10^7\ m^{-1}$).

14. Determine the wavelength and energy emitted when an electron in a hydrogen atom falls from $n = 5$ to $n = 2$ in the visible region.

15. Calculate the energy required to excite an electron in a hydrogen atom from the ground state ($n = 1$) to the second excited state ($n = 3$).

16. What transition in the hydrogen atom spectrum would have the exact same wavelength as the transition from $n = 6$ to $n = 3$ in a Li^{2+} ion (Z = 3)?

17. Find the transition in the hydrogen spectrum that produces a spectral line of the same wavelength as the Lyman transition $n = 2$ to $n = 1$ in a He^+ ion (Z = 2).

18. An electron in a Be^{3+} ion (Z = 4) transitions from $n = 8$ to $n = 4$. Identify the corresponding transition in a hydrogen atom that emits light of the same frequency and wavelength.

VSEPR Theory, Hybridization & Molecular Geometry (19–26)

19. Using VSEPR theory, state the type of hybridization of the central atom and draw the molecular shape of:
- i) H_2S
- ii) SO_4^{2-}

20. Predict the hybridization of the central atom and sketch the geometry of the following species using VSEPR theory:
- i) SF_2
- ii) PO_4^{3-}

21. Using VSEPR theory, determine the hybridization and draw the structures of:
- i) NH_3
- ii) NH_4^+

22. State the hybridization of the central atom and draw the shapes of the following using VSEPR theory:
- i) ClF_3
- ii) ICl_4^-

23. Apply VSEPR theory to state the hybridization of the central atom and draw the structures of:
- i) XeF_2
- ii) XeF_4

24. Determine the central atom hybridization and sketch the 3D geometry of:
- i) BF_3
- ii) BF_4^-

25. Explain using VSEPR theory why OF_2 has a bent (V-shaped) geometry with a bond angle smaller than 109.5°, whereas $BeCl_2$ is linear.

26. State the hybridization of sulfur and draw the molecular structures of:
- i) SO_2
- ii) SO_3

27. Using one specific chemical example for each, differentiate between intermolecular hydrogen bonding and intramolecular hydrogen bonding.

28. Explain why *o*-nitrophenol has a lower boiling point and higher volatility than *p*-nitrophenol based on the type of hydrogen bonding present.

29. Illustrate with diagrams the difference between the hydrogen bonding found in ethanol (C_2H_5OH) and that found in 2-hydroxybenzoic acid (salicylic acid).

30. Explain two major biological advantages of hydrogen bonding in maintaining human life (e.g., in DNA structure or protein folding).

31. Discuss how hydrogen bonding in water molecules supports aquatic and human life on Earth.

32. Briefly explain why a sigma (σ) covalent bond is stronger and has a higher bond dissociation energy than a pi (π) covalent bond.

33. Compare the orbital overlap in a σ bond and a π bond, and explain how this affects free rotation around the bond axis.

34. Explain why a carbon-carbon double bond (C=C) is not twice as strong as a carbon-carbon single bond (C–C).

35. Describe why π electrons are more reactive and accessible to electrophiles than σ electrons.

36. Two gases, ammonia (NH_3, molar mass = 17 g/mol) and hydrogen chloride (HCl, molar mass = 36.5 g/mol), are released simultaneously from opposite ends of a 2.0 m glass tube. Which gas travels faster and why?

37. Perfume X has a molecular mass of 180 a.m.u. and perfume Y has a molecular mass of 310 a.m.u. If both are sprayed at the exact same moment across a room, which perfume will reach an observer first? Explain using kinetic theory.

38. State Graham's law of diffusion and use it to explain why helium balloons deflate faster than balloons filled with nitrogen gas.

39. Two aromatic sprays, Rose (M = 154 a.m.u.) and Vanilla (M = 152 a.m.u.), are released simultaneously at a distance of 5 m from you. Identify which scent reaches you first and justify your answer.

40. Explain why the rate of diffusion of a gas is inversely proportional to the square root of its molecular mass at constant temperature and pressure.

41. Two perfumes are released simultaneously from their containers 10.0 m away from an observer. Perfume P has a molecular mass of 240 a.m.u. and perfume Q has a molecular mass of 150 a.m.u. If you smell the faster perfume in 20 seconds, how long will it take to smell the second perfume?

42. Gas A (molecular mass = 64 a.m.u.) and Gas B (molecular mass = 100 a.m.u.) are released at the same time from a point 6.0 m away. If Gas A is detected after 12 seconds, calculate the time taken for Gas B to be detected.

43. Two insect repellents, M (M = 190 a.m.u.) and N (M = 285 a.m.u.), are sprayed simultaneously 8.0 m away from a sensor. If the sensor detects M in 18 seconds, after how many seconds will it detect N?

44. An unknown gas X takes 30 seconds to diffuse across a 5.0 m room, whereas oxygen gas (O_2, M = 32 a.m.u.) takes 15 seconds to travel the same distance under identical conditions. Calculate the molecular mass of gas X.

45. Two volatile liquids, ester E (M = 88 a.m.u.) and ester F (M = 132 a.m.u.), evaporate simultaneously at one end of a 9.0 m corridor. If ester F takes 25 seconds to reach the other end, how long did ester E take?

46. Sulfur dioxide (SO_2, M = 64 a.m.u.) takes 24 seconds to diffuse through a porous plug. How long will it take an equal volume of methane (CH_4, M = 16 a.m.u.) to diffuse through the same plug under identical conditions?

47. Two chemical vapors, V1 (M = 320 a.m.u.) and V2 (M = 200 a.m.u.), are released simultaneously 12 m away from a detector.

i) Which vapor triggers the detector first and why?

ii) If the first vapor arrives in 16 seconds, calculate the time difference between the arrival of the first and second vapors.

48. A sample of nitrogen gas (N_2, M = 28 a.m.u.) diffuses across a distance of 4.5 m in 10 seconds. How long will it take an unknown gas with a molecular mass of 112 a.m.u. to diffuse across the exact same distance?

49. Two perfumes with molecular masses 180 a.m.u. and 245 a.m.u. are sprayed at the same time 6.5 m away from a person. If the lighter perfume is smelled in 14 seconds, calculate the time required for the heavier perfume to reach the person.

50. Hydrogen sulfide (H_2S, M = 34 a.m.u.) and sulfur trioxide (SO_3, M = 80 a.m.u.) are released simultaneously at a distance of 15 m from an air quality monitor. If H_2S registers on the monitor in 22 seconds, how many seconds later will SO_3 register?

END