

- Q1. A solution contains 20 g NaCl in 95 cm³ solution. The density of the solution is 1.25 gcm⁻³. What is mass% of NaCl?
- Q2. Calculate the mass percentage of aspirin (C₉H₈O) in acetonitrile (CH₃CN) when 6.5 g of C₉H₈O₄ is dissolved in 450 g of CH₃CN.
- Q3. What is the molarity of a solution prepared by mixing 2.0 L of 3 M glucose solutions and 3.0 L of 2.5 M glucose solution?
- Q4. How is the molality of a solution different from its molarity? What is the effect of change in temperature of a solution on its molality and molarity?
- Q5. What is the sum of the mole fractions of all the components in a three component system?
- Q6. Define mole fraction of a component in a solution.
- Q7. How is the molality of a solution different from its molarity?
- Q8. Which of the 1 molar and 1 molal solution is more concentrated and why?
- Q9. Will the molarity of a solution at 50°C be same, less or more than molarity at 25°C?
- Q10. Which out of molarity or molality will change with change in temperature and why?
- Q11. What is the normality of:
(a) 1.5 M H₂SO₄ (b) 1.2 M CH₃COOH (c) 1.0 M NaOH
- Q12. Ethanol is an organic compound, yet it is freely miscible with water. Explain.
- Q13. A solution contains 3.2 g methanol per 500 cm³ of the solution. Calculate its molarity.
- Q14. Calculate the volume of water which should be added to 20 ml of 0.65 M HCl to dilute the solution to 0.2 M.
- Q15. Nalorphene (C₁₉H₂₁NO₃) similar to morphine, is used to combat withdrawal symptoms in narcotic users. Dose of nalorphene generally given is 1.5 mg. Calculate the mass of 1.5 × 10⁻³ m aqueous solution required for the above dose.
- Q16. Calculate the mass percentage of benzene (C₆H₆) and carbon tetrachloride (CCl₄) if 22 g of C₆H₆ is dissolved in 122 g of CCl₄.
- Q17. If the solubility product of CuS is 6 × 10⁻¹⁶, calculate the maximum molarity of CuS in aqueous solution.
- Q18. Calculate the amount of benzoic acid (C₆H₅COOH) required for preparing 250 mL of 0.15 M solution in methanol.
- Q19. Calculate weight of baking soda (NaHCO₃) required in making 400 gram of 0.50 molal aqueous solution.
- Q20. Calculate the mole fraction of benzene in a solution, containing 40% by mass in CCl₄.

- Q21. Calculate molality of 2.5 g of ethanoic acid (CH_3COOH) in 500 g benzene.
- Q22. Calculate the molarity of solution containing 10 g NaOH is dissolved in 900 ml. solution.
- Q23. A solution is prepared by dissolving 0.409 g sulphuric acid in 100 cm^3 of the solution. Calculate its normality.
- Q24. What is the mole-fraction of H_2O_2 and H_2O in 20% aqueous H_2O_2 ?
- Q25. How would you prepare 0.25 m CaCl_2 solution?
- Q26. An antifreeze solution is prepared from 222.6 gram of ethylene glycol $\text{C}_2\text{H}_6\text{O}_2$ and 200 g of water. Calculate molality and molarity of solution if density of solution is 1.072 g/mL.
- Q27. A solution is obtained by mixing 300 g of 25% and 400 g of 40% solution by mass. Calculate the mass percentage of resulting solution.
- Q28. Calculate the molarity of the following:
(a) 30 g of $\text{Ca}(\text{NO}_3)_2 \cdot 3\text{H}_2\text{O}$ in 4.3 L (b) 50 ml of 0.5 m $\cdot \text{H}_3\text{PO}_4$ diluted to 500 ml
- Q29. Molality of an aqueous solution is 1.002 mol/kg. What is mol fraction of solute?
- Q30. The density of water of lake is 1.25 g/ml and one kg of this water contains 98 g of Na^+ ions. What is the molarity of Na^+ ions in the water of lake. (Atomic mass of Na = 23.00 u)
- Q31. Concentrated nitric acid used in the laboratory work is 68% nitric acid by mass in aqueous solution. What should be molarity of such sample of the acid if the density of solution is 1.504 g mL^{-1} ?
- Q32. A sugar syrup of weight 214.2 g contains 34.2 g of sugar ($\text{C}_{12}\text{H}_{22}\text{O}_{11}$). Calculate (i) mole fraction of sugar (ii) molality of sugar syrup.
- Q33. Calculate the molality of K_2CO_3 solution which is formed by dissolving 2.5 g of it in one litre of solution, density of solution is 0.85 g/ml.
- Q34. Calculate (a) molality (b) molarity and (c) mole fraction of KI if the density of 20% (mass/mass) aqueous solution KI is 1.202 g mL^{-1} .
- Q35. Calculate the mole fraction of ethylene glycol ($\text{C}_2\text{H}_6\text{O}_2$) in a solution containing 20% of $\text{C}_2\text{H}_6\text{O}_2$ by mass.
- Q36. A sample of drinking water was found to be severely contaminated with chloroform CHCl_3 , supposed to be carcinogen. The level of contamination was 15 ppm (by mass)
(a) Express this in percent by mass.
(b) Determine the molality of chloroform in the water sample.
- Q37. A solution of glucose in water is labelled as 10% w/w, what would be the molality and mole fraction of each component in the solution? If the density of the solution is 1.2 g mL^{-1} , then what shall be the molarity of the solution?

- S1.** Given, Density of solution = 1.25 gcm^{-3}
Volume of solution = 95 cm^3

$$\text{Mass of solution} = 95 \text{ cm}^3 \times 1.25 \text{ gcm}^{-3} = 118.75 \text{ g}$$

$$\text{Mass \% NaCl} = \frac{\text{Mass of solute}}{\text{Mass of the solution}} \times 100 = \frac{20}{118.75} \times 100 = \mathbf{1.69\%}.$$

- S2. Given:** Mass of aspirin (Solute) = 6.5 g
Mass of CH_3CN (Solvent) = 450 g

$$\text{Mass of solution} = 450 + 6.5 = 456.5 \text{ g}$$

$$\text{Mass percentage of solute} = \frac{\text{Mass of solute}}{\text{Mass of solution}} \times 100 = \frac{6.5}{450 + 6.5} \times 100 = \mathbf{1.424\%}.$$

- S3.** For missing of two solutions,

$$M_1 V_1 + M_2 V_2 = M_3 (V_1 + V_2)$$

$$\text{Putting the appropriate values, } M_3 = \frac{3 \times 2 + 2.5 \times 3}{2 + 3} = \frac{6 + 7.5}{5} = \frac{13.5}{5} = \mathbf{2.7 \text{ M}}.$$

- S4. Molarity** is defined as the number of moles of a solute dissolve per litre of the solution whereas molality is defined as the number of moles of the solute dissolve per kg of the solvent.

Effect of temperature on molarity and molality: Molality is independent of temperature whereas molarity change with temperature because volume depends on temperature and the mass does not.

- S5.** The sum of the mole fractions of all the components in a three component system is one

$$\frac{n_A}{n_A + n_B + n_C} + \frac{n_B}{n_A + n_B + n_C} + \frac{n_C}{n_A + n_B + n_C} = 1$$

where n_A, n_B, n_C are the moles of the three components.

- S6.** Mole fraction of a component in a solution is the ratio of the moles of the components to the sum of the components of different fraction.

$$\chi_A = \frac{n_A}{n_A + n_B}$$

where χ_A is the mole fraction and n_A and n_B are the number of moles of components A and B.

- S7.** Molarity is the number of moles of solute per litre of the solution while molality is the number of moles of solute per kilogram of the solvent. Molarity depends on temperature while molality is independent from temperature.

- S8.** 1 M (molar) solution has higher concentration than 1 m (molal). Because in 1 M solution, 1 mole is dissolved in 1000 ml of solution (solvent + solute) on the other hand in 1 m solution, 1 mole is dissolved in 1000 g (= 1000 mL) of solvent.
- S9.** Molarity at 50°C of a solution will be less than that at 25°C because molarity decreases with temperature. This is because volume of the solution increases with increase in temperature but number of moles of solute remains the same.
- S10.** Molarity changes with rise in temperature, because volume of a solution increases with rise in temperature. This causes change in molarity as it is related to moles of solute in a given volume of solution.
- S11.** Normality = $n \times$ molarity (n = acidity or basicity)
 (a) Normality = $1.5 \times 2 = 3$ N (b) Normality = $1.2 \times 1 = 1.2$ N (c) Normality = $1.0 \times 1 = 1.0$ N
- S12.** Because C_2H_5OH is polar ($O^{S-} - H^{S+}$) and hydrophobic part C_2H_5- is very small in size, hence C_2H_5OH can break hydrogen bonding of water, and can make H-bonding with H_2O .
- S13.** Molecular mass of methanol (CH_4O) = 32 g.mol

$$\text{Number of moles of methanol} = \frac{\text{Mass of methanol}}{\text{Molecular mass of methanol}} = \frac{3.2}{32} = 0.1 \text{ mol}$$

$$\text{Molarity of methanol in } 500 \text{ cm}^3 \text{ solution} = \frac{\text{No. of moles of methanol}}{\text{Volume of solution (in L)}} = \frac{0.1}{500/1000} = \mathbf{0.2 \text{ M.}}$$

S14. For dilution, $M_1 V_1 = M_2 V_2$

$$V_2 = \frac{M_1 V_1}{M_2} = \frac{0.65 \times 20}{0.2} = 65 \text{ ml.}$$

Vol. of water to be added to 20 ml of 0.65 M solution = $V_2 - V_1 = 65 - 20 = \mathbf{45 \text{ ml.}}$

S15. Given,

$$\text{Mass of Nalorphene } (W_B) = 1.5 \text{ mg} = 1.5 \times 10^{-3} \text{ g,}$$

$$\text{Molar mass of Nalorphene } (C_{19}H_{21}NO_3) (M_B) = 311 \text{ g mol}^{-1}$$

$$\text{Molality } (m) = \frac{W_B \times 1000}{M_B \times W_A} \Rightarrow$$

$$1.5 \times 10^{-3} = \frac{1.5 \times 10^{-3} \times 1000}{311 \times W_A}$$

$$W_A = 3.215 \text{ gm}$$

$$\begin{aligned} \text{Mass of solution} &= \text{Mass of solvent} + \text{Mass of solute} \\ &= 3.215 \text{ g} + 1.5 \times 10^{-3} \text{ g} = \mathbf{3.2165 \text{ g.}} \end{aligned}$$

S16. Given,

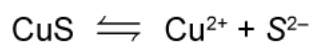
Mass of solute (W_B) = 22 g, Mass of solvent = 122 g, Mass of solution = 144 g

$$\text{Mass \% of } (C_6H_6) = \frac{\text{Mass of Benzene} \times 100}{\text{Total mass of solution}} = \frac{22}{144} \times 100 = 15.27\%$$

$$\text{Mass \% of } CCl_4 = \frac{\text{Mass of } CCl_4 \times 100}{\text{Total mass of solution}} = \frac{122}{144} \times 100 = \mathbf{84.72\%}.$$

S17. Given, Solubility product (K_{SP}) = 6×10^{-16}

Maximum molarity of CuS in aqueous solution = solubility of CuS in mol L^{-1} . If s is the solubility of CuS then



$$[Cu^{2+}] = s, \quad [S^{2-}] = s$$

So,

$$K_{SP} = [Cu^{2+}][S^{2-}] \Rightarrow s \times s = s^2$$

$$s = \sqrt{K_{SP}} = \sqrt{6 \times 10^{-16}}$$

Highest molarity

$$= \mathbf{2.45 \times 10^{-8} M}.$$

S18. Given,

Molarity (M) = 0.15 M, Volume (V) = 250 ml, Molar mass of C_6H_5COOH (M_B) = 122 g mol^{-1}

$$\text{Molarity } (M) = \frac{W_B \times 1000}{M_B \times V \text{ (in mL)}} \Rightarrow 0.15 = \frac{W_B \times 1000}{122 \times 250}$$

$$W_B = \frac{0.15 \times 122 \times 250}{1000} = \mathbf{3.508 g}.$$

S19. Given:

$$\text{Molality} = 0.50 M$$

Molar weight of solute (M_B) = ($NaHCO_3$) = 84 g mol^{-1}

Weight of solvent (W_A) = 400 gram

$$M' = \frac{n_B \times 1000}{W_A} \quad \text{or} \quad M' = \frac{W_B \times 1000}{M_B \times W_A} \quad \text{or} \quad 0.50 = \frac{W_B \times 1000}{84 \times 400}$$

$$W_B = \frac{84 \times 0.50 \times 400}{1000} = \mathbf{16.8 \text{ gram}}$$

S20. Let, Weight of solution = 100 gram,

Weight of CCl_4 = 60 gram, Weight of C_6H_6 = 40 gram

Molar mass $M(C_6H_6)$ = 78, Molar mass $M(CCl_4)$ = 154

$$X_B = \frac{n_{C_6H_6}}{n_{C_6H_6} + n_{CCl_4}} = \frac{40/78}{40/78 + 60/154} = \mathbf{0.5682}.$$

S21. Given:

Weight of solute (W_B) = 2.5 g (ethanoic acid)

Weight of solvent (V) = 500 gram (benzene)

Molar mass of solute (M_B) = 60 g/mol⁻¹

$$(\text{Molality}) M' = \frac{n_B \times 1000}{W_A (\text{gram})} = \frac{W_B \times 1000}{M_B \times W_A} = \frac{2.5 \times 1000}{60 \times 500} = \mathbf{0.083}.$$

S22. Given:

Solute (W_B) = 10 g (NaOH)

Solution (V) = 900 ml

Molar weight (M_B) = 40 g mol⁻¹

$$M = \frac{n_B \times 1000}{V (\text{ML})} \Rightarrow \frac{W_B \times 1000}{M_B \times V (\text{ML})} \Rightarrow \frac{10 \times 1000}{40 \times 900} = \mathbf{0.278}.$$

S23.

$$\text{Normality} = \frac{\text{Gram eq. weight}}{\text{Volume of solution in Lit.}}$$

$$\text{Gram eq. weight} = \frac{\text{Given weight}}{\text{eq. weight}}$$

$$\left(\text{eq. weight} = \frac{MW}{n} = \frac{98}{2} \right)$$

Basicity of H₂SO₄ = 2)

Hence,

$$N = \frac{0.409 \times 1000}{49 \times 100} = 0.083 \text{ N.}$$

S24. 20 g of H₂O₂ is present in 100 g of the solution

∴ Mass of H₂O in 100 g of 20% H₂O₂ solution = 100 – 20 = 80 g

Molecular mass of H₂O₂ = 34, Molecular mass of H₂O = 18

$$\text{Moles of H}_2\text{O}_2 = \frac{20}{34} = 0.59 \text{ mol,}$$

$$\text{Moles of H}_2\text{O} = \frac{80}{18} = 4.44 \text{ mol}$$

$$X_{H_2O_2} = \frac{n_{H_2O_2}}{n_{H_2O} + n_{H_2O_2}} \Rightarrow \frac{0.59}{0.59 + 4.44} = 0.117$$

$$X_{H_2O} = 1 - X_{H_2O_2} \Rightarrow 1 - 0.117 = \mathbf{0.883}.$$

S25. Molecular mass of CaCl₂ = 1 × 40 + 2 × 35.5 = 111 g mol⁻¹

$$\text{Molality} = \frac{\text{No. of moles of the solute}}{\text{Mass of solvent in Kg}}$$

Moles of CaCl_2 in 1 Kg solvent = $0.25 \times 1 = 0.25 \text{ mol}$

$$\begin{aligned}\text{Mass of } \text{CaCl}_2 &= \text{Moles of solute} \times \text{Molecular mass} \\ &= 0.25 \times 111 = \mathbf{27.75 \text{ g.}}\end{aligned}$$

We can prepare 0.27 m CaCl_2 solution by adding 27.75 g of CaCl_2 in 1 Kg of solvent.

S26. Given:

Mass of ethylene glycol (W_B) $\text{C}_2\text{H}_4(\text{OH})_2 = 222.6 \text{ gram}$

Molar weight [$\text{C}_2\text{H}_4(\text{OH})_2$] = 62 g mol^{-1}

Mass of H_2O (W_A) = 200 g

Molar mass (H_2O) = 18 g mol^{-1}

Density of solution (d) = 1.072 g mol^{-1}

Mass of solution (W) = $222.6 + 200 = \mathbf{422.6 \text{ gram}}$

$$\text{Molality } (M) = \frac{n_B \times 1000}{W_A \text{ gram}} = \frac{222.6 \times 1000}{62 \times 200} = \mathbf{17.95 \text{ M}}$$

$$\text{Molarity } (M) = \frac{n_B \times 1000}{V_{MI}}$$

Or
$$= \frac{n_B \times d \times 1000}{W} \quad \left(d = \frac{W}{V}\right) \left(V = \frac{W}{d}\right)$$

$$M = \frac{222.6 \times 1.072 \times 1000}{62 \times 422.6} = \mathbf{9.1 \text{ M}}$$

S27. Given:

$$\text{Weight of solute in solution I}^{\text{st}} = \frac{25 \times 300}{100} = 75 \text{ gram}$$

$$\text{Weight of solute in solution II}^{\text{nd}} = \frac{40 \times 400}{100} = 160 \text{ gram}$$

$$\begin{aligned}\text{Weight \% of mixture} &= \frac{\text{Total weight of solute}}{\text{Total weight of solution}} \times 100 \\ &= \frac{75 + 160}{300 + 400} \times 100 = \mathbf{33.57\% \text{ Solute}}\end{aligned}$$

Hence, mass percentage of resulting solution

$$= 100 - 33.57 = \mathbf{66.43\% \text{ Solvent } (\text{H}_2\text{O})}$$

S28. (a) Given:

Weight of solute (W_B) = 30 gram

Volume of solution (V) = 4.3 L

$$M_B(\text{Ca}(\text{NO}_3)_2 \cdot 2\text{H}_2\text{O}) = 218 \text{ g mol}^{-1}$$

$$M = \frac{n_B \times 1000}{V(\text{ml})}$$

$$M = \frac{n_B}{V(\text{in Lit.})} = \frac{30}{218 \times 4.3} = \mathbf{0.032}.$$

(b) Change the M by Change the volume for same solute is:

$$M_1 V_1 = M_2 V_2$$

$$0.5 \times 50 = M_2 \times 500$$

$$M_2 = \frac{0.5 \times 50}{500} = \mathbf{0.05 \text{ M.}}$$

S29. Given:

$$M = 1.002 \text{ mol/kg}$$

And
$$X_B = \frac{n_B}{n_A + n_B}.$$

If molality is 1.002 mol/kg, we can take number of moles of solute (n_B) = 1.002 mol.

Weight of solvent = 1000 gram

And, solvent is H_2O , molar mass (M_B) = 18.

Hence, number of moles of solvent = $\frac{1000}{18} = \mathbf{55.5}$

i.e.,
$$X_B = \frac{1.002}{55.5 + 1.002} = \frac{1.002}{56.502} = \mathbf{0.017}.$$

S30. Given:

Weight of solvent (W_A) = 1 kg H_2O = 1000 g H_2O

Density of solution = 1.25 g/ml

Weight of solute (W_B) = 98 g (Na^+)

Molar weight (M_B) = 23.00 g mol⁻¹

$$\text{Molarity} = \frac{n_B \times 1000}{V}$$

$$\left(d = \frac{W}{V} \right)$$

or
$$= \frac{n_B \times d \times 1000}{W} = \frac{98 \times 1.25 \times 1000}{23 \times 1000} = \mathbf{5.32 \text{ mol/Lit.}}$$

S31. Given:

68% HNO_3 by mass means 68 g HNO_3 dissolve in 100 g solution

We know that

$$\therefore \text{Volume of solution} = \frac{\text{Mass of solution } (W)}{\text{Density } (d)} \left(\text{Density} = \frac{\text{Mass}}{\text{Volume}} \right) = \frac{100}{1.504} = 66.49 \text{ ml}$$

We know that

$$\text{Mass of solute } (W_B) = 68 \text{ g}$$

$$\text{Molar mass of solute } \text{HNO}_3 = 63 \text{ g mol}^{-1}$$

$$\text{Volume of solution} = 66.49 \text{ ml}$$

$$\text{Molarity } (M) = \frac{W_B \times d \times 1000}{M_B \times W} = \frac{68 \times 1.504 \times 1000}{63 \times 100} = \mathbf{16.23 \text{ M}}$$

S32. Given:

$$\text{Weight of solution } (W) = 214.2 \text{ gram}$$

$$\text{Weight of solute } (W_B) = 34.2 \text{ gram}$$

$$\text{Molar mass of sugar } (M_B) = 342 \text{ g/mol}$$

Mol fraction (X_B),

$$X_B = \frac{n_B}{n_A + n_B}$$

$$n_B = \frac{34.2}{342} = 0.1$$

$$n_A = \frac{180}{18} = 10 \text{ (Solvent is water, } M_A = 18)$$

$$X_B = \frac{0.1}{10 + 0.1} = \frac{0.1}{10.1} = \mathbf{0.0099}$$

$$\text{Molality } (M) = \frac{n_B \times 1000}{W_A}$$

Or

$$M = \frac{n_B \times 1000}{(W - W_B)} \times 1000$$

$$M = \frac{34.2 \times 1000}{342 (214.2 - 34.2)} = \frac{0.1 \times 1000}{180} = \mathbf{0.55 \text{ molal}}$$

S33. Given:

$$\text{Weight of solute } (W_B) = 2.5 \text{ g } (\text{K}_2\text{CO}_3)$$

$$\text{Molar weight of solute } (M_B) = 138 \text{ g/mol}$$

$$\text{Volume of solution } (V) = 1 \text{ Lit.} = 1000 \text{ ml}$$

$$\text{density of solution } (d) = 0.85 \text{ g/ml}$$

$$m = \frac{n_B}{W_A} \times 1000$$

$$n_B = \frac{W_B}{M_B} = \frac{2.5}{138} = 0.018$$

$$W_A = W - W_B \quad \left(d = \frac{W}{V} \right)$$

$$= (d \times V) - W_B \quad (W = d \times V)$$

$$= (0.85 \times 1000) - 2.5 = 850 - 2.5 = 847.50$$

i.e.,
$$m = \frac{0.018}{847.50} \times 1000 = \mathbf{0.021 \text{ mol Kg}^{-1}}$$

S34. According to question,

20% (mass/mass) of KI means 20 gm of KI is dissolved in 80 water. Molar mass of KI = 166 g mol⁻¹ (39 + 127).

(a) Molality of KI = $\frac{W_B \times 1000}{M_B \times W_A \text{ (gm)}} = \frac{20 \times 1000}{166 \times 80} = \mathbf{1.5 \text{ m}}$

(b) Molarity of KI = $\frac{W_B \times 1000 \times \text{Density}}{M_B \times \text{Solution in gram}} = \frac{20 \times 1000 \times 1.202}{166 \times 100} = \mathbf{1.44 \text{ M}}$

(c) No. of moles of KI = $\frac{20}{166} = \mathbf{0.12 \text{ mol}}$, No. of moles H₂O = $\frac{80}{18} = \mathbf{4.4 \text{ mol}}$

Mole fraction of KI (χ_{KI}) = $\frac{n_{\text{KI}}}{n_{\text{KI}} + n_{\text{H}_2\text{O}}} = \frac{0.12}{4.4 + 0.12}$, $\chi_{\text{KI}} = \frac{0.12}{4.52} = \mathbf{0.0265}$

S35. According to question,

20% C₂H₆O₂ by mass means 20 g ethylene glycol dissolve in 100 g solution.

So mass of solute glycol (W_B) = 20 g, Mass of solvent water (W_A) = 80 g

Molar mass of C₂H₆O₂ (M_B) = 62 g mol⁻¹, Molar mass of H₂O (M_A) = 18 g mol⁻¹

$$\text{Moles of C}_2\text{H}_6\text{O}_2 (n_{\text{glycol}}) = \frac{W_B}{M_B} = \frac{20}{62} = 0.322 \text{ mol}$$

$$\text{Moles of water } (n_{\text{water}}) = \frac{W_A}{M_A} = \frac{80}{18} = 4.444 \text{ mol}$$

$$\text{Mole fraction of glycol } (\chi_{\text{glycol}}) = \frac{n_{\text{glycol}}}{n_{\text{glycol}} + n_{\text{water}}} = \frac{0.322}{0.322 + 4.444} = 0.068$$

OR
$$\chi_{\text{glycol}} + \chi_{\text{water}} = 1$$

SO
$$\begin{aligned} \chi_{\text{water}} &= 1 - \chi_{\text{glycol}} \\ &= 1 - 0.068 = \mathbf{0.932}. \end{aligned}$$

S36. (a) Concentration of Chloroform = 15 ppm

$$15 \text{ ppm} = \frac{\text{Mass of chloroform}}{\text{Total mass of solution}}$$

Since mass of chloroform is negligible in comparison to total mass,

$$\text{Total mass} = \text{mass of water}$$

$$\therefore \frac{\text{Mass of chloroform}}{\text{Total mass}} = 15 \times 10^{-6}$$

$$\begin{aligned} \therefore \text{\% of chloroform} &= \frac{\text{Mass of chloroform}}{\text{Total mass}} \times 100 \\ &= 15 \times 10^{-6} \times 100 = \mathbf{15 \times 10^{-4}\%} \end{aligned}$$

(b) Now,
$$\frac{\text{Mass of chloroform}}{\text{Mass of water}} = 15 \times 10^{-6}$$

$$\text{Mass of chloroform} = 15 \times 10^{-6} \times \text{mass of water}$$

$$\text{No. of moles of chloroform} = \frac{15 \times 10^{-6} \times \text{mass of water}}{119.5}$$

$$\therefore \text{Molality} = \frac{\text{Moles of chloroform}}{\text{Mass of water}} = \mathbf{1.25 \times 10^{-4} \text{ m}}$$

S37. Given: 10% (w/w) solution of glucose means 10 g glucose dissolve in 100 g solution,

$$\text{Mass of solution (} W \text{)} = 100 \text{ g, Mass of solute (} W_B \text{)} = 10 \text{ g}$$

$$\text{Mass of solvent (} W_A \text{)} = 100 - 10 = 90 \text{ g}$$

$$\text{Molar mass of water (} M_A \text{)} = 18, \text{ Molar mass of } C_6H_{12}O_6 \text{ (} M_B \text{)} = 180 \text{ g mol}^{-1}$$

$$\text{Mole of water (} n_{H_2O} \text{)} = \frac{90}{18}, \text{ Mole of glucose (} n_{\text{glucose}} \text{)} = \frac{10}{180}$$

$$\text{Molality (} m \text{)} = \frac{W_B \times 1000}{M_B \times W_A} = \frac{10 \times 1000}{180 \times 90} = \mathbf{0.617 \text{ m}}$$

$$\text{Molarity (} M \text{)} = \frac{W_B \times 1000 \times d}{M_B \times W} = \frac{10 \times 1000 \times 1.2}{180 \times 100} = \mathbf{0.67 \text{ M}}$$

$$\left[\because \text{Density (} d \text{)} = \frac{\text{Mass (} M \text{)}}{\text{volume (} V \text{)}} \right]$$

$$\text{Mole fraction of glucose (} \chi_{\text{glucose}} \text{)} = \frac{n_{\text{glucose}}}{n_{H_2O} + n_{\text{glucose}}} = \frac{\frac{10}{180}}{\left(\frac{10}{180} + \frac{90}{18} \right)} = \mathbf{0.01}$$

or Mole fraction of water = (1 – mole fraction of glucose)
= (1 – 0.01) = **0.99**

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- Q1. Mixing of acetone with chloroform takes place with reduction in volume. What type of deviation from Raoult's law is shown in this case?
- Q2. Can we separate the components of azeotropic mixture by distillation?
- Q3. The dissolution of ammonium chloride in water is endothermic process. What is the effect of temperature on its solubility?
- Q4. Two liquids *A* and *B* are mixed and the resulting solution is found to be cooler. What do you conclude about deviation from ideal behaviour?
- Q5. Why is the vapour pressure of a liquid constant at a constant temperature?
- Q6. What happens to vapour of water if a tablespoon of sugar is added to it?
- Q7. At a certain temperature, the vapour pressure (in mm Hg) of CH_3OH and $\text{C}_2\text{H}_5\text{OH}$ solution is represented by $P = 119x + 135$ where x is the mole fraction of CH_3OH . What are the vapour pressures of pure components at this temperature?
- Q8. Two liquid *A* and *B* boil at 145°C and 190°C respectively. Which of these has higher vapour pressure at 80°C ?
- Q9. Give reasons, at higher altitudes, people suffer from a disease called anoxia. In this disease, they become weak and cannot think clearly.
- Q10. A solution of chloroform and acetone is an example of maximum boiling azeotrope, explain.
- Q11. *A* and *B* liquids on mixing produce a warm solution. Which type of deviation from Raoult's law is there?
- Q12. The vapour pressure of pure liquid at 50°C is 100 Nm^{-2} . Calculate the relative lowering of vapour pressure. The mole fraction of solvent in solution is 0.8.
- Q13. 50 ml of a liquid *X* mixed with 50 ml of liquid *Y*. The volume of resulting solution was found to be 99.9 ml. What do you conclude?
- Q14. What are azeotropes?
- Q15. What is Raoult's law? Explain in brief.
- Q16. Two liquid *A* and *B* has vapour pressure of 0.658 bar and 0.264 bar respectively, in an ideal solution of the two. Calculate the mole fraction of *B* at which the two liquids have equal partial pressure.
- Q17. An aqueous solution containing 28% by weight of a liquid. *A* (molecular weight = 140) has a vapour pressure of 0.210 bar at 37°C . Calculate vapour pressure of pure liquid (vapour pressure of water at $37^\circ\text{C} = 0.198\text{ bar}$).
- Q18. At 40°C the vapour pressure of water is 55.3 mm Hg. Calculate the vapour pressure at the same temperature over 10% aqueous solution of urea ($\text{H}_2\text{N} - \text{CO} - \text{NH}_2$).

- Q19.** The vapour pressure of pure liquids *A* and *B* are 450 and 700 mm Hg at 350 K respectively. Find out the composition of the liquid mixture if total vapour pressure is 600 mm Hg. Also find the composition of vapour phase.
- Q20.** The vapour pressure of water is 12.3 kPa at 300 K. Calculate vapour pressure of 1 molal solution of a non-volatile solute in it.
- Q21.** The vapour pressure of pure benzene at a certain temperature is 0.85 bar. A non-volatile, non-electrolyte solid weighing 0.5 g is added to 39.0 g of benzene (molar mass 78 g mol⁻¹) vapour pressure of the solution, then is 0.845 bar. What is the molar mass of the solid substance?
- Q22.** Vapour pressure of pure water at 25°C is 23.76 torr. The vapour pressure of solution containing 5.40 g of a non-volatile substance in 90.0 g water is 23.32 torr. Compute the molecular weight of solute.
- Q23.** Calculate the mol fraction of toluene in the vapour phase which is in equilibrium with a solution of benzene and toluene, where mol fraction of toluene is 0.500. The vapour pressure of pure benzene is 119 torr that of toluene is 37.0 torr at the same temperature.
- Q24.** Heptane and Octane form ideal solution. At 373 K, the vapour pressure of the two liquid components are 105.2 kPa and 46.8 kPa, respectively. What will be the vapour pressure of a mixture of 25.0 g of Heptane and 35.0 g of Octane?
- Q25.** 100 g of liquid *A* (molar mass of 140 g mol⁻¹) was dissolved in 1000 g of liquid *B* (molar mass 180 g mol⁻¹). The vapour pressure of pure liquid *B* was found to be 500 torr. Calculate the vapour pressure of pure liquid *A* and its vapour pressure in the solution if the vapour pressure of the solution is 475 torr.
- Q26.** Two liquid *A* and *B* on mixing form an ideal solution in two following composition.
- (a) In 1st composition 4 mol of *A* mix with 2 mol of *B* and vapour pressure of solution 750 mm of Hg.
- (b) In 2nd composition 6 mol of *A* mix with 2 mol of *B* and vapour pressure of solution 770 mm of Hg.
- What is pure vapour pressure of *A* and *B* of given temperature?
- Q27.** Benzene and toluene form ideal solution on over the entire range of composition. The vapour pressure of pure benzene and toluene at 300 K are 50.71 mm Hg and 32.06 mm Hg respectively. Calculate the mole fraction of benzene in vapour phase if 80 g benzene is mixed with 100 g of toluene.

- S1.** The solution has negative deviation from Raoult's law because decrease in volume indicates strong forces of interaction between the molecules in solution.
- S2.** No, we cannot separate the components of an azeotropic mixture by distillation because at a particular composition, both the components boil at the same temperature.
- S3.** Since dissolution of NH_4Cl in water is endothermic process, its solubility increases with rise in temperature (Le-Chatelier principle).
- S4.** The solution shows positive deviation from ideal behaviour.
- S5.** Vapour pressure is the pressure of the vapour at equilibrium state when rate of evaporation becomes equal to rate of condensation. Equilibrium constant does not change at a particular temperature and therefore, vapour pressure remains constant.
- S6.** Addition of non-volatile solute lowers the vapour pressure of solvent (water).
- S7.** For CH_3OH , $x = 1$, $\text{C}_2\text{H}_5\text{OH}$, $x = 0$
 $\therefore P = 119 + 135$
 $= 254 \text{ mm Hg}$
- For $\text{C}_2\text{H}_5\text{OH}$, $x = 1$, CH_3OH , $x = 0$
 $\therefore P = 119 \times 0 + 135 = 135$.
- S8.** Lower the boiling point, more volatile it is. Therefore, liquid A will have higher vapour pressure at 80°C .
- S9.** At high altitudes, the partial pressure of oxygen is less than that at the ground level. This leads to low concentration of oxygen in the blood and the tissues of the people living at high altitudes. As a result of low oxygen in the blood, the people become weak and unable to think clearly. These are the symptoms of a condition known as anoxia.
- S10.** The solution of chloroform and acetone has lower vapour pressure than ideal solution because of stronger interactions between chloroform and acetone molecules. As a result, total vapour pressure becomes less than the corresponding ideal solution of same composition (*i.e.*, negative deviations). Therefore, the boiling points of solutions are increased and form maximum boiling azeotropes.
- S11.** Negative deviation. Because $\Delta H = -\text{ve}$ means solvent and solute intermolecular bonding in solution become strong.

S12.

$$\frac{P_A^\circ - P_A}{P_A^\circ} = x_B$$

where,

x_B = Mole fraction of solute

$$\text{Mole fraction of solute} = 1 - 0.8 = 0.2$$

∴ Relative lowering of vapour pressure = 0.2.

S13. On mixing attraction forces between X and Y increases so final volume decreases. Solution shows negative deviation.

S14. Azeotropes are those liquid mixtures which boil at a constant temperature and distil over completely at the same temperature without change in composition.

S15. It states that for a solution of two or more miscible volatile liquids, the partial vapour pressure of each component of the solution at a given temperature is directly proportional to its mole fraction.

For solution of A and B

$$P_A \propto \chi_A$$

$$P_A = P_A^\circ \chi_A \quad (P_A^\circ \text{ pure vapour-pressure of solvent})$$

$$P_B \propto \chi_B$$

$$P_B = P_B^\circ \chi_B \quad (P_B^\circ \text{ pure vapour-pressure of solute})$$

$$P = P_A^\circ \chi_A + P_B^\circ \chi_B$$

When solution contains non-volatile solute then partial vapour pressure of solute is zero. In this state vapour pressure of solution is directly proportional to the mole fraction of solvent.

$$P_A \propto \chi_A$$

$$P_A = P_A^\circ \chi_A$$

or

$$P = P_A^\circ \chi_A$$

(P_B is zero)

S16. Pure vapour pressure of A = 0.658

Pure vapour pressure of B = 0.264

Let mole fraction of A = X_A

and, mole fraction of B = X_B

Both partial vapour pressure is equal. $P_A = P_B$

$$\text{i.e.,} \quad 0.658 \times X_A = 0.264 \times X_B$$

$$\text{or} \quad 0.658 (1 - X_B) = 0.264 X_B$$

$$0.658 - 0.658 X_B = 0.264 X_B$$

$$0.658 = 0.264 X_B + 0.658 X_B$$

$$0.658 = 0.922 X_B$$

$$\frac{0.658}{0.922} = X_B = \mathbf{0.713}$$

S17. Let weight of solution = 100 gram

weight of solute (W_B) = 28 gram

Molar mass of solute (M_B) = 140

Vapour pressure of solution = 0.210 bar

weight of solvent (W_A) = 100 – 28 = 72 gram

Molar mass of water (M_A) = 18

Vapour pressure of water = 0.198 bar

$$X_B = \frac{n_B}{n_A + n_B} = \frac{\frac{28}{140}}{\frac{28}{140} + \frac{72}{18}} = 0.047$$

Mol fraction of water (X_A) = 1 – 0.047 = 0.953

And, according to Raoult's law

$$P = P_A^\circ X_A + P_B^\circ X_B$$

$$0.210 = 0.198 \times 0.953 + P_B^\circ \times 0.047$$

$$0.210 - 0.189 = 0.047 P_B^\circ$$

$$\frac{0.021}{0.047} = P_B^\circ = \mathbf{0.446 \text{ bar}}$$

S18. Vapour pressure of pure water at 25°C, $P_A^\circ = 55.3 \text{ mm}$

Molecular mass of urea, $\text{CON}_2\text{H}_4 = 12 + 16 + 2 \times 14 + 4 \times 1$

$$= 12 + 16 + 28 + 4 = 60 \text{ g mol}^{-1}$$

10% aqueous urea solution means 10 gm of urea is present in 100 gm solution.

∴ Mass of water = 100 – 10 = 90 g

$$\text{No. of moles of urea} = \frac{10}{60} = 0.17 \text{ mol}$$

$$\text{No. of moles of water} = \frac{90}{18} = 5 \text{ mol}$$

$$\text{Mole fraction of water} = \frac{5}{5 + 0.17} = 0.967$$

∴ Vapour pressure of water over 10% aq. solution of urea = $P_{\text{water}}^\circ \times X_{\text{water}}$
= 55.3 × 0.967
= **53.48 mm Hg.**

S19. According to question,

$$P = 600 \text{ mm Hg}, P_A^\circ = 450 \text{ mm Hg}, P_B^\circ = 700 \text{ mm Hg}$$

For liquids A and B

$$P = P_A^\circ \chi_A + P_B^\circ \chi_B$$

So $P = P_A^\circ \chi_A + P_B^\circ (1 - \chi_A)$ [$\because \chi_A + \chi_B = 1$]

$$600 = 450 \times \chi_A + 700(1 - \chi_A)$$

$$600 = 450 \times \chi_A + 700 - 700 \chi_A$$

$$-250 \chi_A = -100$$

$$\chi_A = \frac{100}{250} = \mathbf{0.4}$$

We know $\chi_A + \chi_B = 1$

So, $\chi_B = (1 - \chi_A) = (1 - 0.4) = \mathbf{0.6}$

In Vapour Phase

$$\chi_A = \frac{P_A}{P_A + P_B} \Rightarrow \frac{P_A^\circ \chi_A}{P_A^\circ \chi_A + P_B^\circ \chi_B} = \frac{450 \times 0.4}{450 \times 0.4 + 700 \times 0.6}$$
$$= \mathbf{0.3}$$

$$\chi_B = (1 - \chi_A) = (1 - 0.3) = \mathbf{0.7}$$

S20. Given,

1 m solution means 1 mole solute is present in 1000 g solvent that is water.

$$\text{Number of mole of H}_2\text{O} = \frac{1000}{18} = 55.55 \text{ mol}$$

Total number of moles in the solution = $55.55 + 1.0 = 56.55 \text{ mol}$

$$\text{Mole fraction of water } (\chi_{\text{H}_2\text{O}}) = \frac{n_{\text{H}_2\text{O}}}{\text{Total mole of solution}} \Rightarrow \frac{55.55}{56.55} = \mathbf{0.98}$$

According to Raoult's law,

$$P_{\text{H}_2\text{O}} = P_{\text{H}_2\text{O}}^\circ \times \chi_{\text{H}_2\text{O}} = 12.3 \times 0.98 = \mathbf{12.08 \text{ kPa}}$$

S21. According to question,

$$P_A^\circ = 0.85 \text{ bar}, P_S = 0.845 \text{ bar}, M_A = 78 \text{ g mol}^{-1}, W_B = 0.5 \text{ g}, W_A = 39 \text{ g}$$

We know

$$\frac{P_A^\circ - P_S}{P_A^\circ} = \frac{W_B \times M_A}{M_B \times W_A}$$

$$\frac{0.850 \text{ bar} - 0.845 \text{ bar}}{0.850 \text{ bar}} = \frac{0.5 \text{ g} \times 78 \text{ g mol}^{-1}}{M_B \times 39 \text{ g}}$$

$$0.00588 = \frac{0.5 \text{ g} \times 78 \text{ g mol}^{-1}}{M_B \times 39 \text{ g}}$$

$$M_B = \frac{0.5 \text{ g} \times 78 \text{ g mol}^{-1}}{0.00588 \times 39 \text{ g}}$$

$$M_B = \mathbf{170 \text{ g mol}^{-1}}$$

S22. Vapour Pressure of pure water (P_A°) 23.76 torr

Vapour pressure of solution (P) = 23.32 torr

Weight of solute (W_B) = 5.40 gram

Weight of water (W_A) = 90 gram

According to Raoult's law

$$P = P_A^\circ X_A \quad \text{or} \quad P = P_A^\circ \times \frac{n_A}{n_A + n_B} \quad \dots (i)$$

and $n_A = 90/18$

Let $n_B = x$

then from Eq. (i), $23.32 = 23.76 \times \frac{5}{5 + x}$

$$\frac{23.32}{23.76} = \frac{5}{5 + x}$$

$$0.98 (5 + x) = 5 \quad \Rightarrow \quad 0.98 \times 5 + 0.98x = 5$$

$$x = \frac{0.10}{0.98} = 0.102$$

Number of moles of solute (n_B) = 0.102, $W_B = 5.40$ gram

Hence, $n_B = \frac{W_B}{M_B}$

or $M_B = \frac{W_B}{n_B} = \frac{5.40}{0.102} = \mathbf{52.94}$

S23. Mol fraction of toluene $X_T = 0.50$

Mol fraction of benzene $X_B = 1 - 0.50 = 0.50$

Vapour pressure of benzene $P_B^\circ = 119$ torr

Vapour pressure of toluene $P_T^\circ = 37$ torr

i.e., $P_T = 37 \times 0.50 = 18.5$ torr

$$P_B = 119 \times 0.50 = 59.5 \text{ torr}$$

Total vapour pressure = $59.5 + 18.5 = 78.0$ torr

Mole fraction of toluene in vapour phase

$$= \frac{\text{Vapour pressure of toluene}}{\text{Total vapour pressure}} = \frac{18.5}{78} = \mathbf{0.237}$$

S24. Given,

Mass of Heptane = 25 g, Mass of Octane = 35 g

Molar mass of Heptane $C_7H_{16} = 100 \text{ g mol}^{-1}$ ($7 \times 12 + 16 \times 1$)

Molar mass of Octane $C_8H_{18} = 114 \text{ g mol}^{-1}$ ($8 \times 12 + 18 \times 1$)

$$n_{\text{Hept}} = \frac{\text{Mass of Heptane}}{\text{Molar mass of Heptane}} \Rightarrow \frac{25}{100} = \mathbf{0.25}$$

$$n_{\text{Oct}} = \frac{\text{Mass of Octane}}{\text{Molar mass of Octane}} \Rightarrow \frac{35}{114} = \mathbf{0.307}$$

$$\text{Mole fraction of Heptane } (\chi_{\text{Hep}}) = \frac{\text{Mole of Heptane}}{\text{Mole of Heptane} + \text{Mole Octane}} \Rightarrow \frac{0.25}{0.557} = \mathbf{0.449}$$

$$\text{Mole fraction of Octane } (\chi_{\text{Oct}}) = (1 - \text{mole fraction of Heptane}) = 1 - 0.449 = \mathbf{0.551}$$

$$P_{\text{Total}} = P_{\text{Heptane}} + P_{\text{Octane}}$$

$$P_{\text{Total}} = P_{\text{Hep}}^\circ \times \chi_{\text{Hep}} + P_{\text{Oct}}^\circ \times \chi_{\text{Oct}}$$

$$= 105.2 \times 0.449 + 46.8 \times 0.551$$

$$= 47.23 + 25.78 = \mathbf{73.01 \text{ kPa}}$$

S25. Given,

Mass of liquid A = 100 g, Molar mass of A = 140 g mol^{-1} , Mass of liquid B = 1000 g,

Molar mass of B = 180 g mol^{-1}

$$\text{Mole} = \frac{\text{Mass}}{\text{Molar mass}}$$

$$\left[n = \frac{W}{M} \right]$$

$$\text{Mole of liquid (A)} n_A = \frac{100}{140} = 0.714$$

$$\text{Mole of liquid (B)} n_B = \frac{1000}{180} = 5.555$$

$$\text{Total moles in solution} = 5.555 + 0.714 = 6.269$$

$$\text{Mole fraction of (A)} \chi_A = \frac{\text{Mole of A}}{\text{Total moles in solution}} \Rightarrow \frac{0.714}{6.269} = \mathbf{0.114}$$

$$\text{Mole fraction of (B)} \chi_B = 1 - 0.114 = 0.886$$

$$P_{\text{total}} = P_A^\circ \chi_A + P_B^\circ \chi_B$$

$$475 = P_A^\circ \times 0.114 + 500 \times 0.886$$

$$P_A^\circ = \frac{475 - 0.886 \times 500}{0.114} = \mathbf{280.7 \text{ torr.}}$$

And

$$P_A = P_A^\circ \chi_A \Rightarrow 280.7 \times 0.114 = \mathbf{32 \text{ torr.}}$$

S26. (a) In 1st composition mol fraction of A and B is

$$\chi_A = \frac{4}{6} = \frac{2}{3} \quad \chi_B = \frac{2}{6} = \frac{1}{3}$$

And, according to Raoult's law

$$750 = \frac{2}{3} P_A^\circ + \frac{1}{3} P_B^\circ \quad \dots (i)$$

(b) In 2nd composition and mol fraction of A and B.

$$\chi_A = \frac{3}{4} \quad \chi_B = \frac{1}{4}$$

And, According to Raoult's law.

$$770 = \frac{3}{4} P_A^\circ + \frac{1}{4} P_B^\circ \quad \dots (ii)$$

Multiply Eq. (i) by 3 and Eq. (ii) with 4 and compare

$$\left(750 = \frac{2}{3} P_A^\circ + \frac{1}{3} P_B^\circ \right) \times 3$$

$$2250 = 2P_A^\circ + P_B^\circ \quad \dots (iii)$$

$$\left(770 = \frac{3}{4} P_A^\circ + \frac{1}{4} P_B^\circ \right) \times 4$$

$$3080 = 3P_A^\circ + P_B^\circ \quad \dots (iv)$$

From Eq. (iii) and (iv), we get

$$P_A^\circ = 3080 - 2250$$

$$\mathbf{830 \text{ MM of Hg}}$$

And, put the P_A° in Eq. (iii)

$$2250 = 2 \times 830 + P_B^\circ$$

$$P_B^\circ = 2250 - 1660 = \mathbf{590 \text{ mm of Hg}}$$

S27. According to question,

Mass of benzene = 80 g, Molar mass of benzene (C_6H_6) = 78 g mol^{-1} ($12 \times 6 + 1 \times 6$),

Mass of toluene = 100 g, Molar mass of toluene ($C_6H_5CH_3$) = 92 g mol^{-1} ($12 \times 7 + 1 \times 8$)

$$\text{Moles of benzene} = \frac{80}{78} = \mathbf{1.026 \text{ mol}}$$

$$\text{Moles of toluene} = \frac{100}{92} = \mathbf{1.086 \text{ mol}}$$

$$\chi_{\text{Benzene}} = \frac{\text{Mole of benzene}}{\text{Mole of benzene} + \text{Mole of toluene}}$$

$$\chi_{\text{Benzene}} = \frac{1.026}{1.026 + 1.068} = \mathbf{0.48}$$

$$\chi_{\text{Toluene}} = (1 - \chi_{\text{Benzene}})$$

$$= 1 - 0.48$$

$$= \mathbf{0.52}$$

$$\text{Total pressure of solution } P = P_{\text{Benzene}}^{\circ} \times \chi_{\text{Benzene}} + P_{\text{Toluene}}^{\circ} \times \chi_{\text{Toluene}}$$

$$P = 50.71 \times 0.48 + 32.06 \times 0.52$$

$$P = \mathbf{41.021}$$

Mole fraction of benzene in vapour phase

$$= \frac{\text{Partial pressure of benzene}}{\text{Total pressure of solution}}$$

$$= \frac{28.90}{41.012} = \mathbf{0.70}$$

- Q1. Why do gases nearly always tend to be less soluble in liquids as the temperature is raised?
- Q2. State the formula relating pressure of a gas with its mole fraction in liquid solution contact with it.
- Q3. At a same temperature, hydrogen is more soluble in water than helium. Which of them will have a higher value of K_H and why?
- Q4. State Henry's law and mention some of its important applications?

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S1. (a) > (d) > (c) > (e) > (b)

$\text{Ba}_3(\text{PO}_4)_2$ has 5 ions, hence i factor is greater. So freezing point is lower while $\text{C}_2\text{H}_5\text{OH}$ is covalent compound and i factor is 1 and freezing point is higher.

S2. $m_{\text{solute}} = 10 \text{ g}; M_{\text{solvent}} = 100 \text{ g}$

$$\Delta T_f = 0 - (-4.5) = 4.5 \text{ }^\circ\text{C}$$

$$M_{\text{solute}} (\text{KCl}) = 39 + 35.5 = 74.5$$

$$K_f = 1.86 \text{ }^\circ\text{C/mol}^{-1}$$

where,

$$\Delta T_f = i \cdot K_f \cdot m$$

$$= i \cdot K_f \cdot \frac{m_{\text{solute}} \times 1000}{M_{\text{solute}} \times m_{\text{solvent}}}$$

$$\therefore i = \frac{\Delta T_f \times M_{\text{solute}} \times m_{\text{solvent}}}{K_f \times m_{\text{solute}} \times 1000}$$

$$= \frac{4.5 \times 74.5 \times 100}{1.86 \times 10 \times 1000} = 1.80.$$

S3. Weight of solvent (W_A) = 100 gram

Weight of solute (W_B) = 10.0 gram

Molar weight of KCl (solute) = 74.5

Freezing point of solution = $-4.5 \text{ }^\circ\text{C}$

$$\Delta T_f = T_2 - T_1 \quad \text{or} \quad 0 - (-4.5) = 4.5$$

For KCl (complete dissociation) $m = 2$

$$\Delta T_f = i K_f m$$

$$i = \frac{\Delta T_f}{K_f m} = \frac{4.5}{1.86 \times 1.34} = 1.8$$

S4. We know,

$$\pi = iCRT$$

$$\therefore 4.5 = i \times 0.1 \times 0.0821 \times 300$$

$$i = \frac{4.5}{0.1 \times 0.0821 \times 300}$$

$$i = 1.83$$

∴ KNO_3 dissociates as, $\text{KNO}_3 = \text{K}^+ + \text{NO}_3^-$

$$m = 2$$

$$\text{Degree of dissociation, } \alpha = \frac{i - 1}{m - 1}$$

$$= \frac{1.83 - 1}{2 - 1}$$

$$= \mathbf{0.83 \text{ or } 83\% \text{ dissociation.}}$$

S5. Given,

$$\text{Weight of solvent } (W_A) = 1 \text{ kg}$$

$$\Delta T_f = 2 \text{ K}$$

$$K_{f \text{ Water}} = 1.86 \text{ K kg/mol}$$

$$M_B(\text{KCl}) = 74.5 (39 + 35.5) \text{ g mol}^{-1}$$

And, for complete dissociation, $i = m$

($m = \text{no. of ions}$)

$$(i = \text{KCl} = \text{K}^+ + \text{Cl}^- = 2)$$

$$\Delta T_f = i K_f m$$

$$\Delta T_f = i K_f \frac{W_B}{M_B \times W_A (\text{kg})}$$

$$2 = 2 \times 1.86 \times \frac{W_B}{74.5 \times 1 \text{ kg}}$$

$$W_B = \frac{74.5 \times 2}{2 \times 1.86} = 40.05 \text{ g.}$$

S6. For, $\text{K}_4[\text{Fe}(\text{CN})_6] = 4\text{K}^+ + [\text{Fe}(\text{CN})_6]^{4-}$

$$1 \quad 4 \quad 1$$

$$n = 4 + 1 = 5$$

and

$$\alpha = \frac{50}{100} = 0.5$$

From Van't Hoff's law

$$\begin{aligned}(\pi)_{Theo} &= \frac{n}{V}RT \\ &= \frac{1}{10 \times 1} \times 0.082 \times 300 = 0.0082 \times 300 \quad (\because T = 300 \text{ K})\end{aligned}$$

Now,
$$\frac{(\pi)_{Obs.}}{(\pi)_{Theo.}} = \frac{1 + (n - 1)\alpha}{1}$$

or
$$\frac{(\pi)_{Obs.}}{0.0082 \times 300} = \frac{1 + (5 - 1)0.5}{1} = \frac{1 + 4 \times 0.5}{1} = \frac{3}{1}$$

or
$$(\pi)_{Obs} = 0.0082 \times 3 \times 300 = \mathbf{7.38 \text{ atm}}$$

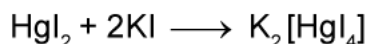
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- Q1. When mercuric iodide is added to an aqueous solution of KI the freezing point is raised, Why?
- Q2. 2 g each of two solutes A and B (molar mass of A > B) are dissolved separately in 50 g each of the same solvent. Which will show greater elevation in boiling point?
- Q3. Equimolar solutions of sodium chloride and glucose are not isotonic. Why?
- Q4. Outer hard shells of two eggs are removed. One of the eggs is placed in pure water and the other is placed in saturated solution of sodium chloride. What will be observed and why?
- Q5. Will the depression in freezing point be same or different if 0.1 mole of sugar or 0.1 mole of glucose is dissolved in one litre of water?
- Q6. Will the elevation in boiling point be same if 0.1 mole of sodium chloride or 0.1 mole of sugar is dissolved in 1 L of water?
- Q7. Explain why a person suffering from high blood pressure is advised to take less quantity of common salt?
- Q8. What would be the value of Vant Hoff's factor for a dilute solution of K_2SO_4 in water?
- Q9. Why does an azeotropic mixture distils without any change in composition?
- Q10. Arrange the following in increasing order of freezing point:
0.2M NaOH, 0.2M Na_2CO_3 , 0.1M $AgNO_3$, 0.1M $(NH_4)_2SO_4 \cdot FeSO_4 \cdot 6H_2O$.
- Q11. Will elevation in boiling point be same for 0.5 M NaCl and 0.5 M sucrose solution?
- Q12. What is reverse osmosis?
- Q13. $CaCl_2$ is used to clear snow from roads on hill stations. Explain.
- Q14. Cutting onions in winter is easier than in summer. Explain.
- Q15. Plants grown in marshy lands generally show bursting of root hair. Why?
- Q16. Define cryoscopic constant.
- Q17. State the condition resulting in reverse osmosis.
- Q18. Define molal elevation constant or ebullioscopic constant. Write the unit also.
- Q19. The depression in freezing point of water observed for the same amount of CH_3COOH , trichloroacetic acid and trifluoroacetic acid increases in the order given above. Explain briefly.
- Q20. The freezing point of a solution of 22 g of CCl_4 dissolved in 800 g of benzene is $4.59^\circ C$. The freezing point of benzene is $5.50^\circ C$. What is the molal freezing point depression constant for benzene?

- Q21. On dissolving 3.24 g of sulphur in 40 g of benzene boiling point of solution was higher than that of benzene by 0.81 K. K_b value of benzene is 2.53 K kg mol⁻¹. What is the molecular formula of sulphur? (Atomic mass of sulphur = 32 g mol⁻¹)
- Q22. How much sucrose, C₁₂H₂₂O₁₁ would have to be dissolved in 1000 g of water in order to raise the boiling point by 1°C? K_b for water is 0.52 Km⁻¹.
- Q23. Calculate the weight of a non-volatile solid of molecular mass 40, that should be dissolved in 100 g octane to reduce the vapour pressure to 20%.
- Q24. The osmotic pressure of a urea solution is 500 mm of Hg at 10°C. The solution is diluted and its temperature raised 25°C to. It is now found that the osmotic pressure of the solution is reduced to 105.3 mm Hg. Determine the extent of dilution of the solution.
- Q25. Calculate the osmotic pressure of a solution containing 4.0 g of a non-volatile (molecular mass 40 amu) per litre of solution at 27 °C ($R = 0.0821 \text{ L atm K}^{-1} \text{ mol}^{-1}$).
- Q26. An aqueous solution of organic compound containing 0.6 g in 21.7 g of water freezes at 272.187 K. What is the molecular mass of the organic compound? K_f for water is 1.86 K⁻¹ and freezing point of water is 273 K.
- Q27. A weak electrolyte, AB is 5% dissociated in aqueous solution. What is the freezing point of a 0.100 molal aqueous solution of AB? (For water K_f is 1.86 deg/molal)
- Q28. One litre aqueous solution of sucrose weighting 1015g is found to record osmotic pressure of 4.82 atm at 293 K. What is the molality of the sucrose solution? ($R = 0.821 \text{ L atm K}^{-1} \text{ mol}^{-1}$).
- Q29. Calculate the boiling point of a solution containing 2 g of the sucrose (C₁₂H₂₂O₁₁) dissolved in 100 g of H₂O. ($K_b = 0.52$)
- Q30. An aqueous solution of glucose containing 12 g of glucose in 100 g of water boils at 100.34°C. Calculate K_b for water in K mol⁻¹ Kg.
- Q31. Calculate the osmotic pressure in pascal exerted by a solution prepared by dissolving 1.0 g of polymer of molar mass 185,000 in 450 mL of water at 37 °C.
- Q32. Calculate the mass of ascorbic acid (Vitamin C, C₆H₈O₆) to be dissolved in 75 g of acetic acid to lower its melting point by 1.5°C. $K_f = 3.9 \text{ L kg mol}^{-1}$.
- Q33. Boiling point of water at 750 mm Hg is 99.63°C. How much sucrose is to be added to 500 g of water such that it boils 100°C?
- Q34. 200 cm³ of an aqueous solution of a portion contains 1.26 g of the protein. The osmotic pressure of such a solution at 300 K is found to be 2.57×10^{-3} bar. Calculate the molar mass of the protein.
- Q35. The boiling point of benzene is 353.23 K, when 1.80 g of a non-volatile solute was dissolved in 90 g of benzene, the boiling point is raised to 354.11 K. Calculate the molar mass of the solute. (K_b for benzene is 2.53 K kg mol⁻¹.)
- Q36. 18 g of glucose, C₆H₁₂O₆ is dissolved in 1 kg of water in a saucepan. At what temperature will the water boil at 1.013 bar? (K_b for water is 0.52 K kg mol⁻¹.)
- Q37. What is the weight of one mole of solute, 0.132 g of which in 29.70 g of C₆H₆ gave a freezing point depression of 0.108°C (K_f for C₆H₆ = 5.12 K Kg mol⁻¹).

- Q38. Assuming complete dissociation, calculate the expected freezing point of a solution prepared by dissolving 6 g of $\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$ (Glauber's salt) in 0.100 Kg of H_2O . (K_f for water = $1.86 \text{ K Kg mol}^{-1}$, Atomic masses; Na = 23, S = 32, O = 16, H = 1)
- Q39. An aqueous solution of 2 per cent non-volatile solute exerts a pressure of 1.004 bar at the normal boiling point of the solvent. What is the molecular mass of the solute?
- Q40. Define the term osmotic pressure. Describe how the molecular mass of a substance can be determined by a method based on measurement of osmotic pressure?
- Q41. A 0.1539 molal aqueous solution of cane sugar (mol. mass = 342 g mol^{-1}) has a freezing point 271 K while the freezing point of pure water is 273.15 K. What will be the freezing point of an aqueous solution containing 5 g of glucose, (Mol. mass = 180 g mol^{-1}) per 100 g of solution?
- Q42. Calculate the mass of a non-volatile solute (molecular mass 40 g mol^{-1}) which should be dissolved in 114 g octane to reduce its vapour pressure to 80%.
- Q43. Calculate the temperature at which a solution containing 54 g glucose, ($\text{C}_6\text{H}_{12}\text{O}_6$) in 250 g of water will freeze. (K_f for water = $1.86 \text{ K mol}^{-1} \text{ kg}$)
- Q44. Explain the following
- 0.5 M aqueous solution of sodium chloride show higher value of osmotic pressure than 0.5 M glucose solution at the same temperature.
 - $P_A^\circ > P_B^\circ$ at 25°C but boiling of liquid A is less than that of liquid B.
- Q45. Vapour pressure of water at 293 K is 17.535 mm Hg. Calculate the vapour pressure of water at 293 K when 25 g of glucose is dissolved in 450 g of water.
- Q46. The vapour pressure of pure water at 298 K is 23.8 mm Hg. If 50 g of urea (NH_2CONH_2) is dissolved in 850 g of water. Calculate the vapour pressure of water for this solution and its relative lowering.
- Q47. An aqueous solution containing 144 g of non-volatile solute having molecular formula $\text{C}_x\text{H}_{2x}\text{O}_x$ is prepared by using 180 g of water. If the solution boils at 101.24°C at one atm pressure. Find out the exact molecular formula of the compound. [$K_b(\text{water}) = 0.512^\circ\text{C kg mol}^{-1}$]
- Q48. A 5% solution (by mass) of cane sugar in water has freezing point of 271 K. Calculate the freezing point of a 5% glucose in water if freezing point of pure water is 273.15 K.
- Q49. (a) Urea forms an ideal solution in water. Determine the vapour pressure of an aqueous solution containing 10% by mass of urea at 40°C . [Vapour pressure of water at $40^\circ\text{C} = 55.3 \text{ mm of Hg}$]
 (b) Why is freezing point depression of 0.1 M sodium chloride solution nearly twice that of 0.1 M glucose solution?
- Q50. At 300 K, 36 g of glucose present per litre in its solution has an osmotic pressure of 4.98 bar. If the osmotic pressure of solution is 1.52 bar at the same temperature, what would be its concentration?
- Q51. Two elements A and B form compounds having molecular formula AB_2 and AB_4 . When dissolved in 20 g of C_6H_6 , 1 g of AB_2 , lowers the freezing point by 2.3 K, while 1.0 g of AB_4 , lowers it by 1.3 K. The molar depression constant for benzene is $5.1 \text{ K kg mol}^{-1}$. Calculate atomic masses of A and B.

S1. HgI_2 forms a complex with KI and therefore, the number of particles in solution decreases.



As a result, the depression in freezing point is less and hence the freezing point increases.

S2. Solution containing solute B will show greater elevation in boiling point because $\Delta T_b \propto \frac{1}{M}$.

S3. Sodium chloride gets dissociated to two ions (Na^+ and Cl^-) and exerts almost double osmotic pressure than glucose (which is non-electrolyte).

S4. The egg placed in water will swell due to osmosis of pure water into the egg. On the other hand, the egg placed in saturated solution of NaCl will shrink due to osmosis of water out of the egg. This is because osmosis always occurs from higher concentration of solvent to lower concentration of solvent.

S5. The depression in freezing point will be same in both the solutions because both are non-electrolytes and give same number of solute particles.

S6. The elevation in boiling point of 0.1 mole of NaCl and 0.1 mole of sugar dissolved in water will not be same. Elevation in boiling point is a colligative property and depends upon the number of solute particles. NaCl is ionic and gives more number of particles due to ionisation than sugar which consists of molecules.

S7. Our body fluids contain number of solutes. If more quantity of salt is consumed the concentration of Na^+ and Cl^- in body fluids will increase which in turn will increase the concentration of solutes in body fluids. This results in the higher osmotic pressure which may damage the blood cells.

S8. $i = 3$.

S9. Azeotropic mixture on boiling forms vapours in the same mole fraction of the two components as present in the liquid mixture.

S10. $0.2\text{M Na}_2\text{CO}_3 < 0.1\text{M (NH}_4)_2\text{SO}_4 \cdot \text{FeSO}_4 \cdot 6\text{H}_2\text{O} < 0.2\text{M NaOH} < 0.1\text{M AgNO}_3$.

S11. No, it will not be same. We know that colligative properties depend upon number of particles or ions. Sucrose is a molecular solid while NaCl is ionic, so in case of ionic solid number of particles are more than sucrose. Thus, the elevation in boiling point for 0.5 M NaCl solution will be more.

S12. When a solution is separated from the solvent by a semipermeable membrane. If the pressure applied to the solution side is more than the osmotic pressure, the solvent will flow from the solution to the solvent side. This phenomenon is called reverse osmosis. For example: Desalination.

S13. CaCl_2 is used to clear snow because it causes depression in freezing point, so ice melts into liquid state. Water flows easily and roads get cleared.

- S14.** Onion vapours have lower kinetic energy and movement at lower temperature so in winters we feel less onion vapours than summers.
- S15.** When plants are grown in marshy lands, due to osmosis water molecules come out from the plants so roots burst.
- S16.** It is the depression in freezing point when 1 mole of non-volatile solute is dissolved in 1000 g of solvent.
- S17.** The extra pressure to be applied on the solution side when the solution and solvent are separated by semipermeable membrane to stop osmosis.
- S18.** Molal elevation constant is the elevation in boiling point when 1 mole of a solute is dissolved in 1000 g of the solvent. It is denoted by K_b . The unit of K_b is $K \text{ kg mol}^{-1}$.
- S19.** This is because the acid strength of the given acid follows the order.

trifluoroacetic acid > trichloroacetic acid > acetic acid.

We know that fluorine is more electronegative than chlorine. So trifluoroacetic acid is stronger than trichloroacetic acid, while acetic is the weakest acid.

Greater the ions produced, greater is the depression in freezing point.

- S20.** Molecular mass of $\text{CCl}_4 = 12 + 4 \times 35.5 = 154 \text{ g/mol}$

$$\begin{aligned} \text{Molality, } m &= \frac{\text{Moles of solute}}{\text{Mass of solvent in Kg}} = \frac{\text{Mass of } \text{CCl}_4 / \text{Mol. mass of } \text{CCl}_4}{\text{Mass of solvent in Kg}} \\ &= \frac{22 / 154}{800 / 1000} = \frac{22 \times 1000}{154 \times 800} = 0.178 \text{ m} \end{aligned}$$

$$\Delta T_f = T_f^\circ - T_f = 5.50 - 4.59 = 0.91^\circ\text{C} = 0.91 \text{ K}$$

$$K_f = \frac{\Delta T_f}{m} = \frac{0.91}{0.178} = 5.11 \text{ K mol}^{-1} \text{ Kg.}$$

S21.

$$\begin{aligned} M_{\text{solute}} &= \frac{K_b \times W_{\text{solute}} \times 1000}{\Delta T_b \times W_{\text{solvent}}} \\ &= \frac{2.53 \times 3.24 \times 1000}{0.81 \times 40} = 253 \text{ g/mol} \end{aligned}$$

Atomic mass of sulphur = 32 g/mol

Molecular mass of $\text{S}_x = 253 \text{ g/mol}$

$$\therefore x = \frac{253}{32} = 7.91 = 8$$

Therefore, molecular formula of sulphur is S_8 .

S22. Molecular mass of sucrose, $(C_{12}H_{22}O_{11}) = 342 \text{ g mol}^{-1}$

$$\Delta T_b = T_b - T_b^\circ = K_b \cdot m$$

$$m = \frac{\Delta T_b}{K_b} = \frac{1^\circ \text{C}}{0.52 \text{ Km}^{-1}} = 1.923 \text{ m}$$

Mass of sucrose needed for 1000 g water

$$= \text{Molality} \times \text{Molecular mass} = 1.923 \times 342 = \mathbf{657.7 \text{ g}}$$

S23. Given, $M_B = 40$; $M_A = 114$; $W_A = 100 \text{ g}$; $P_A^\circ - P_A = 80$

and
$$\frac{P_A^\circ - P_A}{P_A^\circ} = \frac{W_B \times M_A}{M_B \times W_A}$$

$$\frac{80}{100} = \frac{W_B \times 114}{40 \times 100}$$

$$W_B = \frac{80}{100} \times \frac{100 \times 40}{114}$$

$$W_B = 28.07 \text{ g.}$$

S24.
$$\frac{\pi_1}{\pi_2} = \frac{C_1 T_1}{C_2 T_2}$$

or,
$$\frac{C_2}{C_1} = \frac{T_1}{T_2} \times \frac{\pi_2}{\pi_1} = \frac{283}{298} \times \frac{105.3}{500} = \frac{1}{5}$$

Hence, the solution has been diluted 5 times.

S25.
$$n = \frac{\text{Mass of solute}}{\text{Molecular mass of solute}} = \frac{4}{40} = 0.1 \text{ mol}$$

$$T = 273 + 27 = 300 \text{ K}$$

$$V = 1 \text{ litre}$$

We know,

$$\pi V = nRT$$

$$\therefore \pi = \frac{nRT}{V} = \frac{0.1 \times 0.0821 \times 300}{1} = \mathbf{2.46 \text{ atm.}}$$

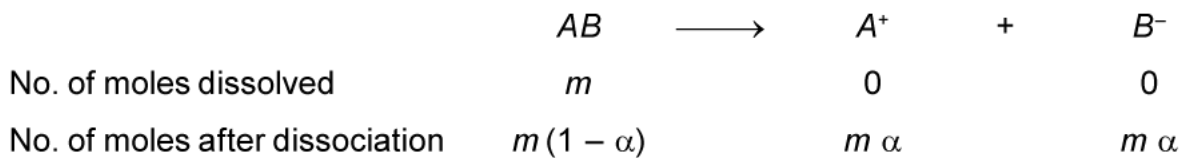
S26.
$$\Delta T_f = T_f^\circ - T_f$$

$$\Delta T_f = 273 - 272.187 = 0.813 \text{ K}$$

$$K_f = \frac{\Delta T_f}{m}$$

$$M_{\text{solute}} = \frac{K_f}{\Delta T_f} \times \frac{W_{\text{solute}} \times 1000}{W_{\text{solvent}}} = \frac{1.86 \times 0.6 \times 1000}{0.813 \times 21.7} = 63.26 \text{ g mol}^{-1}$$

S27. Degree of dissociation, α of $AB = \frac{5}{100} = 0.05$



$$\begin{aligned} \text{Total moles} &= m(1 - \alpha) + m\alpha + m\alpha \\ &= 0.1(1 - 0.05) + 0.1 \times 0.05 + 0.1 \times 0.05 = 0.105 \text{ m} \end{aligned}$$

$$\begin{aligned} \Delta T_f &= K_f \cdot m \\ &= 1.86 \times 0.105 = \mathbf{0.1953 \text{ degree.}} \end{aligned}$$

S28.

$$\pi V = \frac{W}{M} RT$$

$$\therefore W = \frac{\pi VM}{RT} = \frac{4.82 \times 1 \times 342}{0.0821 \times 293} = 68.53 \text{ g}$$

$$\begin{aligned} \text{Mass of the solvent} &= \text{Mass of solution} - \text{Mass of solute} \\ &= 1015 - 68.53 = 0.946 \text{ Kg} \end{aligned}$$

$$\text{Molality} = \frac{68.53}{342 \times 0.946} = \mathbf{0.205 \text{ m.}}$$

S29. Mol. wt of $C_{12}H_{22}O_{11} = 342$

Wt. of solute = 2 g

$T_1 = 373 \text{ K} = 100^\circ\text{C}$

$$\Delta T_b = K_b \cdot \frac{W}{m} \times \frac{1000}{W}$$

or $T_2 - 100 = 0.52 \times \frac{2}{342} \times \frac{1000}{100}$

$$= \frac{0.52 \times 2 \times 10}{342} = \frac{5.2 \times 2}{342} = \frac{10.4}{342}$$

$$T_2 - 100 = \frac{10.4}{342}$$

$$T_2 = \frac{10.4}{342} + 100 = \mathbf{100.03^\circ\text{C}}$$

S30. Given that,

$$m_{\text{solute}} = 12 \text{ g}$$

$$M_{\text{solvent}} = 100 \text{ g}$$

$$\Delta T_b = 100.34 - 100 = 0.34^\circ\text{C}$$

$$M_{\text{solute}} (\text{C}_6\text{H}_{12}\text{O}_6) = 180 \text{ g mol}^{-1}$$

We know,

$$\Delta T_b = K_b \cdot m = K_b \cdot \frac{m_{\text{solute}} \times 1000}{M_{\text{solute}} \times m_{\text{solvent}}}$$

$$\therefore K_b = \frac{\Delta T_b \times M_{\text{solute}} \times m_{\text{solvent}}}{m_{\text{solute}} \times 1000} = \frac{0.34 \times 180 \times 100}{12 \times 1000} = \mathbf{0.51 \text{ K mol}^{-1}\text{Kg.}}$$

S31. According to question,

$$W_B = 1 \text{ g}, \quad M_B = 185000 \text{ g mol}^{-1}, \quad V = 450 \times 10^{-3} \text{ L}, \quad R = 0.0821 \text{ lit atm K}^{-1} \text{ mol}^{-1}$$

$$\pi V = nRT$$

$$\pi = \frac{nRT}{V}$$

$$\pi = \frac{W_B \times R \times T}{M_B \times V} \quad \left[n = \frac{W_B}{M_B} \right]$$

$$\pi = \frac{1 \times 0.0821 \times 310}{185000 \times 450 \times 10^{-3}}$$

$$\pi = \frac{31 \times 0.0821}{45 \times 185} = 0.000305 \text{ atm} = \mathbf{36.95 \text{ Pa.}}$$

S32. According to question,

$$K_f = 3.9 \text{ K kg mol}^{-1}, \quad \Delta T_f = 1.5^\circ\text{C}, \quad W_A = 75 \text{ g},$$

$$\text{Molar mass of } \text{C}_6\text{H}_8\text{O}_6 = 176 \text{ g mol}^{-1} (12 \times 6 + 8 \times 1 + 16 \times 6)$$

$$\Delta T_f = \frac{K_f \times W_B \times 1000}{M_B \times W_A (\text{gm})}$$

$$1.5 = \frac{3.9 \times W_B \times 1000}{176 \times 75}$$

$$W_B = \frac{1.5 \times 176 \times 75}{3.9 \times 1000}$$

$$= \mathbf{5.07 \text{ g.}}$$

S33. According to question,

$$T_b^\circ = 99.63^\circ\text{C}, \quad T_b = 100^\circ\text{C}, \quad M_B = 342 \text{ g mol}^{-1}, \quad K_b = 0.52 \text{ Kg mol}^{-1}$$

$$\Delta T_b = T_b - T_b^\circ$$

$$= 100 - 99.63 = 0.37^\circ\text{C}$$

$$\Delta T_b = \frac{K_b \times W_B \times 1000}{M_B \times W_A(\text{gm})}$$

$$W_B = \frac{M_B \times W_A \times \Delta T_b}{1000 \times K_b}$$

$$W_B = \frac{342 \times 500 \times 0.37}{0.52 \times 1000}$$

$$W_B = \mathbf{121.7 \text{ g}}$$

S34. According to question,

$$\pi = 2.57 \times 10^{-3} \text{ bar}, \quad V = 200 \text{ cm}^3 = 0.2 \text{ L}, \quad T = 300 \text{ K}, \quad W_B = 1.26 \text{ g}$$

$$R = 0.083 \text{ L bar mol}^{-1} \text{ K}^{-1}$$

$$\pi V = nRT$$

$$\pi V = \frac{W_B RT}{M_B}$$

$$M_B = \frac{W_B RT}{\pi V}$$

$$= \frac{1.26 \times 0.083 \times 300}{2.57 \times 10^{-3} \times 0.2}$$

$$M_B = \mathbf{61038.91 \text{ g mol}^{-1}}$$

S35. According to question,

$$\Delta T_b = 354.11 - 353.23 = 0.88 \text{ K}, \quad W_B = 1.8 \text{ g}, \quad K_b = 2.53, \quad W_A = 90 \text{ g}$$

$$\Delta T_b = \frac{K_b \times W_B \times 1000}{M_B \times W_A(\text{gm})}$$

$$M_B = \frac{K_b \times W_B \times 1000}{W_A \times \Delta T_b}$$

$$M_B = \frac{2.53 \times 1.8 \times 1000}{0.88 \times 90}$$

$$M_B = \mathbf{58 \text{ g mol}^{-1}}$$

S36. According to question,

$$W_B = 18 \text{ g}, \quad M_B(\text{C}_6\text{H}_{12}\text{O}_6) = 12 \times 6 + 1 \times 12 + 6 \times 16 = 180 \text{ g mol}^{-1}, \quad W_A = 1 \text{ kg or } 1000 \text{ g},$$

$$K_b = 0.52 \times \text{kg mol}^{-1}$$

$$\Delta T_b = \frac{K_b \times W_B \times 1000}{M_B \times W_A(\text{gm})} = \frac{0.52 \times 18 \times 1000}{180 \times 1000}$$

$$\Delta T_b = 0.052 \text{ K}$$

$$\text{Boiling point } T_b = T_b^\circ + \Delta T_b = 373.15 + 0.052$$

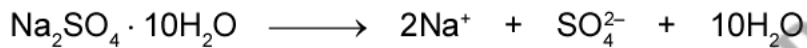
$$T_b = \mathbf{373.202 \text{ K.}}$$

S37. We know,

$$\Delta T_f = K_f \cdot m = K_f \cdot \frac{m_{\text{solute}} \times 1000}{M_{\text{solute}} \times m_{\text{solvent}}}$$

$$\therefore M_{\text{solute}} = K_f \cdot \frac{m_{\text{solute}} \times 1000}{\Delta T_f \times m_{\text{solvent}}} = \frac{5.12 \times 0.132 \times 1000}{0.108 \times 29.70} = \mathbf{210.69 \text{ g mol}^{-1}.$$

S38. Molecular mass of $\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O} = 2 \times 23 + 32 + 4 \times 16 + 10 \times 18$
 $= 322 \text{ g mol}^{-1}$



Van' Hoff factor, $i = 3$ [Where is solvent so not considered]

$$\text{Molality} = \frac{\text{Moles of solute}}{\text{Mass of solvent in Kg}} = \frac{6/322}{0.1}$$

$$\Delta T_f = i \cdot K_f \cdot m = 3 \times 1.86 \times \frac{6}{322 \times 0.1} = \mathbf{1.04 \text{ K}}$$

$$T_f = T - 1.04 = 273 - 1.04 = \mathbf{271.96 \text{ K.}}$$

S39. According to question,

$$P_A = 1.004 \text{ bar}, P_A^\circ = 1.013 \text{ bar}, W_B = 2 \text{ g}, W_A = 100 - 2 = 98 \text{ g}, M_A = 18 (\text{H}_2\text{O})$$

According to Raoult's Law:

$$\frac{P_A^\circ - P_A}{P_A^\circ} = \frac{W_B \times M_A}{M_B \times W_A(\text{gm})}$$

$$M_B = \frac{W_B \times M_A}{W_A} \times \frac{P_A^\circ}{P_A^\circ - P_A}$$

$$M_B = \frac{2 \times 18 \times 1.013}{98(1.013 - 1.004)}$$

$$M_B = \frac{2 \times 18 \times 1.013}{98 \times 0.009} = \mathbf{41.35 \text{ g mol}^{-1}.$$

S40. Osmotic pressure: Osmotic pressure (P) is the pressure which must be applied to the solution to prevent the movement of solvent from lower concentration to higher concentration through a semipermeable membrane

$$\pi V = nRT$$

$$\pi = \frac{nRT}{V}$$

$$\pi = \frac{W_B \times R \times T}{M_B \times V (\text{mL})}$$

$$M_B = \frac{W_B \times R \times T}{\pi \times V}$$

Thus, knowing the quantities

W_B = Mass of solute,

T = Temperature,

π = Osmotic pressure,

V = Volume of solution,

R = Constant.

We can calculate molar mass of the solute by osmotic pressure.

S41. Given, Mass of solute (W_B) = 5 g, Molar mass of glucose (M_B) = 180 g
 Mass of solution = 100 g, Mass of solvent (W_A) = 95 g
 $\Delta T_f = T_f^\circ - T_f = 273.15 - 271 = 2.15 \text{ K}$

$$m = \frac{W_B \times 1000}{M_B \times W_A (\text{gm})} = \frac{5 \times 1000}{180 \times 95} = 0.2923 \text{ mol Kg}^{-1}$$

$$\Delta T_f = K_f \times m$$

$$2.15 = K_f \times 0.2923$$

$$K_f = \frac{2.15}{0.1539} = 13.97$$

$$\Delta T_f = \frac{K_f \times W_B \times 1000}{M_B \times W_A (\text{gm})} = \frac{13.97 \times 5 \times 1000}{180 \times 95} = 4.08$$

$$T_f = T_f^\circ - \Delta T_f$$

$$\text{Freezing point} = 273.15 - 4.08 = 269.07 \text{ K.}$$

S42. According to question,

$$M_B = 40, W_A = 114 \text{ g}, M_A = 114 \text{ g mol}^{-1} (\text{C}_8\text{H}_{18}) (8 \times 12 + 1 \times 18)$$

Suppose the vapour pressure of pure octane = 100 bar and vapour pressure of octane = 80 bar

$$\frac{P_A^\circ - P_A}{P_A^\circ} = \frac{W_B \times M_A}{M_B \times W_A}$$

$$\frac{100 - 80}{100} = \frac{W_B \times 114}{40 \times 114}$$

$$W_B = \frac{100 - 80}{100} \times \frac{40 \times 114}{114} = 8 \text{ g}$$

S43. According to question,

Molecular mass of glucose ($C_6H_{12}O_6$) = 180 g mol^{-1} ($12 \times 6 + 12 \times 1 + 16 \times 6$)

$K_f = 1.86 \text{ K kg mol}^{-1}$, $W_B = 54 \text{ g}$, $M_B = 180 \text{ g mol}^{-1}$, $W_A = 250$

$$\Delta T_f = K_f \times m$$

$$\Delta T_f = \frac{K_f \times W_B \times 1000}{M_B \times W_A (\text{gm})} = \frac{1.86 \times 54 \times 1000}{180 \times 250} = 2.23 \text{ K}$$

Temperature at which solution freezes

$$T_f = 273.15 - 2.23 \text{ K} = 270.77 \text{ K}$$

S44. (a) NaCl ionises in aqueous solution as Na^+ and Cl^- . As a result concentration of particles in NaCl solution becomes more than 4.5 M glucose solution. Consequently, its osmotic pressure becomes larger than that exhibited by 0.5 M glucose solution.

(b) Since P_A° is greater than P_B° . This means that lesser amount of heat is required for liquid A so as to equalise its vapour pressure to atmospheric pressure. Consequently boiling point of A is lower than that of B.

S45. According to question,

Molar mass of glucose $C_6H_{12}O_6 = 180 \text{ g mol}^{-1}$ ($12 \times 6 + 12 \times 1 + 16 \times 6$),

$P_A = 17.535$, $M_B = 25 \text{ g}$, $W_A = 450 \text{ g}$

As we know for dilute solution

$$\frac{P_A^\circ - P_A}{P_A^\circ} = \frac{W_B \times M_A}{M_B \times W_A}$$

$$\frac{17.535 - P_A}{17.535} = \frac{25 \times 18}{180 \times 450}$$

$$\frac{17.535 - P_A}{17.535} = \frac{1}{180}$$

$$17.535 \times 180 - 180 P_A = 17.535$$

$$P_A = 17.44 \text{ mm of Hg.}$$

S46. According to question,

$W_B = 50 \text{ g}$, $M_B = 60 \text{ g mol}^{-1}$, $W_A = 850 \text{ g}$, $M_A = 18 \text{ g mol}^{-1}$

Molar mass of urea (NH_2CONH_2) = 60 g mol^{-1} ($14 + 2 + 12 + 16 + 14 + 2$)

$$\text{Number of moles of urea } \frac{W_B}{M_B} = \frac{50}{60} = \mathbf{0.83 \text{ mol.}}$$

$$\text{Number of moles of H}_2\text{O} = \frac{W_A}{M_A} = \frac{850}{18} = \mathbf{47.2 \text{ mol}}$$

$$\chi_{\text{urea}} = \frac{n_{\text{urea}}}{n_{\text{urea}} + n_{\text{H}_2\text{O}}} = \frac{0.83}{0.83 + 47.2} = \frac{0.83}{48.03} = 0.017$$

$$\frac{P_A^\circ - P_A}{P_A^\circ} = \chi_{\text{urea}}$$

Relative lowering of vapour pressure = 0.017

$$\frac{23.8 - P_A}{23.8} = 0.017$$

$$23.8 - P_A = 0.40$$

$$P_A = \mathbf{23.4 \text{ mm}}$$

S47. Given,

$$T_1 = \text{b.p. of H}_2\text{O} = 100^\circ\text{C}$$

$$T_2 = \text{b.p. of the solution} = 101.24^\circ\text{C}$$

\therefore

$$\Delta T_b = T_2 - T_1 = 101.24 - 100.00 = 1.24^\circ\text{C}$$

Now,

$$[m] = \frac{\Delta T_b}{K_b} = \frac{1.24^\circ\text{C}}{0.512^\circ\text{C kg mol}^{-1}} = 2.42 \text{ mol kg}^{-1}$$

... (i)

Since,

$$[m] = \frac{W_{\text{solute}}}{M_{\text{solute}}} \times \frac{1000}{W_{\text{solvent}}} = \frac{144}{M_{\text{solute}}} \times \frac{1000}{180}$$

or

$$2.42 = \frac{144}{M_{\text{solute}}} \times \frac{1000}{180}, \text{ from equation (i)}$$

or

$$M_{\text{solute}} = 330.5 \text{ g/mole.}$$

If the compound is represented by $\text{C}_x\text{H}_{2x}\text{O}_x$, its empirical formula will be CH_2O .

\therefore Empirical formula weight = 30

So,

$$x = \frac{\text{Molecular weight}}{\text{Empirical formula weight}} = \frac{330.5}{30}$$

Therefore, the molecular formula = $\text{C}_{11}\text{H}_{22}\text{O}_{11}$

S48. According to question,

5% glucose means 5 g glucose dissolve in 100 g solution

$$W_B = 5 \text{ g}, \quad W_A = (100 - 5) = 95 \text{ g}, \quad \Delta T_f = 273.15 - 271 = 2.15 \text{ K}, \quad M_B = 342 \text{ g mol}^{-1} \text{ (for sugar)}$$

$$\Delta T_f = \frac{K_f \times W_B \times 1000}{M_B \times W_A}$$

For sugar,
$$2.15 = \frac{K_f \times 5 \times 1000}{342 \times 95}$$

$$2.15 = K_f \times 0.154 \quad \dots (i)$$

For glucose,
$$\Delta T_f = \frac{K_f \times 5 \times 1000}{180 \times 95}$$

$$\Delta T_f = K_f \times 0.292 \quad \dots (ii)$$

Compare the equation (i) and (ii), we get

$$\frac{2.15}{\Delta T_f} = \frac{K_f \times 0.154}{K_f \times 0.292}$$

$$\Delta T_f = \frac{2.15 \times 0.292}{0.154} = 4.08 \text{ K}$$

Freezing point of glucose solution = $278.15 - 4.08$
 $= 269.07 \text{ K}$

S49. According to question,

(a) Given 10% by mass urea means 10 g of urea dissolve in 100 g solution

$$\text{Mass of urea } (W_B) = 10 \text{ g}$$

Molar mass of urea (NH_2CONH_2) = 60 g mol^{-1} ($14 + 2 + 12 + 16 + 14 + 2$)

$$\text{Mass of water} = 100 - 10 = 90 \text{ g}$$

$$\text{Molecular mass of } \text{H}_2\text{O} = 18 \text{ g mol}^{-1} (2 + 16)$$

$$\frac{P_A^\circ - P_S}{P_A^\circ} = \frac{W_B \times M_A}{M_B \times W_A}$$

$$\frac{55.3 - P_S}{55.3} = \frac{10 \times 18}{60 \times 90}$$

$$\frac{55.3 - P_S}{55.3} = \frac{1}{30}$$

$$30(55.3 - P_S) = 55.3$$

$$1659 - 30 P_S = 55.3$$

$$30 P_S = 1603.7$$

$$P_S = 53.45 \text{ mm of Hg}$$

(b) Sodium chloride dissolves in water to form two ions whereas glucose is non-electrolyte and remains in molecular form only.

S50. According to question,

$$\text{Osmotic Pressure} = 4.98 \text{ bar}, \quad W_B = 36 \text{ g}, \quad V = 1 \text{ litre}, \quad M_B = 180 \text{ g mol}^{-1} \quad (\text{Case I})$$

$$\text{Osmotic Pressure} = 1.52 \text{ bar}, \quad (\text{Case II})$$

For Case I:
$$\pi V = \frac{W_B}{M_B} RT$$

$$4.98 \times 1 = \frac{36}{180} \times R \times T$$

$$4.98 = 0.2 RT. \quad \dots (i)$$

For Case II:
$$1.52 = C \times R \times T$$

$$1.52 = CRT. \quad \dots (ii)$$

Dividing equation (ii) by (i), we get

$$\frac{1.52}{4.98} = \frac{CRT}{0.2 RT}$$

$$C = \frac{1.52 \times 0.2}{4.98}$$

$$C = 0.061 \text{ M}$$

S51. Suppose a and b are atomic mass of A and B respectively

For AB_2 : molecular mass = $a + 2b$

For AB_4 : molecular mass = $a + 4b$

For AB_2 :
$$\Delta T_f = \frac{K_f \times W_B \times 1000}{M_B \times W_A (\text{gm})}$$

$$2.3 = \frac{5.1 \times 1 \times 1000}{(a + 2b) \times 20}$$

For AB_2 :
$$a + 2b = 110.869 \text{ g mol}^{-1} \quad \dots (i)$$

For AB_4 :
$$\Delta T_f = \frac{K_f \times W_B \times 1000}{M_B \times W_A (\text{gm})}$$

$$1.3 = \frac{5.1 \times 1 \times 1000}{(a + 4b) \times 20}$$

For AB_4 :
$$(a + 4b) = 196.15 \text{ g mol}^{-1} \quad \dots (ii)$$

Now subtracting equation (i) and (ii), we get

$$4b - 2b = 196.15 - 110.869$$

$$2b = 85.28$$

$$b = 42.64 \text{ u}$$

The value of b , put in equation (i), we get

$$a + 2(42.64) = 110.869$$

$$a + 85.28 = 110.87$$

$$a = 110.87 - 85.28 = \mathbf{25.58 \text{ u}}$$

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- Q1. Arrange the following aqueous solution in order of increasing freezing point.
(a) 0.10 m C_2H_5OH (b) 0.10 m $Ba_3(PO_4)_2$ (c) 0.10 m Na_2SO_4
(d) 0.10 m KCl (e) 0.10 m Li_3PO_4 .
- Q2. The freezing point of a solution compound of 10 g of KCl in 100 g of water is $-4.5^\circ C$. Calculate the Van't Hoff Factor, i for this solution. (K_f for water = $1.86^\circ C m^{-1}$).
- Q3. Freezing point of a solution composed of 10.0 g of KCl in 100 g of water is $-4.5^\circ C$, calculate Van't Hoff factor (i) for this solution, ($K_f = 1.86^\circ C m^{-1}$).
- Q4. A 0.1 M solution of has an osmotic pressure of 4.5 atm at $27^\circ C$. Calculate the apparent degree of dissociation of the salt in this solution.
- Q5. Calculate the amount of KCl which must be added to 1 kg of water so that the freezing point is depressed by 2 K. Assume KCl is 100% dissociated.
 $K_{f\text{Water}} = 1.86 \text{ K kg/mol}$.
- Q6. A decimolar solution of $K_4[Fe(CN)_6]$ at 300 K is 50% dissociation. Calculate the osmotic pressure of the solution.

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S1. (a) > (d) > (c) > (e) > (b)

$\text{Ba}_3(\text{PO}_4)_2$ has 5 ions, hence i factor is greater. So freezing point is lower while $\text{C}_2\text{H}_5\text{OH}$ is covalent compound and i factor is 1 and freezing point is higher.

S2. $m_{\text{solute}} = 10 \text{ g}; M_{\text{solvent}} = 100 \text{ g}$

$$\Delta T_f = 0 - (-4.5) = 4.5 \text{ }^\circ\text{C}$$

$$M_{\text{solute}} (\text{KCl}) = 39 + 35.5 = 74.5$$

$$K_f = 1.86^\circ\text{C}/\text{mol}^{-1}$$

where,

$$\Delta T_f = i \cdot K_f \cdot m$$

$$= i \cdot K_f \cdot \frac{m_{\text{solute}} \times 1000}{M_{\text{solute}} \times m_{\text{solvent}}}$$

$$\therefore i = \frac{\Delta T_f \times M_{\text{solute}} \times m_{\text{solvent}}}{K_f \times m_{\text{solute}} \times 1000}$$

$$= \frac{4.5 \times 74.5 \times 100}{1.86 \times 10 \times 1000} = \mathbf{1.80}$$

S3. Weight of solvent (W_A) = 100 gram

Weight of solute (W_B) = 10.0 gram

Molar weight of KCl (solute) = 74.5

Freezing point of solution = $-4.5 \text{ }^\circ\text{C}$

$$\Delta T_f = T_2 - T_1 \quad \text{or} \quad 0 - (-4.5) = 4.5$$

For KCl (complete dissociation) $m = 2$

$$\Delta T_f = i K_f m$$

$$i = \frac{\Delta T_f}{K_f m} = \frac{4.5}{1.86 \times 1.34} = 1.8$$

S4. We know,

$$\pi = iCRT$$

$$\therefore 4.5 = i \times 0.1 \times 0.0821 \times 300$$

$$i = \frac{4.5}{0.1 \times 0.0821 \times 300}$$

$$i = 1.83$$

∴ KNO_3 dissociates as, $\text{KNO}_3 = \text{K}^+ + \text{NO}_3^-$

$$m = 2$$

$$\text{Degree of dissociation, } \alpha = \frac{i - 1}{m - 1}$$

$$= \frac{1.83 - 1}{2 - 1}$$

$$= \mathbf{0.83 \text{ or } 83\% \text{ dissociation.}}$$

S5. Given,

$$\text{Weight of solvent } (W_A) = 1 \text{ kg}$$

$$\Delta T_f = 2 \text{ K}$$

$$K_{f \text{ Water}} = 1.86 \text{ K kg/mol}$$

$$M_B(\text{KCl}) = 74.5 (39 + 35.5) \text{ g mol}^{-1}$$

And, for complete dissociation, $i = m$

($m = \text{no. of ions}$)

$$(i = \text{KCl} = \text{K}^+ + \text{Cl}^- = 2)$$

$$\Delta T_f = i K_f m$$

$$\Delta T_f = i K_f \frac{W_B}{M_B \times W_A (\text{kg})}$$

$$2 = 2 \times 1.86 \times \frac{W_B}{74.5 \times 1 \text{ kg}}$$

$$W_B = \frac{74.5 \times 2}{2 \times 1.86} = 40.05 \text{ g.}$$

S6. For, $\text{K}_4[\text{Fe}(\text{CN})_6] = 4\text{K}^+ + [\text{Fe}(\text{CN})_6]^{4-}$

$$1 \quad 4 \quad 1$$

$$n = 4 + 1 = 5$$

and

$$\alpha = \frac{50}{100} = 0.5$$

From Van't Hoff's law

$$\begin{aligned}(\pi)_{Theo} &= \frac{n}{V}RT \\ &= \frac{1}{10 \times 1} \times 0.082 \times 300 = 0.0082 \times 300 \quad (\because T = 300 \text{ K})\end{aligned}$$

Now,
$$\frac{(\pi)_{Obs.}}{(\pi)_{Theo.}} = \frac{1 + (n - 1)\alpha}{1}$$

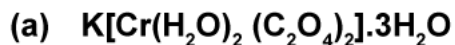
or
$$\frac{(\pi)_{Obs.}}{0.0082 \times 300} = \frac{1 + (5 - 1)0.5}{1} = \frac{1 + 4 \times 0.5}{1} = \frac{3}{1}$$

or
$$(\pi)_{Obs} = 0.0082 \times 3 \times 300 = \mathbf{7.38 \text{ atm}}$$

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- Q1. What is meant by the chelate effect? Give an example.
- Q2. What is meant by hexadentate ligand? Give one example. How is such ligand useful for measuring hardness of water?
- Q3. How does the metal carbonyls gain stability although CO is a weak donor?
- Q4. How is a double salt different from co-ordination compound?
- Q5. Describe one method of preparation of $\text{Ni}(\text{CO})_4$.
- Q6. Write all the possible isomers of $[\text{Pt}(\text{SCN})(\text{NH}_3)_3]\text{SCN}$.
- Q7. The formula $\text{Co}(\text{NH}_3)_5\text{CO}_3\text{Cl}$ could represent a carbonate or a chloride. Write the two possible structures and name them. What type of isomerisms do these exhibit?
- Q8. Draw the structural formula of two isomers of the complex ion $[\text{Co}(\text{NH}_3)_5\text{NO}_2]^{2+}$. Name the type of isomerism and give their IUPAC names.
- Q9. Specify the oxidation numbers of the metals in the following co-ordination entities:
- (a) $[\text{Co}(\text{CN})(\text{H}_2\text{O})(\text{en})_2]^{2+}$ (b) $[\text{PtCl}_4]^{2-}$ (c) $[\text{CrCl}_3(\text{NH}_3)_3]$
(d) $[\text{CoBr}_2(\text{en})_2]^+$ (e) $\text{K}_3[\text{Fe}(\text{CN})_6]$
- Q10. Discuss the nature of bonding in metal carbonyls.
- Q11. Define and explain:
- (a) Racemic mixtures (b) Co-ordination sphere.
- Q12. Discuss the role of complex compounds in areas of (a) electroplating (b) softening of water.
- Q13. Describe the important characteristic of bonding of alkene with transition metal in complexes.
- Q14. What is meant by unidentate, didentate and ambidentate ligands? Give two examples for each.
- Q15. Write the properties of metal carbonyl.
- Q16. Write the factors affecting the stability of a complex ion.
- Q17. A co-ordination compound has formula $\text{CoCl}_3 \cdot 4\text{NH}_3$ and octahedral geometry. It does not liberate ammonia but precipitates chloride ion as AgCl . Give IUPAC name of the complex and write its structural formula.
- Q18. Write the following:
- (a) Ionisation isomer of $[\text{Co}(\text{NH}_3)_5\text{Br}]\text{SO}_4$
(b) Linkage isomer of $[\text{Co}(\text{NH}_3)_5\text{ONO}]\text{Cl}_2$
(c) Coordination isomer of $[\text{Cu}(\text{NH}_3)_4][\text{PtCl}_4]$

Q19. Write down the IUPAC name for each of the following complexes and indicate the oxidation state, electronic configuration and coordination number. Also give stereochemistry and magnetic moment of the complex :

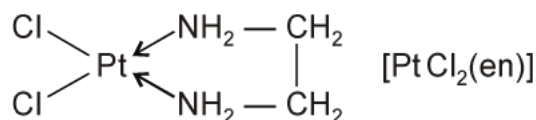


Q20. (a) What is ligand? Give an example of bidentate ligand.

(b) Explain as to how the two complex of nickel, $[\text{Ni}(\text{CN})_4]^{2-}$ and $\text{Ni}(\text{CO})_4$, have different structure, but do not differ in their magnetic behaviour ($\text{Ni} = 28$)

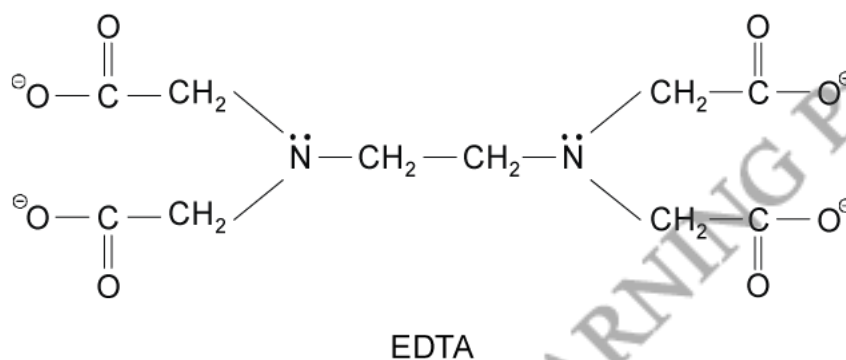
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- S1. When a didentate or polydentate ligand contains donor atoms positioned in such a way that when they co-ordinate with the central metal ion, a five or six membered ring is formed, the effect is called **chelate effect**.



- S2. Hexadentate ligand is a ligand which has 6 donor atoms, e.g., EDTA.

Four donor atoms are oxygen atoms carrying negative charge and two donor atoms are nitrogens carrying lone pairs of electrons.

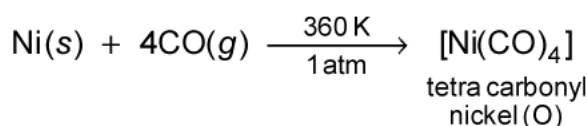


EDTA forms complex with $\text{Ca}^{2\oplus}$ and $\text{Mg}^{2\oplus}$, therefore, it is used for estimating hardness of water.

- S3. CO as a ligand bonds itself to metal atoms through the carbon atoms. It is a weak donor and a weak base. It forms a weak σ bond to the central atom. CO is also an acceptor ligand and forms π bond to the metal. This characteristic property of back bonding stabilises the metal ligand interaction.

Double Salts	Complex Salts
1. It retain their identity in solid state but lose their identity in solution state. 2. Example: $\text{K}_2\text{SO}_4 \cdot \text{Al}_2(\text{SO}_4)_3 \cdot 24\text{H}_2\text{O}$ Potash Alum $\longrightarrow 2\text{K}^+ + 2\text{Al}^{3+} + 4\text{SO}_4^{2-}$	1. They retain their identity in solid as well as solution in state. 2. Example: $\text{K}_4[\text{Fe}(\text{CN})_6]$ $\text{K}_4[\text{Fe}(\text{CN})_6] \longrightarrow 4\text{K}^+ + [\text{Fe}(\text{CN})_6]^{-4}$

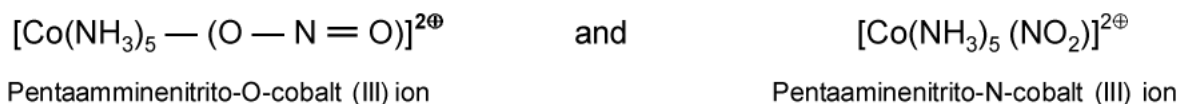
- S5. **Preparation of nickel tetracarbonyl $\text{Ni}(\text{CO})_4$:** It is prepared by passing CO gas over finely divided nickel powder at about 360 K.



- S6. $[\text{Pt}(\text{SCN})(\text{NH}_3)_3]\text{SCN}$
 $[\text{Pt}(\text{SCN})(\text{NH}_3)_3]\text{NCS}$
 $[\text{Pt}(\text{NCS})(\text{NH}_3)_3]\text{SCN}$
 $[\text{Pt}(\text{NCS})(\text{NH}_3)_3]\text{NCS}$

- S7. $[\text{CoCO}_3(\text{NH}_3)_5]\text{Cl}$ Pentaamminecarbonatocobalt (III) chloride.
 $[\text{CoCl}(\text{NH}_3)_5]\text{CO}_3$ Pentaamminechloridocobalt (III) carbonate; Ionization isomerism.

- S8. Two isomers :

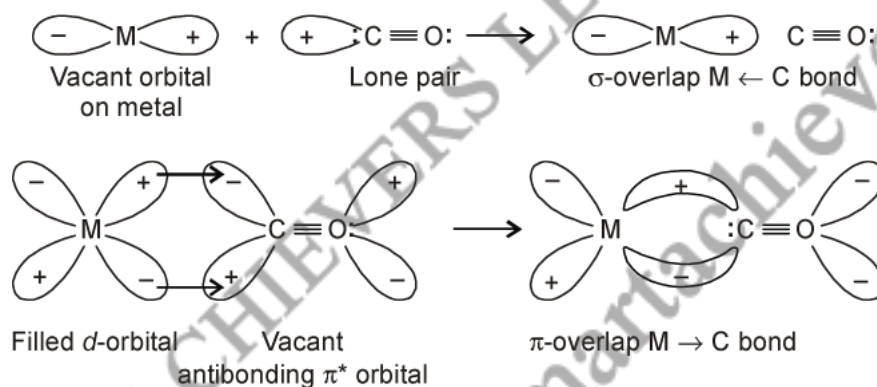


These are called linkage isomers.

- S9. (a) $x + (-1) + (0) + (0) = +2$ Co = +3 (III)
 (b) $x + 4(-1) = -2$ Pt = +2 (II)
 (c) $x + 3(-1) + 0 = 0$ Cr = +3 (III)
 (d) $x + 2(-1) + 0 = +1$ Co = +3 (III)
 (e) $x + 6(-1) = -3$ Fe = +3 (III)

- S10. Bonding in metal carbonyl is described by the following steps:

- (a) There is a donation of *lp* (lone pair) of electrons of carbon (CO) into the suitable empty orbital of the metal atom. This is a dative overlap and forms a sigma $\text{M} \leftarrow \text{C}$ bond (σ bond).



- (b) There is a π -overlap involving donation of electrons from filled metal *d*-orbitals into vacant antibonding π molecular orbitals of CO. This results into the formation of $\text{M} - \text{C}$, π bond. This is also called back donation. The metal to ligand bonding creates a synergic effect which strengthens the bond between CO and the metal.

- S11. (a) **Racemic mixtures:** The mixture having both *dextro*- and *levo*-optical isomers in 1 : 1 or 50% each ratio are called **racemic mixture**.
- (b) **Co-ordination sphere:** The central metal atom and ligand which are directly attached to it or enclosed in a square brackets and are collectively termed called **co-ordination sphere**. The ligand and metal atom inside the square brackets behave as a single constituent.

- S12.** (a) The complex compounds of silver and gold are used as the constituents of electroplating baths for the controlled delivery of metal ions for reduction. $K[Ag(CN)_2]$ and $K[Au(CN)_2]$ are used in electroplating of silver and gold respectively.
- (b) EDTA (ethylene diamine tetraacetate) is used for softening water as it forms complex compounds with Ca^{2+} and Mg^{2+} . Similarly, a complex, sodium hexa meta phosphate ($NaPO_3)_6$ or $Na_2NaP_6O_{18}$] is used to mask Ca^{2+} and Mg^{2+} making them ineffective in the solution. This is possible due to complex compound formation.

S13. The two steps involved in bonding of alkene with transition metal:

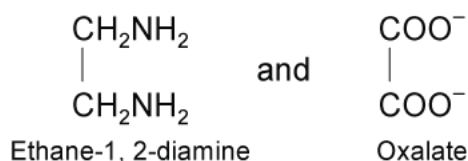
- (a) Delocalised π -electron density of alkene is donated into vacant d -orbital of metal atom forming alkene $\leftarrow M$ bond.
- (b) Back bonding results by the donation of filled d -orbitals on metal into vacant antibonding orbital of alkene. The important characteristic is this 'back-bonding' of electrons.

S14. Unidentate Ligand: A molecule or an ion which has only one donor atom to form one co-ordinate bond with the central metal atom is called **unidentate ligand**.

For examples: Cl^- , NH_3 , H_2O , CN^- etc.

Didentate Ligand: A molecule or an ion which contains two donor atoms and hence forms two co-ordinate bonds with the central metal atom is called a **didentate ligand**.

For example:



Ambidentate Ligand: A molecule or an ion which contains two donor atoms but only one of them forms a co-ordinate bond at a time with central metal atom is called **ambidentate ligand**.

For example: $—CN^-$: or $—NC^-$: and $—NO_2^-$ or $—ONO^-$.

- S15.** (a) Metal carbonyls are mostly solid at room temperature and pressure. Exceptions Fe and Ni carbonyl are liquid.
- (b) The mononuclear carbonyls are volatile and toxic.
- (c) With the exception of $[Fe_2(CO)]$, carbonyls are soluble in hydrocarbon solvent.
- (d) Reactivity of metal carbonyl depends on the central metal and the CO ligands.
- (e) Metal carbonyl use as industrial catalyst and as precursors in organic synthesis.
- S16.** (a) **Charge on the central metal ion:** In general, the greater the charge density on the central ion, the greater is the stability of (f) complexes.
- (b) **Size of metal ion:** As the size of metal ion decreases, the stability of the complex increases.
- (c) **Electronegativity or charge distribution of metal ion:**
- (i) Class a acceptors, which have fairly electropositive metals including the metal of group 1 and 2, inner transition metals and group 3 to 6 transition series form most stable co-ordination entities with ligands containing N, O, F donor atom.

- (ii) Class **b** acceptors which have much electropositive including heavy metals like Rh, Pd, Ag, Ir Au, Pb etc. having relatively full *d*-orbitals. These forms most stable co-ordination entities with ligands containing N, O, and F groups.

(d) **Chelating effect:** Chelating effect also show the more stability of complex ion.

S17. Co-ordination number of cobalt is 6. Ammonia and Cl both are monodentate ligand. In light of given information, it is clear that cobalt is in oxidation state of +3 and it forms co-ordination sphere with four NH₃ and two Cl⁻; third Cl⁻ forms ionisation sphere *i.e.*, formula of complex is [CoCl₂(NH₃)₄]Cl.

Its IUPAC name is: Tetraamminedichloridocobalt (III) chloride.

S18. (a) [Co(NH₃)₅SO₄]Br (b) [Co(NH₃)₅NO₂]Cl₂ (c) [Pt(NH₃)₄][CuCl₄]

S19. (a) K[Cr(H₂O)₂(C₂O₄)₂].3H₂O

IUPAC name : Potassium diaquadioxalato chromate (III) trihydrate.

O.S = +3, Cr(III) : *d*³

C.N. = 6

Stereochemistry = Octahedral,

Conf. : *t*_{2g}³

No. of unpaired electrons, *n* = 3 and Magnetic moment = $\sqrt{3(3+2)} = \sqrt{15} = 3.87$ BM

(b) CrCl₃(py)₃, IUPAC name : Trichloridotripyridinechromium (III)

O.S. = + 3, Cr (III) : *d*³

C.N. = 6

Stereochemistry = Octahedral,

Conf. : *t*_{2g}³

No. of unpaired electrons, *n* = 3 and Magnetic moment = $\sqrt{3(3+2)} = \sqrt{15} = 3.87$ BM

(c) K₄[Mn(CN)₆], IUPAC name : Potassium hexacyanomanganate (II)

O.S. = +2, Mn (II) : *d*⁵

C.N. = 6

Stereochemistry = Octahedral,

Conf. : *t*_{2g}⁵

No. of unpaired electrons, *n* = 1 and Magnetic moment = $\sqrt{1(1+2)} = \sqrt{3} = 1.732$ BM

(d) [Co(NH₃)₅Cl]Cl₂, IUPAC name : Pentaamminechloridocobalt (III) chloride

O.S. = +3, Co(III) : *d*⁶

Stereochemistry = Octahedral

Conf. : *t*_{2g}⁶

No. of unpaired electrons, *n* = 0 and Magnetic moment = 0

(e) $\text{Cs}[\text{FeCl}_4]$, IUPAC name : Cesium tetrachloridoferrate (III)

O.S. = +3, Fe (III) : d^5

Stereochemistry = Tetrahedral,

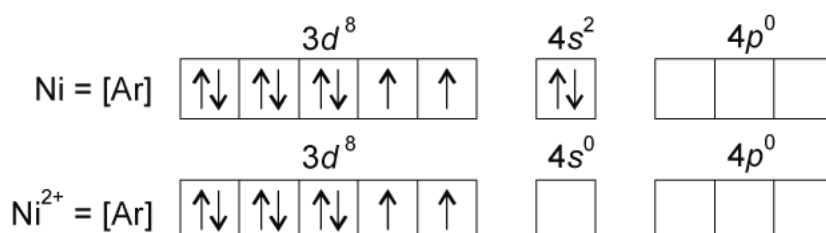
Conf. : e^2t^3

No. of unpaired electrons, $n = 5$ and Magnetic moment = $\sqrt{5(5+2)} = \sqrt{35} = 5.92 \text{ BM}$.

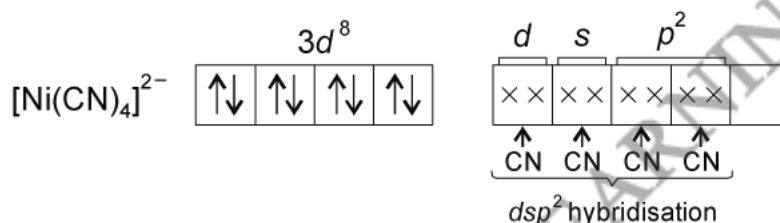
S20. (a) **Ligand:** The ions or molecules having lone pair bound to the central atom or ion in the co-ordination entity are called ligands.

Examples of bidentate ligand: ethane 1, 2-diammine, oxalate ion.

(b) $[\text{Ni}(\text{CN})_4]^{2-}$: Electronic configuration of Ni (28) = $[\text{Ar}] 4s^2, 3d^8$ oxidation state of Ni in $[\text{Ni}(\text{CN})_4]^{2-}$ is +2



Due to strong ligand CN start pairing of electrons in d -orbital

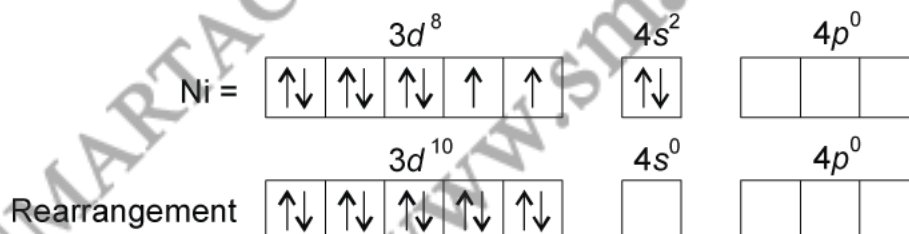


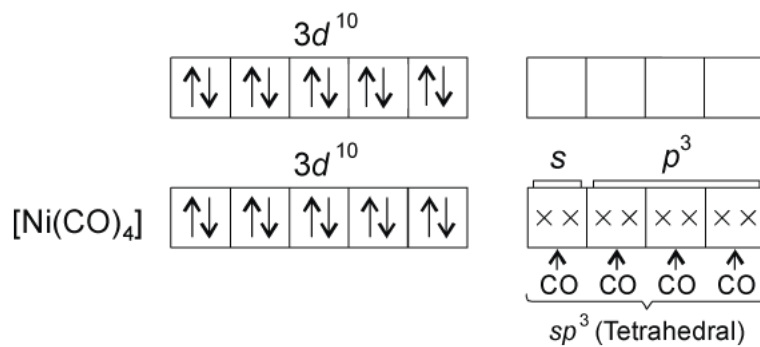
- So,
- Hybridisation = dsp^2
 - Shape = Square-planar
 - Magnetic property = Diamagnetic (Due to paired electrons)

$[\text{Ni}(\text{CO})_4]$: Electronic configuration of $_{28}\text{Ni}$ (28) = $1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 4s^2, 3d^8$

Oxidation state of Ni in $[\text{Ni}(\text{CO})_4]$ is zero.

Due the strong ligand CO start pairing in d -orbital





- So,
- Hybridisation = sp^3
 - Shape = Tetrahedral
 - Magnetic property = Diamagnetic (Due to paired electrons)

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