Solution

NCERT Intext Questions

Q. 1. Calculate the mass percentage of benzene (C_6H_6) and carbon tetrachloride (CCl_4) if 22 g of benzene is dissolved in 122 g of carbon tetrachloride.

Ans. $$\text{Mass percentage of benzene} = \frac{\text{Mass of benzene}}{\text{Mass of solution}} \times 100 = \frac{22\text{g}}{22\text{g} + 122\text{ g}} \times 100 = \mathbf{15.28\%}$$

$$\begin{aligned}\text{Mass percentage of carbon tetrachloride} &= 100 - \text{Mass percentage of benzene}\\ &= 100 - 15.28\\ &= \mathbf{84.72\%}\end{aligned}$$

Q. 2. Calculate the mole fraction of benzene in solution containing 30% by mass in carbon tetrachloride.

Ans. Let the mass of solution be 100 g.

Mass of benzene = 30 g,

∴ Mass of carbon tetrachloride = 100 g – 30 g = 70 g

$$\text{Number of moles of benzene} = \frac{\text{Mass}}{\text{Molar mass}} = \frac{30\text{ g}}{78\text{ g mol}^{-1}} = 0.385\text{ mol}$$

$$\text{Number of moles of carbon tetrachloride} = \frac{\text{Mass}}{\text{Molar mass}} = \frac{70\text{ g}}{154\text{ g mol}^{-1}} = 0.455\text{ mol}$$

$$\text{Mole fraction of benzene} = \frac{\text{Moles of benzene}}{\text{Moles of benzene} + \text{Moles of carbon tetrachloride}}$$

$$= \frac{0.385\text{ mol}}{0.840\text{ mol}} = \mathbf{0.458}$$

Q. 3. Calculate the molarity of each of the following solutions:

(*a*) 30 g of $Co(NO_3)_2 . 6H_2O$ in 4.3 L of solution

(*b*) 30 mL of 0.5 M H_2SO_4 diluted to 500 mL

Ans. (*a*) Mass of solute, $Co(NO_3)_2.6H_2O = 30$ g

Molar mass of $Co(NO_3)_2.6H_2O = 59 + 2(14 + 3 \times 16) + 6 \times 18 = 291\text{ g mol}^{-1}$

$$\text{Number of moles of } Co(NO_3)_2.6H_2O = \frac{\text{Mass}}{\text{Molar Mass}} = \frac{30\text{ g}}{291\text{ g mol}^{-1}} = 0.1\text{ mol}$$

Volume of solution = 4.3 L

$$\text{Molarity of solution} = \frac{\text{Number of moles of solute}}{\text{Volume of solution in litres}} = \frac{0.1\text{ mol}}{4.3\text{ L}} = \mathbf{0.023\text{ mol L}^{-1}}$$

(*b*) $M_1 = 0.5$ M $V_1 = 30$ mL

$M_2 = ?$ $V_2 = 500$ mL

Applying molarity equation, $M_1V_1 = M_2V_2$, we get

$0.5\text{ M} \times 30\text{ mL} = M_2 \times 500\text{ mL}$

$$M_2 = \frac{0.5 \times 30\text{ M}}{500} = \mathbf{0.03\text{ M}}$$

Alternatively,

Number of moles = Molarity × Volume of solution in litres

Number of moles of H_2SO_4 present in 0.5 M of 30 mL H_2SO_4 solution

$$= 0.5\text{ mol L}^{-1} \times 0.03\text{ L} = 0.015\text{ mol}$$

$$\text{Volume of solution} = 500\text{ mL} = \frac{500\text{ L}}{1000} = 0.5\text{ L}$$

$$\therefore \text{Molarity} = \frac{\text{Number of moles of solute}}{\text{Volume of solution in litres}} = \frac{0.015\text{ mol}}{0.5\text{ L}} = \mathbf{0.03\text{ mol L}^{-1}}$$

Q. 4. Calculate the mass of urea (NH_2CONH_2) required in making 2.5 kg of 0.25 molal aqueous solution.

Ans. Mass of required aqueous solution = 2.5 kg = 2500 g

0.25 molal aqueous solution of urea means 0.25 mole of urea is dissolved in 1000 grams of water.

Mass of water = 1000 g

Moles of urea = 0.25 mol

Molar mass of urea (H_2NCONH_2) = $4 \times 1 + 2 \times 14 + 1 \times 12 + 1 \times 16 = 60 \text{ g mol}^{-1}$

$$\text{Mass of urea} = \text{Number of moles of urea} \times \text{Molar mass of urea}$$

$$\therefore \quad \text{Mass of 0.25 moles of urea} = 0.25 \text{ mol} \times 60 \text{ g mol}^{-1} = 15 \text{ g}$$

Mass of solution = 1000 g + 15 g = 1015 g

$\because$ 1015 g of aqueous solution contains urea = 15 g

$$\therefore \text{ 2500 g of aqueous solution will require urea} = \frac{15 \text{ g}}{1015 \text{ g}} \times 2500 \text{ g} = \mathbf{36.95 \text{ g}}$$

Q. 5. Calculate (*i*) molality (*ii*) molarity and (*iii*) mole fraction of KI if the density of 20% (mass/mass) aqueous KI is 1.202 g mL^{-1}.

Ans. 20% (mass/mass) aqueous KI solution means that

Mass of KI = 20 g

Mass of solution = 100 g

$\therefore$ Mass of solvent (water) = 100 – 20 = 80 g

(*i*) Calculation of molality

$$\text{Molar mass of KI} = 39 + 127 = 166 \text{ g mol}^{-1}$$

$$n_{KI} = \frac{20 \text{ g}}{166 \text{ g mol}^{-1}} = 0.120$$

$$\text{Molality of solution} = \frac{n_{KI}}{W_{H_2O}} \times 1000 = \frac{0.120}{80} \times 1000 = \mathbf{1.5 \text{ m}}$$

(*ii*) Calculation of molarity

$$\text{Density of solution} = 1.202 \text{ g mL}^{-1}$$

$$\text{Volume of solution} = \frac{100 \text{ g}}{1.202 \text{ g mL}^{-1}} = 83.2 \text{ mL} = 0.0832 \text{ L}$$

$$\text{Molarity of solution} = \frac{n_{KI}}{\text{Volume of solution in L}} = \frac{0.120 \text{ mol}}{0.0832 \text{ L}} = \mathbf{1.44 \text{ M}}$$

Alternatively,

$$\text{Molarity} = \frac{\text{mass/mass } \% \times d \times 10}{\text{Molar mass of KI}} = \frac{20 \times 1.202 \times 10}{166} = \frac{240.4}{166} = \mathbf{1.45 \text{ M}}$$

(*iii*) Calculation of mole fraction of KI

$$n_{KI} = 0.120 \text{ mol}$$

$$n_{H_2O} = \frac{\text{Mass of water}}{\text{Molar mass of water}} = \frac{80 \text{ g}}{18 \text{ g mol}^{-1}} = 4.44 \text{ mol}$$

$$x_{KI} = \frac{n_{KI}}{n_{H_2O} + n_{KI}} = \frac{0.120 \text{ mol}}{4.44 \text{ mol} + 0.12 \text{ mol}} = \frac{0.120 \text{ mol}}{4.560 \text{ mol}} = \mathbf{0.0263}$$

Q. 6. H_2S, a toxic gas with rotten egg-like smell, is used for qualitative analysis. If the solubility of H_2S in water at STP is 0.195 m, calculate Henry's law constant.

Ans. 0.195 m aqueous solution of H_2S means 0.195 mole of H_2S is dissolved in 1000 g of water.

$$\text{Number of moles of water in 1000 g} = \frac{1000 \text{ g}}{18 \text{ g mol}^{-1}} = 55.55 \text{ mol}$$

Number of moles of H_2S = 0.195 mol

$$x_{H_2S} = \frac{n_{H_2S}}{n_{H_2S} + n_{H_2O}} = \frac{0.195 \text{ mol}}{0.195 \text{ mol} + 55.55 \text{ mol}} = \frac{0.195 \text{ mol}}{55.745 \text{ mol}} = 0.0035$$

According to Henry's law, $p_{H_2S} = K_H \times x_{H_2S}$

$\therefore \quad 0.987 \text{ bar} = K_H \times 0.0035$

$$K_H = \frac{0.987 \text{ bar}}{0.0035} = \mathbf{282\ bar}$$

Q. 7. Henry's law constant for CO_2 in water is 1.67×10^8 Pa at 298 K. Calculate the quantity of CO_2 in 500 mL of soda water when packed under 2.5 atm CO_2 pressure at 298 K.

Ans. $p_{CO_2} = 2.5 \text{ atm} = 2.5 \times 10^5$ Pa

$K_H = 1.67 \times 10^8$ Pa

According to Henry's law,

$$p_{CO_2} = K_H \times x_{CO_2}$$

$$\therefore \quad x_{CO_2} = \frac{p_{CO_2}}{K_H} = \frac{2.5 \times 10^5 \text{ Pa}}{1.67 \times 10^8 \text{ Pa}}$$

$$= 1.5 \times 10^{-3}$$

Mass of water = Density of water × Volume of water

= 1 g/mL × 500 mL = 500 g

Number of moles of water, (n_{H_2O})

$$= \frac{\text{Mass of water}}{\text{Molar mass}} = \frac{500 \text{ g}}{18 \text{ g/mol}} = 27.78 \text{ mol}$$

$$x_{CO_2} = \frac{n_{CO_2}}{n_{H_2O} + n_{CO_2}} = \frac{n_{CO_2}}{n_{H_2O}}$$

$$\Rightarrow \quad n_{CO_2} = x_{CO_2} \times n_{H_2O}$$

$$= 1.5 \times 10^{-3} \times 27.78 \text{ mol}$$

$$= 41.67 \times 10^{-3} \text{ mol}$$

Mass of CO_2 = Number of moles of CO_2 × Molar mass

$= 41.67 \times 10^{-3}$ mol × 44 g/mol

= **1.834 g**

Q. 8. The vapour pressure of pure liquids *A* and *B* are 450 and 700 mm Hg respectively at 350 K. Find out the composition of the liquid mixture if the total vapour pressure is 600 mm Hg. Also find the composition of the vapour phase.

Ans. According to Raoult's law,

$$p = p^\circ_A x_A + p^\circ_B x_B$$

$$= p^\circ_A x_A + p^\circ_B (1 - x_A) = p^\circ_B + (p^\circ_A - p^\circ_B) x_A$$

Here, $p^\circ_A = 450$ mm Hg; $p^\circ_B = 700$ mm Hg; $p = 600$ mm Hg

Substituting the values, we get

$$600 = 700 + (450 - 700) x_A$$

$$250 x_A = 100 \quad \text{or} \quad x_A = \frac{100}{250} = \mathbf{0.4}$$

Also, $x_A + x_B = 1$ or $x_B = 1 - x_A = 1 - 0.4 = \mathbf{0.6}$

$p_A = p^\circ_A x_A$ and $p_B = p^\circ_B x_B$

$p_A = 450 \text{ mm Hg} \times 0.4$ and $p_B = 700 \text{ mm Hg} \times 0.6$

$p_A = 180$ mm Hg and $p_B = 420$ mm Hg

In vapour phase,

Mole fraction of A, $$y_A = \frac{p_A}{p_A + p_B} = \frac{180 \text{ mm Hg}}{180 \text{ mm Hg} + 420 \text{ mm Hg}} = \mathbf{0.30}$$

Mole fraction of B, $$y_B = \frac{p_B}{p_A + p_B} = \frac{420 \text{ mm Hg}}{180 \text{ mm Hg} + 420 \text{ mm Hg}} = \mathbf{0.70}$$

Q. 9. Vapour pressure of pure water at 298 K is 23.8 mm Hg. 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.

Ans. Here, $p_A^o = 23.8$ mm Hg

$W_B = 50$ g, M_B (urea) $= 60$ g mol^{-1}

$W_A = 850$ g, M_A (water) $= 18$ g mol^{-1}

Applying Raoult's law, $$\frac{p_A^o - p_s}{p_A^o} = \frac{n_B}{n_A + n_B} = \frac{W_B/M_B}{W_A/M_A + W_B/M_B}$$

$$= \frac{50/60}{850/18 + 50/60}$$

$$= \frac{0.83}{47.22 + 0.83} = \frac{0.83}{48.05} = \mathbf{0.017}$$

Thus, relative lowering of vapour pressure = **0.017**

Substituting $p_A^o = 23.8$ mm Hg, we get

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

On solving we get,

$$p_s = \mathbf{23.40 \text{ mm Hg}}$$

Hence, vapour pressure of water in the solution is **23.4 mm Hg.**

Q. 10. 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 at 100°C?

Ans. Molecular mass of sucrose, $(C_{12}H_{22}O_{11})$, $M_B = 12 \times 12 + 22 \times 1 + 11 \times 16 = 342$ g mol^{-1}

Mass of water = 500 g

Elevation in boiling point, $\Delta T_b = 100\text{ °C} - 99.63\text{ °C} = 0.37\text{ °C} = 0.37$ K

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

$$W_B = \frac{0.37 \times 342 \times 500}{1000 \times 0.52} = \mathbf{122 \text{ g}}$$

Q. 11. Calculate the mass of ascorbic acid (Vitamin C, $C_6H_8O_6$) to be dissolved in 75 g of acetic acid to lower its melting point by 1.5°C. $K_f = 3.9$ K kg mol^{-1}. ***[CBSE 2020 (56/1/1)]***

Ans. Molecular mass of ascorbic acid, $M_B = 6 \times 12 + 8 \times 1 + 6 \times 16 = 176$ g mol^{-1}

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

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

$$= \frac{1.5 \times 176 \times 75}{3.9 \times 1000} = \mathbf{5.08 \text{ g}}$$

Q. 12. Calculate the osmotic pressure in pascals 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.

Ans. $$\pi = CRT = \frac{n_B}{V} RT$$

Number of moles of solute dissolved, $n_B = \dfrac{1.0\text{ g}}{185{,}000\text{ g mol}^{-1}} = \dfrac{1}{185{,}000}\text{mol}$

$V = 450\text{ mL} = 0.450\text{ L}$

$T = 37°\text{C} = 37 + 273 = 310\text{ K}$

$R = 8.314\text{ kPa K}^{-1}\text{ mol}^{-1} = 8.314 \times 10^3\text{ Pa L K}^{-1}\text{ mol}^{-1}$

Substituting these values in (*i*), we get

$$\pi = \frac{1}{185{,}000}\text{ mol} \times \frac{1}{0.45\text{ L}} \times 8.314 \times 10^3\text{ Pa L K}^{-1}\text{ mol}^{-1} \times 310\text{ K} = \mathbf{30.96\ Pa}$$

NCERT Exercises

Q. 1. Define the term solution. How many types of solutions are formed? Write briefly about each type with an example.

Ans. Refer to Points to remember 1 and 2.

Q. 2. Suppose a solid solution is formed between two substances, one whose particles are very large and the other whose particles are very small. What type of this solid solution is likely to be?

Ans. Interstitial solid solution.

Q. 3. Define the following terms

(*i*) mole fraction **(*ii*) molality**

(*iii*) molarity **(*iv*) mass percentage**

Ans. Refer to Points to remember 3.

Q. 4. Concentrated nitric acid used in the laboratory is 68% nitric acid by mass in aqueous solution. What should be the molarity of such a sample of the acid if the density of the solution is 1.504 g mL^{-1}?

Ans. Consider 100 g sample of HNO_3 solution. As solution is 68% (*w*/*w*),

∴ Mass of nitric acid = 68 g

Molar mass of $HNO_3 = 63\text{ g mol}^{-1}$

∴ Number of moles of solute, $HNO_3 = \dfrac{68}{63}\text{ mol} = 1.079\text{ mol}$

Density of solution = 1.504 g mL^{-1}

∴ Volume of solution $= \dfrac{\text{Mass}}{\text{Density}} = \dfrac{100\text{ g}}{1.504\text{ g mL}^{-1}} = 66.5\text{ mL} = 0.0665\text{ L}$

Molarity of the solution $= \dfrac{\text{Moles of the solute}}{\text{Volume of solution in L}} = \dfrac{1.079\text{ mol}}{0.0665\text{ L}} = \mathbf{16.23\ mol\ L^{-1}}$

Alternatively,

Molarity of the solution $= \dfrac{\text{mass/mass }\% \times d \times 10}{\text{Molar mass of }HNO_3} = \dfrac{68 \times 1.504 \times 10}{63} = \dfrac{1022.723}{63} = \mathbf{16.23\ M}$

Q. 5. A solution of glucose in water is labelled as 10 per cent 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}, what shall be the molarity of the solution? **[*CBSE (AI) 2014*]**

Ans. 10% w/w solution of glucose means 10 grams of glucose is present in 100 g of solution, *i.e.*, 90 g of water.

Number of moles of glucose $= \dfrac{10\text{ g}}{180\text{ g mol}^{-1}} = 0.055\text{ mol}$

Number of moles of water $= \dfrac{90\text{ g}}{18\text{ g mol}^{-1}} = 5\text{ mol}$

$$\text{Molality of the solution} = \frac{\text{Number of moles of glucose}}{\text{Mass of water (in kg)}} = \frac{0.055}{0.09\text{ kg}} = \mathbf{0.61\ mol\ kg^{-1}}$$

$$\text{Mole fraction of glucose, } x_{C_6H_{12}O_6} = \frac{n_{C_6H_{12}O_6}}{n_{C_6H_{12}O_6} + n_{H_2O}} = \frac{0.055\text{ mol}}{5\text{ mol} + 0.055\text{ mol}} = \mathbf{0.01}$$

$$\text{Mole fraction of water, } x_{H_2O} = 1 - x_{C_6H_{12}O_6} = 1.00 - 0.01 = \mathbf{0.99}$$

$$\text{Volume of 100 g glucose solution} = \frac{\text{Mass of solution}}{\text{Density of solution}}$$

$$= \frac{100\text{g}}{1.2\text{ g mL}^{-1}} = \frac{1000}{12}\text{ mL} = \frac{1}{12}\text{L}$$

$$\text{Molarity of the solution} = \frac{\text{Number of moles of glucose}}{\text{Volume of solution}} = \frac{0.055\text{ mol}}{\frac{1}{12}\text{L}} = \mathbf{0.660\ mol\ L^{-1}}$$

Q. 6. How many mL of a 0.1 M HCl are required to react completely with 1g mixture of Na_2CO_3 and $NaHCO_3$ containing equimolar amounts of both?

Ans. **To calculate the number of moles of the components in the mixture.**

Let Na_2CO_3 present in the mixture be x g

∴ $NaHCO_3$ present in the mixture = $(1 - x)$ g.

Molar mass of $Na_2CO_3 = 2 \times 23 + 12 + 3 \times 16 = 106\text{ g mol}^{-1}$

Molar mass of $NaHCO_3 = 23 + 1 + 12 + 3 \times 16 = 84\text{ g mol}^{-1}$

$$\therefore \quad n_{Na_2CO_3} = \frac{x}{106}\text{ mol}, \; n_{NaHCO_3} = \frac{1-x}{84}\text{ mol}$$

As mixture contains equimolar amounts of the two,

$$\therefore \quad \frac{x}{106} = \frac{1-x}{84} \quad \text{or} \quad 106 - 106x = 84x$$

$$\text{or} \quad x = \frac{106}{190} = 0.558\text{ g}$$

$$\text{Thus,} \quad \text{Moles of } Na_2CO_3 = \frac{0.558}{106} = 0.00526$$

$$\text{Moles of } NaHCO_3 = \frac{1 - 0.558}{84} = \frac{0.442}{84} = 0.00526$$

To calculate the moles of HCl required.

$$Na_2CO_3 + 2HCl \longrightarrow 2NaCl + H_2O + CO_2$$

$$NaHCO_3 + HCl \longrightarrow NaCl + H_2O + CO_2$$

1 mole of Na_2CO_3 requires HCl = 2 moles

∴ 0.00526 mole of Na_2CO_3 requires HCl = 0.00526 × 2 moles = 0.01052 moles

1 mol of $NaHCO_3$ requires HCl = 1 mol

∴ 0.00526 moles of $NaHCO_3$ requires HCl = 0.00526 moles

∴ Total HCl required = 0.01052 moles + 0.00526 moles = 0.01578 moles

To calculate volume of 0.1 M HCl.

0.1 moles of 0.1 M HCl are present in 1000 mL of HCl.

$$0.01578\text{ moles of 0.1 M HCl will be present in HCl} = \frac{1000}{0.1} \times 0.01578 = \mathbf{157.8\ mL}$$

Q. 7. A solution is obtained by mixing 300 g of 25% and 400 g of 40% solution by mass. Calculate the mass percentage of the resulting solution.

Ans. $$\text{300 g of 25\% solution contains solute} = \frac{300 \times 25}{100} = 75\text{ g}$$

$$\text{400 g of 40\% solution contains solute} = \frac{400 \times 40}{100} = 160\text{ g}$$

$$\text{Total mass of solute} = 160\text{ g} + 75\text{ g} = 235\text{ g}$$

$$\text{Total mass of solution} = 300\text{ g} + 400\text{ g} = 700\text{ g}$$

$$\%\text{ of solute in the final solution} = \frac{235}{700} \times 100 = \mathbf{33.5\%}$$

$$\%\text{ of solvent in the final solution} = 100 - 33.5 = \mathbf{66.5\%}$$

Q. 8. An antifreeze solution is prepared from 222.6 g of ethylene glycol, $C_2H_4(OH)_2$ and 200 g of water. Calculate the molality of the solution. If the density of the solution is 1.072 g mL^{-1}, then what shall be the molarity of the solution?

Ans. Mass of ethylene glycol = 222.6 g

Molar mass of ethylene glycol, $C_2H_4(OH)_2$ = 62 g mol^{-1}

$$\text{Number of moles of ethylene glycol} = \frac{222.6\text{ g}}{62\text{ g mol}^{-1}} = 3.59\text{ mol}$$

$$\text{Mass of water} = 200\text{ g} = 0.20\text{ kg}$$

$$\text{Molality of solution} = \frac{\text{Moles of ethylene glycol}}{\text{Mass of solvent (in kg)}} = \frac{3.59\text{ mol}}{0.20\text{ kg}} = \mathbf{17.95\ mol\ kg^{-1}}$$

$$\text{Total mass of the solution} = 222.6\text{ g} + 200\text{ g} = 422.6\text{ g}$$

$$\text{Volume of solution} = \frac{\text{Mass of solution}}{\text{Density of solution}} = \frac{422.6\text{ g}}{1.072\text{ g mL}^{-1}} = 394.2\text{ mL} = 0.3942\text{ L}$$

$$\text{Molarity of solution} = \frac{\text{Moles of ethylene glycol}}{\text{Volume of solution (in L)}} = \frac{3.59\text{ mol}}{0.3942\text{ L}} = \mathbf{9.1\ mol\ L^{-1}}$$

Q. 9. A sample of drinking water was found to be severely contaminated with chloroform, $CHCl_3$ which is supposed to be a carcinogen. The level of contamination was 15 ppm (by mass).

(*i*) Express this in percent by mass.

(*ii*) Determine the molality of chloroform in the water sample.

Ans. Let the mass of solution be 10^6 g.

Mass of solute, chloroform = 15 g

(*i*)
$$\%\text{ by mass of chloroform} = \frac{\text{Mass of chloroform}}{\text{Mass of solution}} \times 100$$

$$= \frac{15\text{ g}}{10^6\text{ g}} \times 100 = \mathbf{15 \times 10^{-4}\ \%}$$

(*ii*) Mass of solvent, water = $10^6\text{ g} - 15\text{ g} \approx 10^6\text{ g} \approx 10^3\text{ kg}$

$$\text{Number of moles of chloroform, } CHCl_3 = \frac{\text{Mass of chloroform}}{\text{Molar mass}} = \frac{15\text{ g}}{119.5\text{ g mol}^{-1}} = \mathbf{0.126\ mol}$$

$$\text{Molality of solution} = \frac{\text{Number of moles of chloroform}}{\text{Mass of water (in kg)}} = \frac{0.126\text{ mol}}{10^3\text{ kg}}$$

$$= \mathbf{1.26 \times 10^{-4}\ mol\ kg^{-1}}$$

Q. 10. What role molecular interaction play in the solution of alcohol and water?

Ans. There is intermolecular hydrogen bonding in alcohol as well as in water. On mixing, the magnitude of attractive forces tends to decrease. Due to decrease in attractive forces, the solution shows positive deviations from ideal behaviour. As a result, the solution will have higher vapour pressure and lower boiling point as compared to that of pure water and pure alcohol separately.

Q. 11. Why do gases always tend to be less soluble in liquid as the temperature is raised?

Ans.
$$\text{Gas} + \text{Liquid} \rightleftharpoons \text{Dissolved gas};\ \Delta H = -\text{ ve}$$

Dissolution of gas in liquid is an exothermic process. As the temperature is increased, according to the Le Chatelier's principle the equilibrium will shift backward. This results in decrease of solubility of gases in liquid.

Q. 12. State Henry's law and mention some important applications.

Ans. Refer to Points to remember 2(*c*).

Q. 13. The partial pressure of ethane over a solution containing 6.56×10^{-3} g of ethane is 1 bar. If the solution contains 5.00×10^{-2} g of ethane, then what shall be the partial pressure of the gas?

Ans. According to Henry's law, $m = K_H \times p$

Case I. $6.56 \times 10^{-3} \text{g} = K_H \times 1 \text{ bar}$

or, $K_H = 6.56 \times 10^{-3} \text{ g bar}^{-1}$

Case II. $5.00 \times 10^{-2} \text{ g} = (6.56 \times 10^{-3} \text{ g bar}^{-1}) \times p$

or
$$p = \frac{5.00 \times 10^{-2} \text{ g}}{6.56 \times 10^{-3} \text{ g bar}^{-1}} = \mathbf{7.62 \text{ bar}}$$

Q. 14. What is meant by positive and negative deviations from Raoult's law and how is the sign of $\Delta_{\text{mix}}H$ related to positive and negative deviations from Raoult's law?

Ans. Refer to Points to remember 5(*b*).

Q. 15. An aqueous solution of 2% non-volatile solute exerts a pressure of 1.004 bar at the normal boiling point of the solvent. What is the molar mass of the solute?

Ans. Vapour pressure of pure water at the boiling point ($p°$) = 1 atm = 1.013 bar

Vapour pressure of solution (p_s) = 1.004 bar

Mass of solute, $W_B = 2$ g

Mass of solution = 100 g

Mass of solvent, $W_A = 100 \text{ g} - 2 \text{ g} = 98$ g

Applying Raoult's law for dilute solution (being 2%)

$$\frac{p_A^{\circ} - p_s}{p_A^{\circ}} = x_B = \frac{n_B}{n_A + n_B} \simeq \frac{n_B}{n_A} = \frac{W_B/M_B}{W_A/M_A} = \frac{W_B}{M_B} \times \frac{M_A}{W_A}$$

$$\frac{(1.013 \text{ bar} - 1.004 \text{ bar})}{1.013 \text{ bar}} = \frac{2 \text{ g} \times 18 \text{ g mol}^{-1}}{M_B \times 98 \text{ g}}$$

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

Q. 16. Heptane and octane form an ideal solution. At 373 K, the vapour pressures of the two liquid components are 105.2 kPa and 46.8 kPa, respectively. What will be the vapour pressure of a mixture of 26.0 g of heptane and 35.0 g of octane?

Ans. Molar mass of heptane, $C_7H_{16} = 100 \text{ g mol}^{-1}$

Molar mass of octane, $C_8H_{18} = 114 \text{ g mol}^{-1}$

$$n_{C_7H_{16}} = \frac{26.0 \text{ g}}{100 \text{ g mol}^{-1}} = 0.26 \text{ mol}$$

$$n_{C_8H_{18}} = \frac{35.0 \text{ g}}{114 \text{ g mol}^{-1}} = 0.31 \text{ mol}$$

$$x_{C_7H_{16}} = \frac{n_{C_7H_{16}}}{n_{C_7H_{16}} + n_{C_8H_{18}}} = \frac{0.26}{0.26 + 0.31} = 0.456$$

$$x_{C_8H_{18}} = 1 - x_{C_7H_{16}}$$
$$= 1 - 0.456 = 0.544$$

$$p_{C_7H_{16}} = 105.2 \text{ kPa} \times 0.456$$
$$= 47.97 \text{ kPa}$$

$$p_{C_8H_{18}} = 46.8 \text{ kPa} \times 0.544 = 25.46 \text{ kPa}$$

$$p_{\text{total}} = p_{C_7H_{16}} + p_{C_8H_{18}}$$
$$= 47.97 + 25.46 = \mathbf{73.43 \text{ kPa}}$$

Q. 17. The vapour pressure of water is 12.3 kPa at 300 K. Calculate the vapour pressure of 1 molal solution of a non-volatile solute in it.

Ans. 1 molal solution means 1 mol of the solute is present in 1000 g of the solvent, H_2O (assuming the solution to be dilute).

$$n_{H_2O} = \frac{1000}{18} = 55.5 \text{ moles}$$

$$x_{\text{solute}} = \frac{1}{1+55.5} = 0.0177$$

Also, $$x_{\text{solute}} = \frac{p_A^o - p_s}{p_A^o} \Rightarrow 0.0177 = \frac{12.3 - p_s}{12.3}$$

or $$p_s = \mathbf{12.08\ kPa}$$

Q. 18. Calculate the mass of a non-volatile solute (molar mass 40 g mol^{-1}) which should be dissolved in 114 g octane to reduce its vapour pressure to 80%.

Ans. $p_s = 80\% \text{ of } p^o = \frac{80 \times p^o}{100} = 0.80\ p^o;\ n_B = \frac{W_B}{40}$ mol

$$n_{C_8H_{18}} = \frac{114 \text{ g}}{114 \text{ g mol}^{-1}} = 1 \text{ mol (Molar mass of } C_8H_{18} = 114 \text{ g mol}^{-1})$$

Now, $$\frac{p^o - p_s}{p^o} = x_B$$

$$\frac{p^o - 0.80p^o}{p^o} = \frac{n_B}{n_B + n_{C_8H_{18}}} = \frac{W_B/40}{W_B/40 + 1}$$

$$0.2\left(\frac{W_B}{40} + 1\right) = \frac{W_B}{40} \quad \text{or} \quad \frac{0.8\,W_B}{40} = 0.2$$

or $$W_B = \mathbf{10\ g}$$

Q. 19. A solution containing 30 g of a non-volatile solute exactly in 90 g of water has a vapour pressure of 2.8 kPa at 298 K. Further 18 g of water is then added to the solution, the new vapour pressure becomes 2.9 kPa at 298 K. Calculate (*i*) molar mass of the solute (*ii*) vapour pressure of water at 298 K.

Ans. (*i*) Suppose the molar mass of the solute = M_B g mol^{-1}

Number of moles of solute, $n_B = \frac{30}{M_B}$ mol

Number of solvent (water), $n_A = \frac{90 \text{ g}}{18 \text{ g mol}^{-1}} = 5$ mol

According to Raoult's law,

$$\frac{p_A^o - p_s}{p_A^o} = \frac{n_B}{n_A + n_B}, \text{ i.e., } \frac{p_A^o - 2.8}{p_A^o} = \frac{30/M_B}{5 + (30/M_B)}$$

or $$1 - \frac{2.8}{p_A^o} = \frac{30/M_B}{5 + (30/M_B)}$$

or $$\frac{2.8}{p_A^o} = 1 - \frac{30/M_B}{5 + (30/M_B)} = \frac{5 + 30/M_B - 30/M_B}{5 + (30/M_B)} = \frac{5}{5 + (30/M_B)}$$

or $$\frac{p_A^o}{2.8} = \frac{5 + (30/M_B)}{5} = 1 + \frac{6}{M_B} \qquad ...(i)$$

After adding 18 g of water,

Number of moles of water $(n_A) = \frac{108}{18} = 6$ mol

According to Raoult's law,

$$\therefore \quad \frac{p_A^o - 2.9}{p_A^o} = \frac{30/M_B}{6 + (30/M_B)}$$

$$\text{or} \quad 1 - \frac{2.9}{p_A^o} = \frac{30/M_B}{6 + (30/M_B)}$$

$$\text{or} \quad \frac{2.9}{p_A^o} = 1 - \frac{30/M_B}{6 + (30/M_B)} = \frac{6 + (30/M_B) - (30/M_B)}{6 + (30/M_B)} = \frac{6}{6 + (30/M_B)}$$

$$\text{or} \quad \frac{p_A^o}{2.9} = \frac{6 + (30/M_B)}{6}$$

$$\text{or} \quad \frac{p_A^o}{2.9} = 1 + \frac{5}{M_B} \qquad \text{...}(ii)$$

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

$$\frac{2.9}{2.8} = \frac{1 + (6/M_B)}{1 + (5/M_B)}$$

$$\text{or} \quad 2.9\left(1 + \frac{5}{M_B}\right) = 2.8\left(1 + \frac{6}{M_B}\right)$$

$$\text{or} \quad 2.9 + \frac{14.5}{M_B} = 2.8 + \frac{16.8}{M_B} \quad \text{or} \quad \frac{2.3}{M_B} = 0.1 \quad \text{or} \quad M_B = \mathbf{23\ g\ mol^{-1}}$$

(*ii*) Putting the value of M_B in equation (*i*), we get

$$\frac{p_A^o}{2.8} = 1 + \frac{6}{23} = \frac{29}{23}$$

$$\text{or} \quad p_A^o = \frac{29}{23} \times 2.8 = \mathbf{3.53\ kPa}$$

Q. 20. A 5% solution (by mass) of cane sugar in water has a freezing point of 271 K. Calculate the freezing point of a 5% glucose in water if the freezing point of pure water is 273.15 K.

Ans. Let the mass of solution = 100 g

∴ Mass of the cane sugar = 5 g

Mass of solvent, water = 100 g – 5 g = 95 g

$\Delta T_f = 273.15\ \text{K} - 271\ \text{K} = 2.15\ \text{K}$

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

$$K_f = \frac{2.15 \times 342 \times 95}{5 \times 1000} = \mathbf{13.97\ K\ kg\ mol^{-1}}$$

For 5% solution of glucose in water

$$\Delta T_f = \frac{K_f \times W_B \times 1000}{M_B \times W_A} = \frac{13.97 \times 5 \times 1000}{180 \times 95}$$

$$\Delta T_f = 4.08\ \text{K}$$

Freezing point of glucose solution, $T_f = \Delta T_f^o - \Delta T_f = 273.15\ \text{K} - 4.08\ \text{K} = \mathbf{269.07\ K}$

Q. 21. Two elements *A* and *B* form compounds having molecular formula AB_2 and AB_4. When dissolved in 20 g of benzene (C_6H_6). 1 g of AB_2 lowers the freezing point by 2.3 K whereas 1.0 g of AB_4 lowers it by 1.3 K. The molal depression constant for benzene is 5.1 K kg mol^{-1}. Calculate atomic masses of *A* and *B*.

Ans. We know,

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

$\therefore \quad M_{AB_2} = \dfrac{5.1 \times 1 \times 1000}{2.3 \times 20} = 110.87 \text{ g mol}^{-1}$

Similarly, $\quad M_{AB_4} = \dfrac{5.1 \times 1 \times 1000}{1.3 \times 20} = 196.15 \text{ g mol}^{-1}$

Suppose atomic masses of A and B are 'a' and 'b' respectively. Then

Molar mass of $AB_2 = a + 2b = 110.87 \text{ g mol}^{-1}$ ...(*i*)

Molar mass of $AB_4 = a + 4b = 196.15 \text{ g mol}^{-1}$ ...(*ii*)

Subtracting equation (*i*) from equation (*ii*), we get

$2b = 85.28$ or $b = 42.64$

Substituting the value of b in equation (*i*), we get

$a + 2 \times 42.64 = 110.87$ or $a = 25.59$

Thus, Atomic mass of A = **25.59 u**

Atomic mass of B = **42.64 u**

Q. 22. At 300 K, 36 g of glucose present in a litre of its solution has an osmotic pressure of 4.98 bar. If the osmotic pressure of the solution is 1.52 bar at the same temperature, what would be its concentration?

Ans. Osmotic pressure, $\pi = CRT$

First case:

$$\text{Number of moles of glucose, } C_6H_{12}O_6 = \frac{36 \text{ g}}{180 \text{ g mol}^{-1}} = 0.2 \text{ mol}$$

$$\text{Molar concentration of solution, } C = \frac{0.2 \text{ mol}}{1 \text{ L}} = 0.2 \text{ mol L}^{-1}$$

$$\therefore \quad 4.98 \text{ bar} = 0.2 \text{ mol L}^{-1} \times R \times 300 \text{ K} \quad ...(i)$$

Second case:

$$1.52 = C \times R \times 300 \text{ K} \quad ...(ii)$$

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

$$\frac{1.52 \text{ bar}}{4.98 \text{ bar}} = \frac{C \times R \times 300 \text{ K}}{0.2 \text{ mol L}^{-1} \times R \times 300 \text{ K}}$$

$$0.305 = \frac{C}{0.2 \text{ mol L}^{-1}}$$

or $\quad C = \mathbf{0.0610 \text{ mol L}^{-1}}$

Q. 23. Suggest the most important type of intermolecular interaction in the following pairs:
(*i*) *n*-hexane and *n*-octane (*ii*) I_2 and CCl_4 (*iii*) $NaClO_4$ and water (*iv*) methanol and acetone (*v*) acetonitrile (CH_3CN) and acetone (C_3H_6O).

Ans. (*i*) Dispersion or London forces as both are non-polar.

(*ii*) Dispersion or London forces as both are non-polar.

(*iii*) Ion–dipole interactions as sodium chlorate gives Na^+ and ClO_4^- ions and water is a polar molecule.

(*iv*) Dipole–dipole interactions as both are polar molecules.

(*v*) Dipole–dipole interactions as both are polar molecules.

Q. 24. Based on solute–solvent interactions, arrange the following in order of increasing solubility in *n*-octane and explain.

Cyclohexane, KCl, CH_3OH, CH_3CN

Ans. (*i*) Cyclohexane and *n*-octane both are non-polar. Hence, they will mix completely in all proportions.

(*ii*) KCl is an ionic compound whereas n-octane is non-polar. Hence, KCl will not dissolve at all in *n*-octane.

(*iii*) CH_3OH and CH_3CN both are polar but CH_3CN is less polar than CH_3OH. As *n*-octane is non-polar, CH_3CN will dissolve more than CH_3OH in *n*-octane.

Therefore, the order of solubility in *n*-octane will be KCl < CH_3OH < CH_3CN < Cyclohexane.

Q. 25. Amongst the following compounds, identify which are insoluble, partially soluble and highly soluble in water: *(i)* phenol, *(ii)* toluene, *(iii)* formic acid, *(iv)* ethylene glycol, *(v)* chloroform, *(vi)* pentanol.

Ans. *(i)* Partially soluble as it has non-polar C_6H_5 group and polar —OH group which can form hydrogen bond with water.

(ii) Insoluble as toluene is non-polar while water is polar.

(iii) Highly soluble as formic acid can form hydrogen bonds with water.

(iv) Highly soluble as ethylene glycol can form hydrogen bonds with water.

(v) Insoluble as chloroform despite its polarity, cannot form hydrogen bonds with water.

(vi) Partially soluble as —OH group is polar but the bulky C_5H_{11} part is non-polar.

Q. 26. If the density of some lake water is 1.25 g mL^{-1} and contains 92 g of Na$^+$ ions per kg of water, calculate the molality of Na$^+$ ions in the lake.

Ans. Number of moles of Na$^+$ ion $= \dfrac{92\text{ g}}{23\text{ g mol}^{-1}} = 4$ mol

$$\text{Molality of Na}^+\text{ ions} = \frac{\text{Number of moles of Na}^+\text{ ions}}{\text{Mass of water in kg}}$$

$$= \frac{4\text{ mol}}{1\text{ kg}} = 4\text{ mol kg}^{-1} = \mathbf{4\ m}$$

Q. 27. If the solubility product of CuS is 6 × 10^{-16}, calculate the maximum molarity of CuS in aqueous solution.

Ans. Maximum molarity of CuS in aqueous solution = Solubility of CuS in mol L^{-1}.

If S is the solubility of CuS in mol L^{-1} then

$$\begin{array}{ccccc} CuS & \rightleftharpoons & Cu^{2+} & + & S^{2-} \\ & & S & & S \end{array}$$

$$K_{sp} = [Cu^{2+}]\,[S^{2-}] = S \times S = S^2$$

∴ $S^2 = 6 \times 10^{-16}$

or $S = \sqrt{6 \times 10^{-16}} = \mathbf{2.45 \times 10^{-8}\ mol\ L^{-1}}$

Maximum molarity of CuS in aqueous solution = **2.45 × 10^{-8} mol L^{-1}**

Q. 28. Calculate the mass percentage of aspirin ($C_9H_8O_4$) in acetonitrile (CH_3CN) when 6.5 g of $C_9H_8O_4$ is dissolved in 450 g of CH_3CN.

Ans. Mass of solution = 6.5 g + 450 g = 456.5 g

$$\text{Mass \% of aspirin} = \frac{\text{Mass of aspirin}}{\text{Mass of solution}} \times 100 = \frac{6.5}{456.5} \times 100 = \mathbf{1.424\%}$$

Q. 29. Nalorphene ($C_{19}H_{21}NO_3$) 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.

Ans. 1.5 × 10^{-3} m solution means that 1.5 × 10^{-3} mole of nalorphene is dissolved in 1kg of water.

Molar mass of $C_{19}H_{21}NO_3$ = 19 × 12 + 21 + 14 + 48 = 311 g mol^{-1}

1.5 × 10^{-3} mole of $C_{19}H_{21}NO_3$ = 1.5 × 10^{-3} × 311 g = 0.467 g

∴ Mass of solution = 1000 g + 0.467 g = 1000.467 g

∴ Thus, for 0.467 g of nalorphene, solution required = 1000.467 g

Hence, for 1.5 × 10^{-3} g of nalorphene, solution required $= \dfrac{1000.467\text{g}}{0.467} \times 1.5 \times 10^{-3}\text{ g} = \mathbf{3.21\ g}$

Q. 30. Calculate the amount of benzoic acid (C_6H_5COOH) required for preparing 250 mL of 0.15 mol L^{-1} solution in methanol.

Ans.

$$\text{Molarity} = \frac{\text{Mass of solute/Molar mass}}{\text{Volume of solution (in litres)}}$$

$$\text{Mass of benzoic acid} = \text{Molarity} \times \text{Volume of solution} \times \text{Molar mass}$$

$$\text{Volume of solution} = 250\text{ mL} = \frac{250}{1000}\text{ L} = 0.25\text{ L}$$

$$\text{Molar mass of benzoic acid, } C_6H_5COOH = 7 \times 12 + 6 \times 1 + 2 \times 16 = 122\text{ g mol}^{-1}$$

$$\text{Mass of benzoic acid} = 0.15\text{ mol L}^{-1} \times 0.25\text{ L} \times 122\text{ g mol}^{-1} = \mathbf{4.575\text{ g}}$$

Q. 31. The depression in freezing point of water observed for the same amount of acetic acid, tri-chloroacetic acid and trifluoroacetic acid increases in the order as given. Explain briefly.

Ans. The depression in freezing points are in the order:

$$CH_3COOH < Cl_3CCOOH < F_3CCOOH$$

Fluorine, being the most electronegative, has the highest negative inductive effect. As a result of this, trifluoroacetic acid is the strongest acid while acetic acid is the weakest acid. Hence, trifluoroacetic acid ionises to the largest extent while acetic acid ionises to the minimum extent to give ions in their solutions in water. Greater the ions produced, greater is the depression in freezing point. Hence, the depression in freezing point is the maximum for the trifluoroacetic acid and minimum for acetic acid.

Q. 32. Calculate the depression in the freezing point of water when 10 g of $CH_3CH_2CHClCOOH$ is added to 250 g of water; $K_a = 1.4 \times 10^{-3}$, $K_f = 1.86$ K kg mol^{-1}.

Ans. Number of moles of $CH_3CH_2CHClCOOH = \dfrac{10\text{ g}}{122.5\text{ g mol}^{-1}} = 8.16 \times 10^{-2}$ mol

$$\text{Molality of the solution} = \frac{\text{No. of moles of solute}}{\text{Mass of solvent (in grams)}} \times 1000$$

$$= \frac{8.16 \times 10^{-2}}{250} \times 1000 = 0.3264\text{ mol kg}^{-1}$$

If α is the degree of dissociation of $CH_3CH_2CHClCOOH$, then

	$CH_3CH_2CHClCOOH \rightleftharpoons$	$CH_3CH_2CHClCOO^-$ +	H^+
Initial conc.	C mol L^{-1}	0	0
At equilibrium	$C(1-\alpha)$	$C\alpha$	$C\alpha$

$$K_a = \frac{C\alpha \,.\, C\alpha}{C(1-\alpha)} = C\alpha^2 \qquad \text{[Considering } (1-\alpha) = 1 \text{ for dilute solution]}$$

or $$\alpha = \sqrt{\frac{K_a}{C}} = \sqrt{\frac{1.4 \times 10^{-3}}{0.3264}} = 0.065$$

Calculation of van't Hoff factor:

	$CH_3CH_2CHClCOOH \rightleftharpoons$	$CH_3CH_2CHClCOO^-$ +	H^+
Initial moles	1	0	0
Moles at equilibrium	$1-\alpha$	α	α

Total number of mole of particles after dissociation $= 1 - \alpha + \alpha + \alpha = 1 + \alpha$

$$i = \frac{\text{Total number of moles of particles after dissociation}}{\text{Number of particles before dissociation}}$$

or, $$i = \frac{1+\alpha}{1} = 1 + \alpha = 1 + 0.065 = 1.065$$

$\therefore$ $$\Delta T_f = i\,K_f\,m$$

$$= (1.065)\,(1.86)\,(0.3264) = \mathbf{0.65\text{ K}}$$

Q. 33. 19.5 g of CH_2FCOOH is dissolved in 500 g of water. The depression in the freezing point observed is 1.0°C. Calculate the van't Hoff factor and dissociation constant of fluoroacetic acid.

OR

When 19.5 g of F—CH_2—COOH (Molar mass = 78 g mol^{-1}) is dissolved in 500 g of water, the depression in freezing point is observed to be 1°C. Calculate the degree of dissociation of F—CH_2—COOH.

(Given: K_f of water = 1.86 K kg mol^{-1}) **[*CBSE 2020 (56/3/1)*]**

Ans. **Calculation of van't Hoff factor (*i*):**

Number of moles of fluoroacetic acid $= \dfrac{19.5 \text{ g}}{78 \text{ g mol}^{-1}} = 0.25 \text{ mol}$

$$\text{Molality, } m = \frac{\text{Number of moles of fluoroacetic acid}}{\text{Mass of water in kg}} = \frac{0.25 \text{ mol}}{0.5 \text{ kg}}$$

$$= 0.5 \text{ mol kg}^{-1}$$

$$\Delta T_f = i \times K_f \times m \quad \Rightarrow \quad i = \frac{\Delta T_f}{K_f \times m}$$

Here, $\Delta T_f = 1.0$ K; $K_f = 1.86$ K kg mol^{-1}; $m = 0.5$ mol kg^{-1}

$$i = \frac{1.0 \text{ K}}{1.86 \text{ K kg mol}^{-1} \times 0.5 \text{ mol kg}^{-1}} = \mathbf{1.0753}$$

Calculation of dissociation constant, K_a:

$$FCH_2COOH \rightleftharpoons FCH_2COO^- + H^+$$

	FCH_2COOH	FCH_2COO^-	H^+
Initial conc.	0.5	0	0
At equilibrium	$0.5(1-\alpha)$	$0.5\,\alpha$	$0.5\,\alpha$

$$\text{Total} = 0.5\,(1+\alpha)$$

$$i = \frac{0.5(1+\alpha)}{0.5} = 1 + \alpha \quad \text{or} \quad \alpha = i - 1 = 1.0753 - 1 = 0.0753$$

$$K_a = \frac{0.5\alpha + 0.5\alpha}{0.5\,(1-\alpha)} = \frac{0.5\,\alpha^2}{1-\alpha} = \frac{0.5 \times (0.0753)^2}{1 - 0.0753}$$

$$K_a = \mathbf{3.07 \times 10^{-3}}$$

Q. 34. **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.**

Ans. $p_A^0 = 17.535$ mm Hg; $W_B = 25$ g; $W_A = 450$ g; $M_B = 180$ g mol^{-1}; $M_A = 18$ g mol^{-1}

Substituting the values in the expression

$$\frac{p_A^\circ - p_s}{p_A^\circ} = \frac{W_B \times M_A}{M_B \times W_A}, \text{ we get}$$

$$\frac{17.535 - p_s}{17.535} = \frac{25 \times 18}{180 \times 450} \quad \text{or} \quad 1 - \frac{p_s}{17.535} = \frac{1}{180}$$

$$\frac{179}{180} = \frac{p_s}{17.535} \quad \text{or} \quad p_s = \mathbf{17.44 \text{ mm Hg}}$$

Q. 35. **Henry's law constant for the molality of methane in benzene at 298 K is 4.27×10^5 mm Hg. Calculate the solubility of methane in benzene at 298 K under 760 mm Hg.**

Ans. Here, $K_H = 4.27 \times 10^5$ mm Hg,

$p = 760$ mm Hg

According to Henry's law, $p = K_H \times x_{CH_4}$

$$\therefore \quad x_{CH_4} = \frac{p}{K_H} = \frac{760 \text{ mm Hg}}{4.27 \times 10^5 \text{ mm Hg}} = 1.78 \times 10^{-3}$$

Mole fraction of methane in benzene, $x_{CH_4} = \mathbf{1.78 \times 10^{-3}}$

Q. 36. **100 g of liquid *A* (molar mass 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 total vapour pressure of the solution is 475 torr.**

Ans. $n_A = \dfrac{100 \text{ g}}{140 \text{ g mol}^{-1}} = \dfrac{5}{7} \text{ mol}$ and $n_B = \dfrac{1000 \text{ g}}{180 \text{ g mol}^{-1}} = \dfrac{50}{9} \text{ mol}$

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

$$\therefore \quad x_A = \frac{5/7}{5/7 + 50/9} = \frac{5/7}{395/63} = \frac{5}{7} \times \frac{63}{395} = \frac{45}{395} = 0.114$$

$$\therefore \quad x_B = 1 - 0.114 = 0.886$$

Also, given $P_B^0 = 500$ torr

According to Raoult's law,

$$p_A = x_A p_A^\circ = 0.114 \times p_A^\circ \qquad ...(i)$$

$$p_B = x_B p_B^\circ = 0.886 \times 500 = 443 \text{ torr}$$

$$P = p_A + p_B$$

$$475 = 0.114 \; p_A^\circ + 443$$

$$\text{or} \quad p_A^\circ = \frac{475 - 443}{0.114} = \mathbf{280.7\ torr}$$

Substituting this value in equation (*i*), we get

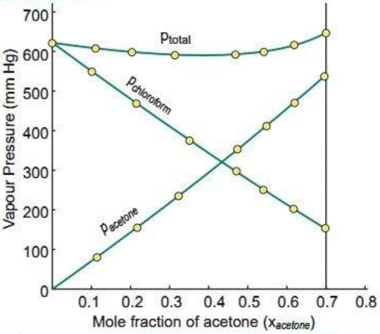
$$P_A = 280.7 \times 0.114 = \mathbf{32\ torr}$$

Q. 37. Vapour pressures of pure acetone and chloroform at 328 K are 741.8 mm Hg and 632.8 mm Hg respectively. Assuming that they form ideal solution over the entire range of composition, plot p_{total}, $p_{chloroform}$ and $p_{acetone}$ as a function of $x_{acetone}$, the experimental data observed for different compositions of mixture is:

$100 \times x_{acetone}$	**0**	**11.8**	**23.4**	**36.0**	**50.8**	**58.2**	**64.5**	**72.1**
$p_{acetone}$ / mm Hg	**0**	**54.9**	**110.1**	**202.4**	**322.7**	**405.9**	**454.1**	**521.1**
$p_{chloroform}$ / mm Hg	**632.8**	**548.1**	**469.4**	**359.7**	**257.7**	**193.6**	**161.2**	**120.7**

Plot this data also on the same graph paper. Indicate whether it has positive deviation or negative deviation from the ideal solution.

Ans.



$x_{acetone}$	0	0.118	0.234	0.360	0.508	0.582	0.645	0.721
$p_{acetone}$ / mm Hg	0	54.9	110.1	202.4	322.7	405.9	454.1	521.1
$p_{chloroform}$ / mm Hg	632.8	548.1	469.4	359.7	257.7	193.6	161.2	120.7
p_{total}	632.8	603.0	579.5	562.1	580.4	599.5	615.3	641.8

Since the plot for p_{total} dips downwards, the solution shows negative deviation from the ideal behaviour.

Q. 38. Benzene and toluene form ideal solution over the entire range of composition. The vapour pressures 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 the vapour phase if 80 g of benzene is mixed with 100 g of toluene.

Ans. Molar mass of benzene (C_6H_6) = 78 g mol^{-1}

Molar mass of toluene (C_7H_8) = 92 g mol^{-1}

$$n_{C_6H_6} = \frac{80\text{ g}}{78\text{ g mol}^{-1}} = 1.026\text{ mol}$$

$$n_{C_7H_8} = \frac{100}{92\text{ g mol}^{-1}} = 1.087\text{ mol}$$

$$\therefore \quad x_{C_6H_6} = \frac{n_{C_6H_6}}{n_{C_6H_6} + n_{C_7H_8}} = \frac{1.026}{1.026 + 1.087} = \frac{1.026}{2.113} = 0.486$$

$$x_{C_7H_8} = 1 - 0.486 = 0.514$$

$$p^{\circ}_{C_6H_6} = 50.71\text{ mm Hg},\ p^{\circ}_{C_7H_8} = 32.06\text{ mm Hg}$$

Applying Raoult's law

$$p_{C_6H_6} = x_{C_6H_6} \times p^{\circ}_{C_6H_6} = 0.486 \times 50.71\text{ mm Hg} = 24.65\text{ mm Hg}$$

$$p_{C_7H_8} = x_{C_7H_8} \times p^{\circ}_{C_7H_8} = 0.514 \times 32.06\text{ mm Hg} = 16.48\text{ mm Hg}$$

$\therefore$ Mole fraction of benzene in the vapour phase $= \dfrac{p_{C_6H_6}}{p_{C_6H_6} + p_{C_7H_8}}$

$$= \frac{24.65}{24.65 + 16.48} = \frac{24.65}{41.13} = \mathbf{0.60}$$

Q. 39. The air is a mixture of a number of gases. The major components are oxygen and nitrogen with approximate proportion of 20% is to 79% by volume at 298 K. The water is in equilibrium with air at a pressure of 10 atm. At 298 K, if the Henry's law constants for oxygen and nitrogen at 298 K are 3.30×10^7 mm and 6.51×10^7 mm respectively, calculate the composition of these gases in water.

Ans. Partial pressure of oxygen, $p_{O_2} = \dfrac{20}{100} \times 10\text{ atm} = 2\text{ atm} = 2 \times 760\text{ mm Hg} = 1520\text{ mm Hg}$

Partial pressure of nitrogen, $p_{N_2} = \dfrac{79}{100} \times 10\text{ atm} = 7.9\text{ atm} = 7.9 \times 760\text{ mm Hg} = 6004\text{ mm Hg}$

$K_H(O_2) = 3.30 \times 10^7$ mm, $K_H(N_2) = 6.51 \times 10^7$ mm

Applying Henry's law, $\quad p_{O_2} = K_H \times x_{O_2}$

or $\quad x_{O_2} = \dfrac{p_{O_2}}{K_H} = \dfrac{1520\text{ mm}}{3.30 \times 10^7\text{ mm}} = \mathbf{4.61 \times 10^{-5}}$

$\quad p_{N_2} = K_H \times x_{N_2}$

or $\quad x_{N_2} = \dfrac{p_{N_2}}{K_H} = \dfrac{6004\text{ mm}}{6.51 \times 10^7\text{ mm}} = \mathbf{9.22 \times 10^{-5}}$

Q. 40. Determine the amount of $CaCl_2$ ($i = 2.47$) dissolved in 2.5 litre of water such that its osmotic pressure is 0.75 atm at 27°C.

Ans. $\quad \pi = \dfrac{i \times W_B \times R \times T}{M_B \times V} \quad$ or $\quad W_B = \dfrac{\pi \times M_B \times V}{i \times R \times T}$

Molar mass of $CaCl_2$, $M_B = 40 + 2 \times 35.5 = 111\text{ g mol}^{-1}$

$$\text{Mass of } CaCl_2,\ W_B = \frac{0.75\text{ atm} \times 111\text{ g mol}^{-1} \times 2.5\text{ L}}{2.47 \times 0.0821\text{ L atm K}^{-1}\text{ mol}^{-1} \times 300\text{ K}}$$

$$= \mathbf{3.42\ g}$$

Q. 41. Determine the osmotic pressure of a solution prepared by dissolving 25 mg of K_2SO_4 in 2 litre of water at 25°C, assuming that it is completely dissociated. [*CBSE Delhi 2013, 2019 (56/5/2)*]

Ans. K_2SO_4 dissolved = 25 mg = 0.025 g

Volume of solution = 2 L, T = 25°C = 298 K

Molar mass of $K_2SO_4 = 2 \times 39 + 32 + 4 \times 16 = 174\text{ g mol}^{-1}$

Since K_2SO_4 dissociates completely as $K_2SO_4 \longrightarrow 2K^+ + SO_4^{2-}$

$$i = \frac{\text{Number of moles of particles after dissociation}}{\text{Number of moles of particles before dissociation}} = \frac{3}{1} = 3$$

Applying van't Hoff equation,

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

$$= \frac{3 \times 0.025\ \text{g} \times 0.0821\ \text{L atm K}^{-1}\ \text{mol}^{-1} \times 298\ \text{K}}{174\ \text{g mol}^{-1} \times 2\ \text{L}} = \mathbf{5.27 \times 10^{-3}\ atm}$$

Multiple Choice Questions

Choose and write the correct option(s) in the following questions.

1. **Which of the following is an example of a solid solution?** [*CBSE Sample Paper 2022*]
   (*a*) Sea water (*b*) Sugar solution
   (*c*) Smoke (*d*) 22 carat gold
2. **One kilogram of sea water sample contains 6 mg of dissolved O_2. The concentration of O_2 in ppm in the sample is**
   (*a*) 0.06 (*b*) 60 (*c*) 6 (*d*) 0.6
3. **An azeotropic mixture of two liquids has a boiling point higher than either of the two liquids when it** [*CBSE 2023(56/3/3)*]
   (*a*) shows large negative deviation from Raoult's law.
   (*b*) shows no deviation from Raoult's law.
   (*c*) shows large positive deviation from Raoult's law.
   (*d*) obeys Raoult's law.
4. **50 mL of an aqueous solution of glucose $C_6H_{12}O_6$ (Molar mass : 180 g/mol) contains 6.02×10^{22} molecules. The concentration of the solution will be** [*CBSE 2020 (56/2/1)*]
   (*a*) 0.1 M (*b*) 0.2 M (*c*) 1.0 M (*d*) 2.0 M
5. **On dissolving sugar in water at room temperature solution feels cool to touch. Under which of the following cases dissolution of sugar will be most rapid?** [*NCERT Exemplar*]
   (*a*) Sugar crystals in cold water (*b*) Sugar crystals in hot water
   (*c*) Powdered sugar in cold water (*d*) Powdered sugar in hot water
6. **Solubility of gases in liquids decreases with rise in temperature because dissolution is an** [*CBSE Sample Paper 2022*]
   (*a*) endothermic and reversible process. (*b*) exothermic and reversible process.
   (*c*) endothermic and irreversible process. (*d*) exothermic and irreversible process.
7. **Which of the following factor(s) affect the solubility of a gaseous solute in the fixed volume of liquid solvent?** [*NCERT Exemplar*]
   (*i*) nature and solute (*ii*) temperature (*iii*) pressure
   (*a*) (*i*) and (*iii*) at constant *T* (*b*) (*i*) and (*ii*) at constant *P*
   (*c*) (*ii*) and (*iii*) only (*d*) (*iii*) only
8. **Value of Henry's constant K_H** [*CBSE 2023 (56/2/1)*]
   (*a*) increases with decrease in temperature.
   (*b*) decreases with increase in temperature.
   (*c*) increases with increase in temperature.
   (*d*) remains constant.

9. Low concentration of oxygen in the blood and tissues of people living at high altitude is due to [*CBSE 2023 (56/1/1)*]

(*a*) high atmospheric pressure.
(*b*) low temperature.
(*c*) low atmospheric pressure.
(*d*) both low temperature and high atmospheric pressure.

10. Which one of the following pairs will not form an ideal solution? [*CBSE 2023 (56/3/3)*]

(*a*) Benzene and Toluene
(*b*) Nitric acid and Water
(*c*) Hexane and Heptane
(*d*) Ethyl chloride and Ethyl bromide

11. Considering the formation, breaking and strength of hydrogen bond, predict which of the following mixtures will show a positive deviation from Raoult's law? [*NCERT Exemplar*]

(*a*) Methanol and acetone
(*b*) Chloroform and acetone
(*c*) Nitric acid and water
(*d*) Phenol and aniline

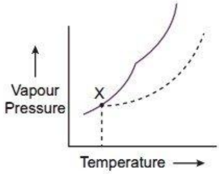
12. Intermolecular forces between two benzene molecules are nearly of same strength as those between two toluene molecules. For a mixture of benzene and toluene, which of the following is not true?

(*a*) $\Delta_{mix}H$ = zero
(*b*) $\Delta_{mix}V$ = zero
(*c*) These will form minimum boiling azeotrope.
(*d*) These will form an ideal solution.

13. When 1 mole of benzene is mixed with 1 mole of toluene, the vapour will contain (Given: vapour pressure of benzene = 12.8 kPa and vapour pressure of toluene = 3.85 kPa). [*CBSE Sample Paper 2021*]

(*a*) equal amount of benzene and toluene as it forms an ideal solution.
(*b*) unequal amount of benzene and toluene as it forms a non ideal solution.
(*c*) higher percentage of benzene.
(*d*) higher percentage of toluene.

14. In the following diagram point, 'X' represents [*CBSE 2022 (56/3/4)*]



(*a*) boiling point of solution
(*b*) freezing point of solvent
(*c*) boiling point of solvent
(*d*) freezing point of solution

15. An unripe mango placed in a concentrated salt solution to prepare pickle, shrivels because ______________. [*NCERT Exemplar*]

(*a*) it gains water due to osmosis.
(*b*) it loses water due to reverse osmosis.
(*c*) it gains water due to reverse osmosis.
(*d*) it loses water due to osmosis.

16. In which of the following cases blood cells will shrink? [*CBSE Sample Paper 2022*]

(*a*) when placed in water containing more than 0.9% (mass /volume) NaCl solution.
(*b*) when placed in water containing less than 0.9% (mass /volume) NaCl solution.
(*c*) when placed in water containing 0.9% (mass/volume) NaCl solution.
(*d*) when placed in distilled water.

17. The colligative property used for the determination of molar mass of polymers and proteins is [*CBSE 2023 (56/1/1)*]

(*a*) osmotic pressure.
(*b*) depression in freezing point.
(*c*) relative lowering in vapour pressure.
(*d*) elevation is boiling point.

18. Which of the following statements is false? [*NCERT Exemplar*]

(*a*) Units of atmospheric pressure and osmotic pressure are the same.

(*b*) In reverse osmosis, solvent molecules move through a semipermeable membrane from a region of lower concentration of solute to a region of higher concentration.

(*c*) The value of molal depression constant depends on nature of solvent.

(*d*) Relative lowering of vapour pressure, is a dimensionless quantity.

19. The values of Van't Hoff factors for KCl, NaCl and K_2SO_4, respectively, are ______________. [*NCERT Exemplar*]

(*a*) 2, 2 and 2 (*b*) 2, 2 and 3 (*c*) 1, 1 and 2 (*d*) 1, 1 and 1

20. The boiling point of a 0.2 m solution of a non-electrolyte in water is (K_b for water = 0.52 K kg mol^{-1}) [*CBSE 2022 (56/3/4)*]

(*a*) 100° C (*b*) 100.52° C (*c*) 100.104° C (*d*) 100.26° C

21. Which of the following aqueous solution will have highest boiling point? [*CBSE 2023 (56/5/2)*]

(*a*) 1.0 M KCl (*b*) 1.0 M K_2SO_4

(*c*) 2.0 M KCl (*d*) 2.0 M K_2SO_4

22. How much ethyl alcohol must be added to 1 litre of water so that the solution will freeze at –14°C? (K_f for water = 1.86°C/mol) [*CBSE Sample Paper 2022*]

(*a*) 7.5 mol (*b*) 8.5 mol (*c*) 9.5 mol (*d*) 10.5 mol

23. Molal elevation constant is calculated from the enthalpy of vapourisation ($\Delta_{vap}H$) and boiling point of the pure solvent (T_0) using the relation

(*a*) $K_b = \dfrac{M_A RT_0^2}{1000\,\Delta_{vap}H}$ (*b*) $K_b = \dfrac{1000\,RT_0^2}{M_A \Delta_{vap}H}$ (*c*) $K_b = \dfrac{\Delta_{vap}H}{1000\,M_A RT_0^2}$ (*d*) $K_b = \dfrac{1000\,M_A T_0^2}{\Delta_{vap}HR}$

24. Which of the following statements is false? [*NCERT Exemplar*]

(*a*) Two different solutions of sucrose of same molality prepared in different solvents will have the same depression in freezing point.

(*b*) The osmotic pressure of a solution is given by the equation $\pi = CRT$ (where C is the molarity of the solution).

(*c*) Decreasing order of osmotic pressure for 0.01 M aqueous solutions of barium chloride, potassium chloride, acetic acid and sucrose is $BaCl_2 > KCl > CH_3COOH >$ sucrose.

(*d*) According to Raoult's law, the vapour pressure exerted by a volatile component of a solution is directly proportional to its mole fraction in the solution.

25. On mixing 20 mL of acetone with 30 mL of chloroform, the total volume of the solution is [*CBSE 2022 (56/3/4)*]

(*a*) < 50 mL (*b*) = 50 mL (*c*) > 50 mL (*d*) = 10 mL

26. Which of the following analogies is correct?

(*a*) Gaseous solution : Camphor in nitrogen gas :: Solid solutions : Copper dissolved in Gold

(*b*) Molarity : Moles/litre :: Molality : Grams/litre

(*c*) Ideal solution : $\Delta H_{mix} = 0$ :: Negative deviation : $\Delta H_{mix} > 0$

(*d*) Minimum boiling azeotrope : Ethanol and water mixture :: Maximum boiling azeotrope : Acetone and CS_2 mixture

27. A compound undergoes complete dimerization in a given organic solvent. The Van't Hoff factor '*i*' is [*CBSE 2023(54/4/2)*]

(*a*) 2.0 (*b*) 0.5 (*c*) 0.25 (*d*) 1.0

Answers

1. (*d*) **2.** (*c*) **3.** (*a*) **4.** (*d*) **5.** (*d*) **6.** (*b*) **7.** (*c*) **8.** (*c*) **9.** (*c*) **10.** (*b*)
11. (*a*) **12.** (*c*) **13.** (*c*) **14.** (*a*) **15.** (*d*) **16.** (*a*) **17.** (*a*) **18.** (*b*) **19.** (*b*) **20.** (*d*)
21. (*c*) **22.** (*a*) **23.** (*a*) **24.** (*a*) **25.** (*a*) **26.** (*a*) **27.** (*b*)

Assertion-Reason Questions

In the following questions, two statements are given—one labeled Assertion (A) and the other labeled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below:

(a) Both Assertion (A) and Reason (R) are correct statements, and Reason (R) is the correct explanation of the Assertion (A).

(b) Both Assertion (A) and Reason (R) are correct statements, but Reason (R) is not the correct explanation of the Assertion (A).

(c) Assertion (A) is correct, but Reason (R) is incorrect statement.

(d) Assertion (A) is incorrect, but Reason (R) is correct statement.

1. **Assertion** (*A*) : Molarity of a solution changes with temperature.
   Reason (*R*) : Molarity is a colligative property. [*CBSE Sample Paper 2022*]
2. **Assertion** (*A*) : The solubility of a gas in a liquid increases with increase of pressure.
   Reason (*R*) : The solubility of a gas in a liquid is directly proportional to the pressure of the gas.
3. **Assertion** (*A*) : Aquatic species are more comfortable in cold water rather than in warm water.
   Reason (*R*) : Different gases have different K_H values at the same temperature. [*CBSE Sample Paper 2021*]
4. **Assertion** (*A*) : Nitric acid and water form maximum boiling azeotrope.
   Reason (*R*) : Azeotropes are binary mixture shaving the same composition in liquid and vapour phase. [*CBSE Sample Paper 2021*]
5. **Assertion** (*A*) : Non-ideal solutions form azeotropic mixture.
   Reason (*R*) : Maximum boiling azeotropes are formed by a solution showing negative deviation. [*CBSE 2020 (56/3/3)*]
6. **Assertion** (*A*) : An ideal solution obeys Henry's law.
   Reason (*R*) : In an ideal solution, solute-solute as well as solvent-solvent interactions are similar to solute-solvent interaction. [*CBSE 2020 (56/5/3)*]
7. **Assertion** (*A*) : A raw mango placed in a saline solution loses water and shrivel into pickle.
   Reason (*R*) : Through the process of reverse osmosis, raw mango shrivel into pickle. [*CBSE 2022 (56/3/4)*]
8. **Assertion** (*A*) : The vapour pressure of a liquid decreases if some non-volatile solute is dissolved in it.
   Reason (*R*) : The relative lowering of vapour pressure of a solution containing a non-volatile solute is equal to the mole fraction of the solute in the solution.
9. **Assertion** (*A*) : When glucose is added to water, an elevation in boiling point is observed.
   Reason (*R*) : The lowering of vapour pressure causes elevation in the boiling point. [*CBSE 2023 (56/4/2)*]
10. **Assertion** (*A*) : When NaCl is added to water a depression in freezing point is observed.
    Reason (*R*) : The lowering of vapour pressure of a solution causes depression in the freezing point.
11. **Assertion** (*A*) : When a solution is separated from the pure solvent by a semipermeable membrane, the solvent molecules pass through it from pure solvent side to the solution side.
    Reason (*R*) : Diffusion of solvent occurs from a region of high concentration solution to a region of low concentration solution.
12. **Assertion** (*A*) : Osmotic pressure is a colligative property.
    Reason (*R*) : Osmotic pressure is directly proportional to molarity. [*CBSE 2020 (56/3/1)*]
13. **Assertion** (*A*) : Molecular mass of polymers cannot be calculated using boiling point or freezing point method.
    Reason (*R*) : Polymers solutions do not possess a constant boiling point or freezing point.
14. **Assertion** (*A*) : Cryoscopic constant depends on nature of solvent.
    Reason (*R*) : Cryoscopic constant is a universal constant. [*CBSE Sample Paper 2022*]

Answers

1. (*c*) **2.** (*a*) **3.** (*b*) **4.** (*b*) **5.** (*b*) **6.** (*d*) **7.** (*c*) **8.** (*b*) **9.** (*a*) **10.** (*a*)
11. (*c*) **12.** (*a*) **13.** (*c*) **14.** (*c*)

Passage-based/Case-based/ Source-based Questions

Read the given passages and answer the questions that follow.

PASSAGE-1

The spontaneous flow of the solvent through a semipermeable membrane from a pure solvent to a solution or from a dilute solution to a concentrated solution is called osmosis. The phenomenon of osmosis can be demonstrated by taking two eggs of the same size. In an egg, the membrane below the shell and around the egg material is semi-permeable. The outer hard shell can be removed by putting the egg in dilute hydrochloric acid. After removing the hard shell, one egg is placed in distilled water and the other in a saturated salt solution. After some time, the egg placed in distilled water swells-up while the egg placed in salt solution shrinks.

The external pressure applied to stop the osmosis is termed as osmotic pressure (a Colligative property). Reverse osmosis takes place when the applied external pressure becomes larger than the osmotic pressure.

1. **What are isotonic solutions?**
2. **Name one SPM which can be used in the process of reverse osmosis.**
3. **What do you expect to happen when red blood corpuscles (RBC's) are placed in 0.5% NaCl solution?**

OR

Which one of the following will have higher osmotic pressure in 1 M KCl or 1 M urea solution?

Answers

1. Solutions having equal osmotic pressure are called isotonic solutions.
2. Cellulose acetate placed on a suitable support.
3. RBC's are isotonic with 0.9% NaCl solution, so they will swell and may even burst when placed in 0.5% NaCl solution.

OR

1 M KCl will have higher osmotic pressure because its dissociates to give K^+ and Cl^- ions while urea does not dissociate into ions in the solution.

PASSAGE-2

A solution which obeys Raoult's law strictly is called an ideal solution, while a solution which shows deviations from Raoult's law is called a non-ideal solution or real solution. Suppose the molecules of the solvent and solute are represented by *A* and *B* respectively, and let γ_{AB}, γ_{AA} and γ_{BB} are the attractive forces between *A*—*B*, *A*—*A* and *B*—*B* respectively. An ideal solution of the components *A* and *B* is defined as the solution in which the intermolecular interactions between the components *A*—*B* are of the same magnitude as the intermolecular interactions found in the pure components *A*—*A* and *B*—*B*. Similarly,a non- ideal solution of the components *A* and *B* is defined as the solution in which the intermolecular interactions between the components *A*—*B* are of the different magnitude as the intermolecular interactions found in the pure components *A*—*A* and *B*—*B*.

1. **Which type of deviation will be shown by the solution, if $\gamma_{AB} < \gamma_{AA}$.**
2. **On mixing liquid A and liquid B, volume of the resulting solution decreases, what type of deviation from Raoult's law is shown by?**
3. **Write two characteristics of non-ideal solution.**

OR

(*i*) What type of liquids form the ideal solution?
(*ii*) Give one example of an ideal solution.

Answers

1. Solution will show positive deviation.
2. The solution will show negative deviation from Raoult's law.
3. $\Delta H_{\text{mix}} \neq 0, \Delta V_{\text{mix}} \neq 0.$

OR

(*i*) Liquids that have similar structures and polarities from ideal solutions.
(*ii*) Benzene + Toluene

CONCEPTUAL QUESTIONS

Q. 1. What type of colloid is formed when a solid is dispersed in a liquid? Give an example. [*CBSE (AI) 2017*]

Ans.

Ans. ② A sol is formed when a solid is dispersed in a liquid.
Example – Cell fluids, paints, Gold sol, etc.

[*Topper's Answer 2017*]

Q. 2. What is the meaning of 10% glucose solution?

Ans. 10% glucose solution means 10 g of glucose dissolved in 100 g of solution.

Q. 3. Define mole fraction. [*CBSE Delhi 2012*]

Ans. Mole fraction of a component in a solution may be defined as the ratio of moles of that component to the total number of moles of all the components present in the solution.

Q. 4. How does the molarity of a solution change with temperature?

Ans. Molarity decreases with increase in temperature as volume of solution increases with increase in temperature.

Q. 5. When and why is molality preferred over molarity in handling solutions in chemistry?

Ans. Molality is preferred in studies that involves changes in temperature as in some of the colligative properties of solutions. This is because molality depends on masses of solvent which do not change with temperature.

Q. 6. The dissolution of ammonium chloride in water is an endothermic process but still it dissolves in water readily. Why? [*HOTS*]

Ans. This is because of entropy change. In this case, ΔS is +ve.

$$NH_4Cl(aq) \longrightarrow NH_4^+(aq) + Cl^-(aq)$$

The ions that were held together in crystalline solid are free and moving in all possible directions. Its entropy has increased and this makes $T\Delta S > \Delta H$, *i.e.*, $\Delta G = -$ve.

Q. 7. Why are the aquatic species more comfortable in cold water in comparison to warm water? [*CBSE 2019 (56/2/3), (56/4/1)*]

Ans. At a given pressure, the solubility of oxygen in water increases with decrease in temperature. Presence of more oxygen at lower temperature makes the aquatic species more comfortable in cold water.

Q. 8. What is the similarity between Raoult's law and Henry's law? [*CBSE Delhi 2014*]

Ans. The similarity between Raoult's law and Henry's law is that in both the laws, the partial vapour pressure of the volatile component or gas is directly proportional to its mole fraction in the solution.

Q. 9. What type of liquids form ideal solutions?

Ans. Liquids that have similar structures and polarities form ideal solutions.

Q. 10. Write two characteristics of non-ideal solution. [*CBSE 2019 (56/5/2)*]

Ans. $\Delta_{mix}H \neq 0$ and $\Delta_{mix}V \neq 0$

Q. 11. Under what condition do non-ideal solutions show negative deviations?

Ans. When the new forces of interaction between the components are stronger than those in the pure components, then non-ideal solutions show negative deviations.

Q. 12. What are maximum boiling azeotropes? Give one example.

Ans. Maximum boiling azeotropes are those which boil at higher temperature than boiling point of each component in pure state, *e.g.*, 68% nitric acid and 32% water by mass.

Q. 13. Why is the vapour pressure of a solution of glucose in water lower than that of water? [*NCERT Exemplar*]

Ans. This is due to decrease in the escaping tendency of the water molecules from the surface of solution as some of the surface area is occupied by non-volatile solute, glucose particles.

Q. 14. Identify which liquid will have a higher vapour pressure at 90°C if the boiling points of two liquids A and B are 140°C and 180°C, respectively. [*CBSE 2020 (56/1/1)*]

Ans. Liquid A will have higher vapour pressure.

Q. 15. Define molal depression constant or cryoscopic constant.

Ans. It is the depression in freezing point when 1 mole of non-volatile solute is dissolved in 1000 g of solvent.

Q. 16. What do you understand by the term that K_f for water is 1.86 K kg mol^{-1}?

Ans. It means that the freezing point of water is lowered by 1.86 K when 1 mole of non-volatile solute is dissolved in 1 kg of water.

Q. 17. What is an antifreeze?

Ans. A substance such as ethylene glycol which is added to water to lower its freezing point is called an antifreeze. It is named so as it delays freezing.

Q. 18. What is de-icing agent? How does it work?

Ans. Common salt is called de-icing agent as it lowers the freezing point of water to such an extent that it does not freeze to form ice. Thus, it is used to clear snow from roads.

Q. 19. Why is glycol and water mixture used in car radiators in cold countries? [*HOTS*]

Ans. Ethylene glycol lowers the freezing point of water. Due to this, coolant in radiators will not freeze. Otherwise, radiator will burst due to freezing of coolant (water).

Q. 20. What are isotonic solutions? [*CBSE Delhi 2012, 2014*]

Ans. The solutions of the same osmotic pressure at a given temperature are called isotonic solutions.

Q. 21. How is it that measurement of osmotic pressures is more widely used for determining molar masses of macromolecules than the elevation in boiling point or depression in freezing point of their solutions? [*HOTS*]

Ans. The osmotic pressure method has the advantage over elevation in boiling point or depression in freezing point for determining molar masses of macromolecules because

(*i*) Osmotic pressure is measured at the room temperature and the molarity of solution is used instead of molality.

(*ii*) Compared to other colligative properties, its magnitude is large even for very dilute solutions.

Q. 22. What is the van't Hoff factor for a compound which undergo dimerisation in an organic solvent?

Ans.

$$2X \longrightarrow X_2$$

$$i = \frac{\text{Number of moles of particles after association}}{\text{Number of moles of particles before association}} = \frac{1}{2}$$

Q. 23. What would be the value of van't Hoff factor for a dilute solution of K_2SO_4 in water?

Ans. In dilute solution, $K_2SO_4 \longrightarrow 2K^+ + SO_4^{2-}$

$$\text{van't Hoff factor, } i = \frac{\text{Number of moles of particles after dissociation}}{\text{Number of moles of particles before dissociation}} = \frac{3}{1} = 3.$$

Q. 24. Out of two 0.1 molal aqueous solutions of glucose and of potassium chloride, which one will have a higher boiling point and why? [*CBSE (F) 2013, 2019 (56/3/2)*]

Ans. 0.1 m KCl solution will have higher boiling point as KCl dissociates in the solution.

Q. 25. Why is osmotic pressure of 1 M KCl higher than 1 M urea solution?

Ans. This is because KCl dissociates to give K^+ and Cl^- ions while urea being a molecular solid does not dissociate into ions in the solution.

Short Answer Questions–I

Each of the following questions are of 2 marks.

Q. 1. Explain the solubility rule "like dissolves like" in terms of intermolecular forces that exist in solutions.

Ans. A substance (solute) dissolves in a solvent if the intermolecular interactions are similar in both the components; for example, polar solutes dissolve in polar solvents and non polar solutes in non polar solvents and thus we can say "like dissolves like".

Q. 2. State Henry's law. Write its one application. What is the effect of temperature on solubility of gases in liquid? *[CBSE (F) 2016]*

Ans. It states that the partial pressure of a gas in vapour phase (p) is proportional to the mole fraction of the gas (x) in the solution.

$$p \propto x \quad \text{or} \quad p = K_H x \qquad \text{where } K_H \text{ is the Henry's constant.}$$

Application of Henry's law:

To increase the solubility of CO_2 in soft drinks and soda water, the bottle is sealed under high pressure.

Effect of temperature on solubility:

As dissolution is an exothermic process, therefore, according to Le Chatelier's principle solubility should decrease with rise in temperature.

Q. 3. Henry's law constant (K_H) for the solution of methane in benzene at 298 K is 4.27×10^5 mm Hg. Calculate the solubility of methane in benzene at 298 K under 760 mm Hg. *[CBSE (F) 2013]*

Ans. Here, $K_H = 4.27 \times 10^5$ mm Hg, $p = 760$ mm Hg

According to Henry's law, $p = K_H \, x_{CH_4}$

$$\therefore \qquad x_{CH_4} = \frac{p}{K_H} = \frac{760 \text{ mm Hg}}{4.27 \times 10^5 \text{mm Hg}} = 1.78 \times 10^{-3}$$

Mole fraction of methane in benzene, x_{CH_4} **= 1.78 × 10⁻³**.

Q. 4. State Raoult's law for the solution containing volatile components. What is the similarity between Raoult's law and Henry's law? *[CBSE Delhi 2014; 2020 (56/5/1)]*

Ans. It states that for a solution of volatile liquids, the partial vapour pressure of each component in the solution is directly proportional to its mole fraction. According to Raoult's law, for a volatile component, A of the solution $P_A \propto x_A$ or $P_A = P_A^0 x_A$, where P_A^0 is the vapour pressure of pure component A.

If one of the component is so volatile that it exist as a gas then according to Henry's law $p = K_H x$, where K_H is the Henry law constant *i.e.*, the partial vapour pressure of the volatile component (gas) is directly proportional to its mole fraction in the solution.

Thus the similarity between Raoult's law and Henry's law is that in both the laws, the partial vapour pressure of the volatile component or gas is directly proportional to its mole fraction in the solution.

Q. 5. State Raoult's law for the solution containing volatile components. Write two differences between an ideal solution and a non-ideal solution. *[CBSE Panchkula 2015]*

Ans. Raoult's law states that for a solution of volatile liquids the partial vapour pressure of each component is directly proportional to its mole fraction.

Differences between Ideal and non-Ideal solutions

S.No.	Ideal solution	Non-Ideal solution
(i)	Obeys Raoult's law over entire range of concentration *i.e.*, $P_A = P_A^o x_A$; $P_B = P_B^o x_B$	Does not obey Raoult's law over entire range of concentration, *i.e.*, $P_A \neq P_A^o x_A$; $P_B \neq P_B^o x_B$
(ii)	$\Delta_{mix} H = 0$; $\Delta_{mix} V = 0$	$\Delta_{mix} H \neq 0$; $\Delta_{mix} V \neq 0$
(iii)	Does not form azeotrope.	Forms azeotrope.

(Any two)

Q. 6. Write two differences between a solution showing positive deviation and a solution showing negative deviation from Raoult's law. [*CBSE East 2016*]

Ans.

Solutions showing positive deviation from Raoult's law	Solution showing negative deviation from Raoult's law
(*i*) $P_A > P_A^\circ x_A$ and $P_B > P_B^\circ x_B$	(*i*) $P_A < P_A^\circ x_A$ and $P_B < P_B^\circ x_B$
(*ii*) $\Delta_{\text{mix}} H > 0, \Delta_{\text{mix}} V > 0$	(*ii*) $\Delta_{\text{mix}} H < 0, \Delta_{\text{mix}} V < 0$
(*iii*) Form minimum boiling azeotropes.	(*iii*) Form maximum boiling azeotropes.

(*Any two*)

Q. 7. State Raoult's law for a solution containing non-volatile solute. What type of deviation from Raoult's law is shown by a solution of chloroform and acetone and why? [*CBSE (F) 2017*]

Ans. It states that the relative lowering of vapour pressure is equal to mole fraction of solute when solvent alone is volatile and is expressed as

$$\frac{p_A^\circ - p_{\text{Total}}}{p_A^\circ} = x_B$$

A solution of chloroform and acetone shows negative deviation from Raoult's law. This is because chloroform molecule is able to form H–bond with acetone molecule as shown below.

It decreases the escaping tendency of molecules of each component from the surface of solution and consequently the vapour pressure decreases resulting in negative deviation from Raoult's law.

Q. 8. **(*i*) Why is an increase in temperature observed on mixing chloroform and acetone?** [*CBSE 2019 (56/2/3)*]

(*ii*) Why does sodium chloride solution freeze at a lower temperature than water? [*CBSE (F) 2013*]

Ans. (*i*) The bonds between chloroform molecules and molecules of acetone are dipole-dipole interactions but on mixing, the chloroform and acetone molecules, they start forming hydrogen bonds which are stronger bonds resulting in the release of energy. This gives rise to an increase in temperature.

(*ii*) When a non-volatile solute is dissolved in a solvent, the vapour pressure decreases. As a result, the solvent freezes at a lower temperature.

Q. 9. Define azeotropes. What type of azeotrope is formed by negative deviation from Raoult's law? Give an example. [*CBSE 2023 (56/4/2)*] [*CBSE Delhi 2015*]

Ans. Azeotropes are binary liquid mixtures having the same composition in liquid and vapour phase and boil at a constant temperature.

Maximum boiling azeotrope is formed by negative deviation from Raoult's law. A mixture of 68% nitric acid and 32% water by mass is an example of maximum boiling azeotrope.

Q. 10. What type of deviation from Raoult's law is shown by a mixture of ethanol and acetone? Give reason. [*CBSE 2023 (56/4/2)*]

Ans. Mixture of ethanol and acetone show positive deviation from Raoult's law. The pure ethanol molecules have strong hydrogen-bonds between them. On adding acetone these intermolecular forces of attractions are weakened. Hence, the ethanol molecules car easily get vapourized, and increase the vapour pressure.

Q. 11. What type of deviation from Raoult's law is observed by mixing chloroform and acetone? Why is a decrease in vapour pressure observed on mixing chloroform and acetone? [*CBSE (C) 2021*]

Ans. A mixture of chloroform and acetone shows negative deviation. Due to the formation of H-bond between $CHCl_3$ and acetone, vapour pressure of the solution decreases.

Q. 12. **(*i*) Gas (*A*) is more soluble in water than Gas (*B*) at the same temperature. Which one of the two gases will have the higher value of K_H (Henry's constant) and why?**

(*ii*) In non-ideal solution, what type of deviation shows the formation of maximum boiling azeotropes? [*CBSE Central 2016*]

Ans. (*i*) According to Henry's law, $p = K_H x$, *i.e.*, higher the value of K_H lower is the solubility of the gas in the liquid. Therefore, Gas *B* will have higher value of K_H than gas A.

(*ii*) Negative deviation from Raoult's law.

Q. 13. The vapour pressure of pure liquid X and pure liquid Y at 25°C are 120 mm Hg and 160 mm Hg respectively. If equal moles of X and Y are mixed to form an ideal solution, calculate the vapour pressure of the solution. ***[CBSE 2023 (56/2/1)]***

Ans. Moles of $X(n_x)$ = Moles of $Y(n_y)$

Let $n_x = n_y = n$

Mole fraction of X, $X_x = \dfrac{n_x}{n_x + n_y} = \dfrac{n}{n+n} = \dfrac{n}{2n} = 0.5$

Mole fraction of of Y, $x_y = 1 - X_x = 1 - 0.5 = 0.5$

Here, $P_x^{\circ} = 120$ mmHg $P_y^{\circ} = 160$ mmHg, $X_x = 0.5$, $X_y = 0.5$

Substituting the values in the expression, $P_x^{\circ} X_x + P_y^{\circ} X_y$, we get

$$P = 120 \text{ mmHg} \times 0.5 + 160 \text{ mmHg} \times 0.5 = 60 \text{ mmHg} + 80 \text{ mmHg}$$

$$P = 140 \text{ mmHg}$$

Q. 14. A glucose solution which boils at 101.04°C at 1 atm. What will be relative lowering of vapour pressure of an aqueous solution of urea which is equimolal to given glucose solution?

(Given: K_b for water is 0.52 K kg mol^{-1}) ***[CBSE Sample Paper 2021]***

Ans. $\Delta T_b = 101.04°\text{C} - 100.0°\text{C} = 1.04\ °\text{C}$ or 1.04 K

$$\Delta T_b = K_b \,.\, m \text{ or } m = \frac{\Delta T}{K_b}$$

$$m = \frac{1.04 \text{ K}}{0.52 \text{ K kg mol}^{-1}} = 2 \text{ mol kg}^{-1} \; or \; 2 \text{ molal}$$

2 molal aqueous glucose ($C_6H_{12}O_6$) solution means that 2 mole of glucose per kilogram of water, *i.e.*, 1000 g of water.

Now,
$$n_{H_2O} = \frac{1000 \text{ g}}{18 \text{ g mol}^{-1}} = 55.5 \text{ mol}; \; n_{C_6H_{12}O_6} = 2 \text{ mol}$$

$$x_{C_6H_{12}O_6} = \frac{n_{C_6H_{12}O_6}}{n_{H_2O} + n_{C_6H_{12}O_6}} = \frac{2 \text{ mol}}{55.5 \text{ mol} + 2 \text{ mol}}$$

$$x_{C_6H_{12}O_6} = \frac{2 \text{ mol}}{57.5 \text{ mol}} = 0.0347$$

According to Raoult's law

Relative lowering of vapour pressure = Mole fraction of solute

As the aqueous solutions of glucose and urea are equimolar and relative lowering vapour pressure is a colligative property.

Therefore relative lowering of vapour pressure of aqueous solution of urea = 0.0347 atm.

Q. 15. When 1.5 g of a non-volatile solute was dissolved in 90 g of benzene, the boiling point of benzene raised from 353.23 K to 353.93 K. Calculate the molar mass of the solute.

(K_b for benzene = 2.52 K kg mol^{-1}) ***[CBSE Chennai 2015]***

Ans. $\Delta T_b = 353.93 \text{ K} - 353.23 \text{ K} = 0.7 \text{ K}$

Substituting $W_B = 1.5$ g, $W_A = 90$ g, $\Delta T_b = 0.7$ K, $K_b = 2.52$ K kg mol^{-1} in the expression

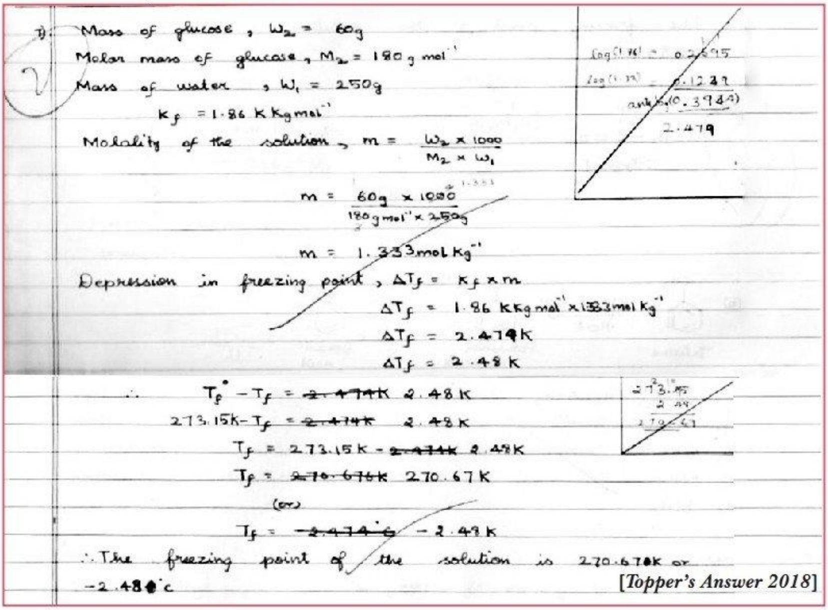
$$M_B = \frac{K_b \times W_B \times 1000}{\Delta T_b \times W_A}, \text{ we get}$$

$$M_B = \frac{2.52 \times 1.5 \times 1000}{0.7 \times 90}$$

$$\mathbf{M_B = 60 \text{ g mol}^{-1}}$$

Q. 16. Calculate the freezing point of a solution containing 60 g of glucose (Molar mass = 180 g mol^{-1}) in 250 g of water. (K_f of water = 1.86 K kg mol^{-1}) *[CBSE Delhi 2018]*

Ans.



i) Mass of glucose, W_2 = 60g

Molar mass of glucose, M_2 = 180 g mol^{-1}

Mass of water, W_1 = 250g

K_f = 1.86 K Kg mol^{-1}

Molality of the solution, $m = \frac{W_2 \times 1000}{M_2 \times W_1}$

$m = \frac{60g \times 1000}{180 g\, mol^{-1} \times 250g}$

m = 1.333 mol Kg^{-1}

Depression in freezing point, $\Delta T_f = K_f \times m$

ΔT_f = 1.86 K Kg mol^{-1} × 1.333 mol Kg^{-1}

ΔT_f = 2.479 K

ΔT_f = 2.48 K

∴ $T_f^{\circ} - T_f$ = ~~2.474K~~ 2.48 K

273.15K − T_f = ~~2.474K~~ 2.48 K

T_f = 273.15 K − ~~2.474K~~ 2.48K

T_f = ~~270.676K~~ 270.67 K

(or)

T_f = ~~2.474°C~~ − 2.48 K

∴ The freezing point of the solution is 270.670K or −2.480°C

log(1.86) = 0.2695

log(1.33) = 0.1249

antilog(0.3944)

2.479

273.15

2.48

270.67

[*Topper's Answer 2018*]

Q. 17. For a 5% solution of urea (Molar mass = 60 g/mol), calculate the osmotic pressure at 300 K. [R = 0.0821 K atm J^{-1} mol^{-1}] *[CBSE 2020 (56/1/1)]*

Ans. Osmotic pressure, $\pi = \dfrac{W \times R \times T}{M \times V}$

$W = 5$ g, $R = 0.0821$ L atm K^{-1} mol^{-1}, $V = \dfrac{100}{1000} = 0.1$ litre, $M = 60$ g/mol, $T = 300$ K

$$\pi = \frac{5 \times 0.0821 \times 300}{60 \times 0.1}$$

$$= \frac{123.15}{6} = \mathbf{20.525\ atm}$$

Q. 18. Visha took two aqueous solution—one containing 7.5 g of urea (Molar mass = 60 g/mol) and the other containing 42.75 g of substance Z in 100 g of water, respectively. It was observed that both the solutions froze at the same temperature. Calculate the molar mass of Z. *[CBSE 2020 (56/1/1)]*

Ans. $\Delta T_f(\text{urea}) = \Delta T_f(Z)$ ½

$$K_f \times \frac{w\ \text{urea}}{M\ \text{urea}} \times \frac{1000}{w\ \text{solvent}} = K_f \times \frac{wz}{Mz} \times \frac{1000}{W\ \text{solvent}}$$ ½

$$\frac{7.5}{60} \times \frac{1000}{100} = \frac{42.75}{Mz} \times \frac{1000}{100}$$

$$Mz = \frac{42.75 \times 60}{7.50} = 342 \text{ g/mol}$$ (or by any other correct method)

(½ mark may be deducted for no or incorrect unit) **1**

[*CBSE Marking Scheme 2020 (56/1/1)*]

Q. 19. 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. **[*CBSE Delhi 2012*]**

Ans. Osmotic pressure (π) is defined as the extra pressure that must be applied to the solution side in order to prevent the flow of solvent molecules into it through a semipermeable membrane.

According to van't Hoff equation

$$\pi = \frac{n_B}{V} RT$$

where π is the osmotic pressure, R is the gas constant and V is the volume of solution in litres containing n_B moles of the solute.

If W_B grams of the solute of molar mass, M_B is present in the solution, then

$$n_B = \frac{W_B}{M_B} \text{ and we can write}$$

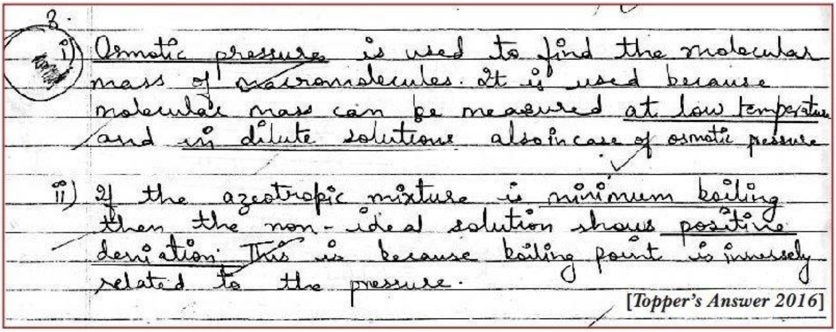
$$\pi = \frac{W_B \times R \times T}{M_B \times V} \qquad \text{or} \qquad M_B = \frac{W_B \times R \times T}{\pi \times V}$$

Thus, knowing W_B, T, π and V, the molecular mass of the solute, M_B can be calculated.

Q. 20. ***(i)* Write the colligative property which is used to find the molecular mass of macromolecules.**

***(ii)* In non-ideal solution, what type of deviation shows the formation of minimum boiling azeotropes?** **[*CBSE (North Region) 2016*]**

Ans.



3.

i) Osmotic pressure is used to find the molecular mass of macromolecules. It is used because molecular mass can be measured at low temperatu and in dilute solutions also in case of osmotic pressure

ii) If the azeotropic mixture is minimum boiling then the non-ideal solution shows positive deviation. This is because boiling point is inversely related to the pressure.

[*Topper's Answer 2016*]

Q. 21. Give reasons: **[*CBSE 2019 (56/2/1)*]**

***(i)* Cooking is faster in pressure cooker than in cooking pan.**

***(ii)* Red Blood Cells (RBC) shrink when placed in saline water but swell in distilled water.**

Ans. (*i*) The use of pressure cooker reduces cooking time because the weight over the lid does not allow the steam to go out. As a result, pressure inside the cooker becomes high. Higher the pressure, higher is the boiling point and faster is the cooking.

(*ii*) As the concentration of saline solution is higher than the concentration inside the cell. Thus water will move outside the cytoplasm and the cell will shrink while, distilled water is hypotonic, when RBCs are placed in distilled water, water will enter the cell through simple diffusion and lead to cell swelling.

Q. 22. ***(i)* On mixing liquid X and liquid Y, volume of the resulting solution decreases. What type of deviation from Raoult's law is shown by the resulting solution? What change in temperature would you observe after mixing liquids X and Y?**

***(ii)* What happens when we place the blood cell in water (hypotonic solution)? Give reason.**

[*CBSE Allahabad 2015*]

Ans. (*i*) • The solution will show negative deviation from Raoult's law.

• Temperature will rise.

(*ii*) Due to osmosis water enters into the cell and blood cell will swell.

Q. 23. Define the following terms:

(*i*) Abnormal molar mass **(*ii*) van't Hoff factor (*i*)** **[*CBSE Delhi 2017*]**

Ans. (*i*) When the molar mass of a substance determined by using any of the colligative properties comes out to be different than the theoretically expected molar mass, the substance said to show abnormal molar mass.

(*ii*) van't Hoff factor (*i*) gives the extent of association or dissociation of the solute particles in the solution. It may be defined as the ratio of observed colligative property to calculated colligative property.

$$i = \frac{\text{Observed colligative property}}{\text{Calculated colligative property}}$$

Q. 24. Will the elevation in boiling point be same if 0.1 mol of sodium chloride or 0.1 mol of sugar is dissolved in 1 L of water? Explain. **[*CBSE Sample Paper 2016*] [*HOTS*]**

Ans. No, the elevation in boiling point is not the same. NaCl, being an electrolyte, dissociates almost completely to give Na^+ and Cl^- ions whereas glucose, being non-electrolyte does not dissociate. Hence, the number of particles in 0.1 M NaCl solution is nearly double than 0.1 M glucose solution. Elevation in boiling point being a colligative property, is therefore, nearly twice for 0.1 M NaCl solution than for 0.1 M glucose solution.

Q. 25. Predict the state of the solute in the solution in the following situations:

(*i*) When '*i*' is found to be 0.3. **(*ii*) When '*i*' is found to be 4.** **[*CBSE 2020 (56/2/2)*]**

Ans. (*i*) Associated (*ii*) Dissociated **1 + 1**

[*CBSE Marking Scheme 2020 (56/2/2)*]

Short Answer Questions–II

Each of the following questions are of 3 marks.

Q. 1. (*i*) Differentiate between Ideal solution and Non-ideal solution.

(*ii*) 30 g of urea is dissolved in 846 g of water. Calculate the vapour pressure of water for this solution if vapour pressure of pure water at 298 K is 23.8 mm Hg. **[*CBSE 2023 (56/1/1)*]**

Ans. (*i*) **Differences between Ideal and non-Ideal solutions:**

S.No.	Ideal solution	Non-Ideal solution
(*i*)	Obeys Raoult's law over entire range of concentration *i.e.*, $P_A = P^o_A x_A$; $P_B = P^o_B x_B$	Does not obey Raoult's law over entire range of concentration, *i.e.*, $P_A \neq P^o_A x_A$; $P_B \neq P^o_B x_B$
(*ii*)	$\Delta_{mix} H = 0$; $\Delta_{mix} V = 0$	$\Delta_{mix} H \neq 0$; $\Delta_{mix} V \neq 0$
(*iii*)	Does not form azeotrope.	Forms azeotrope.

(*Any two*)

(*ii*) $W_B = 30\text{g}$, $W_A = 846$ g, $M_B = 80$ g mol^{-1}, $M_A = 18$g mol^{-1}, $P^\circ_A = 23.8$ mmHg

Substituting the values in the expression

$$\frac{P^\circ_A - P}{P^\circ_A} = \frac{W_B \square M_A}{M_B \square W_A}, \text{ we get}$$

$$\frac{23.8 \text{ mmHg } P}{23.8 \text{ mmHg}} = \frac{30\text{g} \times 18 \text{ g mol}^{-1}}{60 \text{ g mol}^{-1} \times 846 \text{ g}} = \frac{1}{94}$$

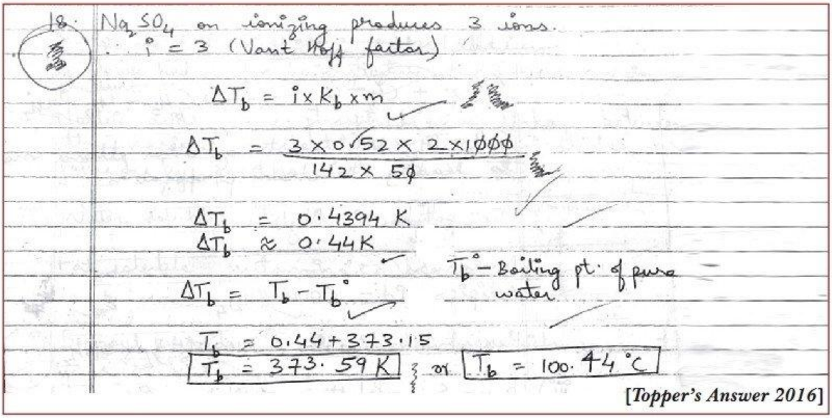
$$23.8 \text{ mmHg} - P = \frac{23.8 \text{ mmHg}}{94} = 0.25 \text{ mmHg}$$

$$P = 23.80 \text{ mmHg} - 0.25 \text{ mmHg} = 23.55 \text{ mmHg}$$

Q. 2. Calculate the boiling point of solution when 2 g of Na_2SO_4 ($M = 142$ g mol^{-1}) was dissolved in 50 g of water, assuming Na_2SO_4 undergoes complete ionisation.

(K_b for water = 0.52 K kg mol^{-1}) **[*CBSE North 2016*]**

Ans.



18. Na_2SO_4 on ionizing produces 3 ions.

∴ $i = 3$ (Vant Hoff factor)

$$\Delta T_b = i \times K_b \times m$$

$$\Delta T_b = \frac{3 \times 0.52 \times 2 \times 1000}{142 \times 50}$$

$$\Delta T_b = 0.4394 \text{ K}$$

$$\Delta T_b \approx 0.44 \text{K}$$

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

T_b° – Boiling pt. of pure water

$$T_b = 0.44 + 373.15$$

$$\boxed{T_b = 373.59 \text{K}} \text{ or } \boxed{T_b = 100.44\,^{\circ}\text{C}}$$

[*Topper's Answer 2016*]

Q. 3. A solution of glucose (Molar mass = 180 g mol^{-1}) in water has a boiling point of 100.20°C. Calculate the freezing point of the same solution. Molal constants for water K_f and K_b are 1.86 K kg mol^{-1} and 0.512 K kg mol^{-1} respectively. **[*CBSE (F) 2017*]**

Ans. $\Delta T_b = 100.20°C - 100°C = 0.20°C$ or 0.20 K

$\Delta T_b = K_b \,.\, m \qquad \Rightarrow \qquad m = \Delta T_b / K_b$

$$m = \frac{0.20 \text{ K}}{0.512 \text{ K kg mol}^{-1}} \text{ or } m = 0.39 \text{ mol kg}^{-1}$$

$$\Delta T_f = K_f\, m,$$

$$\Delta T_f = 1.86 \text{ K kg mol}^{-1} \times 0.39 \text{ mol kg}^{-1} = 0.725 \text{ K}$$

$$T_f = T_f^0 - \Delta T_f$$

$$= 273.15 \text{ K} - 0.725 \text{ K}$$

$$\mathbf{= 272.425 \text{ K}}$$

Q. 4. When 19.5 g of F—CH_2—COOH (Molar mass = 78 g mol^{-1}), is dissolved in 500 g of water, the depression in freezing point is observed to be 1°C. Calculate the degree of dissociation of F—CH_2—COOH.

[Given: K_f for water = 1.86 K kg mol^{-1}] **[*CBSE 2023 (56/2/1)*]**

Ans.

$$\text{Moles of F—CH}_2\text{—COOH} = \frac{\text{Mass of F—CH}_2\text{—COOH}}{\text{Molar mass}}$$

$$\text{Molality, } m = \frac{\text{Moles of F—CH}_2\text{—COOH}}{\text{Mass of solvent, water (in kg)}}$$

$$= \frac{0.25 \text{ mol}}{500 \text{ g}} \times 1000 \text{ g kg}^{-1} = 0.5 \text{ mol kg}^{-1}$$

$$\Delta T_f = i \times K_f \times m \text{ or } i = \frac{\Delta T_f}{K_f \,\square m}$$

Substituting the values, $\Delta T_f = 1°C$ or 1K, $K_f = 1.86$ K kg mol^{-1}, m = 0.5 mol kg^{-1} in above expression, we get

$$i = \frac{1 \text{ K}}{1.86 \text{ K kg mol}^{-1} \times 0.5 \text{ mol kg}^{-1}} = 1.0753$$

If α represents the degree of dissociation of F—CH$_2$—COOH then we would have 0.5 (1 – α) mole of F—CH$_2$—COOH left in undissociated, 0.5 × mole of F—CH$_2$—COO$^-$ and 0.5 × mole of H$^+$ ions at equilibrium.

	F—CH$_2$—COOH ⇌	F—CH$_2$—COO$^-$ +	H$^+$
Inital conc.	0.5	0	0
At equilibrium	$0.5(1-\alpha)$	0.5α	0.5α

Thus, total number of moles of particles at equilibrium = 0.5 – 0.5α + 0.5α + 0.5α = 0.5(1 + α)

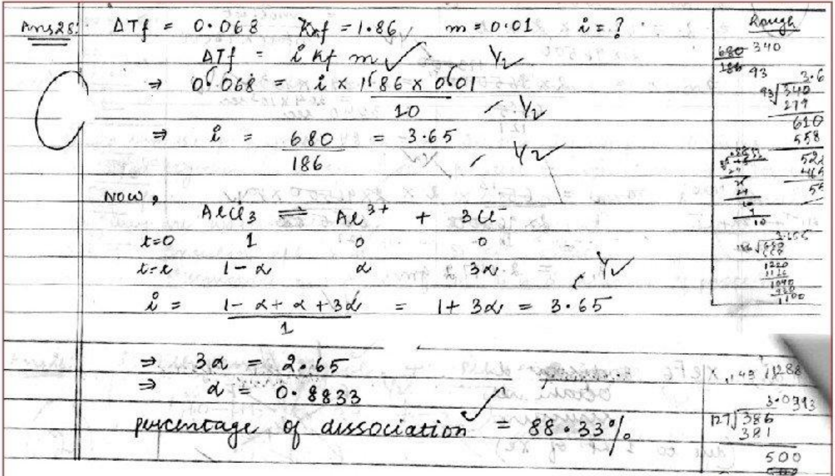
$$i = \frac{\text{Total number of moles of particles after dissociation}}{\text{Number of moles of particles before dissociation}}$$

$$i = \frac{0.5(1+\alpha)}{0.5} = 1+\alpha \quad \Rightarrow \quad \alpha = i-1$$

or α = 1.0753 –1 = 0.0753 or α = 7.53%

Q. 5. A 0.01 m aqueous solution of AlCl$_3$ freezes at –0.068 °C. Calculate the percentage of dissociation. [Given: K_f for water = 1.86 K kg mol^{-1}] ***[CBSE 2020 (56/5/1)]***

Ans.



Ans 28: $\Delta T_f = 0.068$ $K_f = 1.86$ $m = 0.01$ $i = ?$

$\Delta T_f = i K_f m$ ½

$\Rightarrow 0.068 = i \times \frac{1.86 \times 0.01}{10}$ ½

$\Rightarrow i = \frac{680}{186} = 3.65$ ½

Now,

$AlCl_3 \rightleftharpoons Al^{3+} + 3Cl^-$

$t=0$ 1 0 0

$t=t$ $1-\alpha$ α 3α ½

$i = \frac{1-\alpha+\alpha+3\alpha}{1} = 1+3\alpha = 3.65$

$\Rightarrow 3\alpha = 2.65$

$\Rightarrow \alpha = 0.8833$

percentage of dissociation = 88.33%

Rough

[Topper's Answer 2020]

Q. 6. 3.9 g of benzoic acid dissolved in 49 g of benzene shows a depression in freezing point of 1.62 K. Calculate the van't Hoff factor and predict the nature of solute (associated or dissociated). [Given: Molar mass of benzoic acid = 122 g mol^{-1}, K_f for benzene = 4.9 K kg mol^{-1}] ***[CBSE Delhi 2015]***

Ans. The given quantities are

$W_B = 3.9$ g, $W_A = 49$ g, $\Delta T_f = 1.62$ K, $M_B = 122$ g mol^{-1} and $K_f = 4.9$ K kg mol^{-1}

Substituting these values in the equation,

$$M_B = \frac{K_f \times W_B \times 1000}{\Delta T_f \times W_A}, \text{ we get}$$

$$M_B = \frac{4.9 \times 3.9 \times 1000}{1.62 \times 49}$$

$$M_B = 240.74 \text{ g mol}^{-1}$$

Thus, observed molecular mass of benzoic acid in benzene = 240.74 g mol^{-1}

Normal molecular mass of benzoic acid = 122 g mol^{-1}

$$i = \frac{\text{Normal molecular mass}}{\text{Observed molecular mass}}$$

$$i = \frac{122 \text{ g mol}^{-1}}{240.74 \text{ g mol}^{-1}} = \mathbf{0.507}$$

As $i < 1$, therefore, benzoic acid will undergo association in benzene.

Q. 7. Calculate the freezing point of a solution containing 0.5 g KCl (Molar mass = 74.5 g/mol) dissolved in 100 g water, assuming KCl to be 92% ionized. K_f of water = 1.86 K kg/mol.

[*CBSE Sample Paper 2020*]

Ans. $\alpha = 92\% = \frac{92}{100} = 0.92$, As $\alpha = \frac{i-1}{n-1}$

$\therefore\ 0.92 = \frac{i-1}{2-1} \Rightarrow i = 1.92$

Here, $W_B = 0.5$ g, $M_B = 74.5$ g mol^{-1}, $W_A = 100$ g, $K_f = 1.86$ K kg mol^{-1}, $i = 1.92$

Substituting these values in the expression,

$$\Delta T_f = \frac{i \times K_f \times W_B \times 1000}{M_B \times W_A}, \text{ we get}$$

$$\Delta T_f = \frac{1.92 \times 1.86 \text{K kg mol}^{-1} \times 0.5 \text{ g} \times 1000 \text{ g kg}^{-1}}{74.5 \text{ g mol}^{-1} \times 100 \text{ g}} = 0.24 \text{ K}$$

$$T_f = T_f^\circ - \Delta T_f = 273.15 \text{ K} - 0.24 \text{ K}$$

$$T_f = \mathbf{272.91 \text{ K}}$$

Q. 8. If benzoic acid (M. = 122 g mol^{-1}) is associated into a dimer when dissolved in benzene and the osmotic pressure of a solution of 6.1 g of benzoic acid in 100 mL benzene is 6.5 atm at 27°C, then what is the percentage association of benzoic acid?

(Given: R = 0.0821 L atm K^{-1} mol^{-1}) **[*CBSE 2023 (56/4/2)*]**

Ans. Given,

Weight of benzene = 6.1 g

Molar mass = 122 g mol^{-1}

Volume = 100 mL = 0.1 L

Osmotic pressure = 6.5 atm

Temperature = 27°C = 300 K

We know, $\pi = i\text{CRT}$ (i = Van't Hoff factor)

Putting the value of π, C, R and T

$$6.5 = i \times \frac{(6.1/122)}{0.1} \times 0.0821 \times 300$$

$\Rightarrow$ $i = 0.5278$

The dimerization of CH_3COOH can be represented as:

$$2CH_3COOH \rightleftharpoons (CH_3COOH)_2$$

At $t = 0$: 1 0

After association : $1-\alpha$ $\frac{\alpha}{2}$

Number of moles before association = 1

Number of moles after association = $1 - \alpha + \frac{\alpha}{2}$

$= 1 - \frac{\alpha}{2}$ (where α = degree of association)

We know, $$i = \frac{\text{Number of moles after association}}{\text{Number of moles before association}}$$

$$0.5278 = \frac{1 - \frac{\alpha}{2}}{1}$$

$$\Rightarrow \qquad \alpha = 0.9443$$

So, percentage association = 94.43%

Q. 9. At 300 K, 30 g of glucose, $C_6H_{12}O_6$ present per litre in its solution has an osmotic pressure of 4.98 bar. If the osmotic pressure of another glucose solution is 1.52 bar at the same temperature, calculate the concentration of the other solution. ***[CBSE 2019 (56/4/2)]***

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

$$4.98 = 4.98 = \frac{30 \times R \times 300}{180 \times 1} = 50R \qquad \text{...}(i)$$

$$1.52 = C \times R \times 300 = 300CR \qquad \text{...}(ii)$$

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

$$\frac{300CR}{50R} = \frac{1.52}{4.98} \quad \Rightarrow \quad C = \mathbf{0.051\ M}$$

Q. 10. A solution containing 1.9 g per 100 mL of KCl (M = 74.5 g mol^{-1}) is isotonic with a solution containing 3 g per 100 mL of urea (M = 60 g mol^{-1}). Calculate the degree of dissociation of KCl solution. Assume that both the solutions have same temperature. ***[CBSE 2019 (56/2/1)]***

Ans. $$\pi_1 \text{ (urea)} = \pi_2 \text{ (KCl)} \qquad \tfrac{1}{2}$$

$$C_1RT = iC_2RT$$

$$\frac{n_1}{V_1} = i\frac{n_2}{V_2} \ (V_1 = V_2) \qquad 1$$

$$\frac{3}{60} = i \times \frac{1.9}{74.5}$$

$$i = 1.96 \qquad \tfrac{1}{2}$$

Degree of dissociation, $$\propto = \frac{i-1}{n-1}$$

$$= \frac{1.96 - 1}{2 - 1}$$

$$= 0.96 \text{ or } 96\% \qquad 1$$

[CBSE Marking Scheme 2019 (56/2/1)]

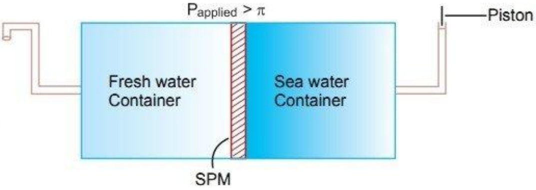
Q. 11. Given alongside is the sketch of a plant for carrying out a process.

(*i*) Name the process occurring in the given plant.

(*ii*) To which container does the net flow of solvent take place?

(*iii*) Name one SPM which can be used in this plant.

(*iv*) Give one practical use of the plant.



Ans. (*i*) Reverse osmosis.

(*ii*) Fresh water container.

(*iii*) Cellulose acetate placed on a suitable support.

(*iv*) Desalination of sea water.

Long Answer Questions

Each of the following questions are of 5 marks.

Q. 1. **(*i*) Define the following terms:**

(*a*) Molarity

(*b*) Molal elevation constant (K_b)

(*ii*) A solution containing 15 g urea (molar mass = 60 g mol^{-1}) per litre of solution in water has the same osmotic pressure (isotonic) as a solution of glucose (molar mass = 180 g mol^{-1}) in water. Calculate the mass of glucose present in one litre of its solution. **[*CBSE (AI) 2014*]**

Ans. (*i*) (*a*) Molarity may be defined as number of moles of solute dissolved in one litre of solution.

$$\text{Molarity} = \frac{\text{Moles of solute}}{\text{Volume of solution (in litre)}}$$

(*b*) Molal elevation constant may be defined as the elevation in boiling point when one mole of solute is dissolved in 1000 grams of the solvent.

(*ii*) Osmotic pressure, $\pi = \dfrac{W_B \times R \times T}{M_B \times V}$

Osmotic pressure of urea solution = $\dfrac{15 \times R \times T}{60 \times 1}$

Osmotic pressure of glucose solution = $\dfrac{W_B \times R \times T}{180 \times 1}$

As, Osmotic pressure of urea solution = Osmotic pressure of glucose solution

Therefore, $\dfrac{15 \times R \times T}{60 \times 1} = \dfrac{W_B \times R \times T}{180 \times 1}$

Mass of glucose, $W_B = \dfrac{15 \times 180}{60} = \mathbf{45\ g}$

Q. 2. **(*i*) Explain why on addition of 1 mol glucose to 1 litre water the boiling point of water increases.**

(*ii*) Henry's law constant for CO_2 in water is 1.67×10^8 Pa at 298 K. Calculate the number of moles of CO_2 in 500 mL of soda water when packed under 2.53×10^5 Pa at the same temperature. **[*CBSE (AI) 2017*]**

Ans. (*i*) On addition of glucose, a non-volatile solute to water (a volatile solvent) the vapour pressure of water decreases. In order to make the solution boil, its vapour pressure must be increased by raising the temperature above the boiling point of pure water. In other words, there is an increase in the boiling point of water.

(*ii*) According to Henry's law, $P_{CO_2} = K_H \times x_{CO_2}$ or $x_{CO_2} = \dfrac{P_{CO_2}}{K_H}$

$$\therefore \quad x_{CO_2} = \frac{2.53 \times 10^5 \text{ Pa}}{1.67 \times 10^8 \text{ Pa}} = 1.51 \times 10^{-3}$$

Mass of water = Density of water × volume of water

$= 1 \text{ g mL}^{-1} \times 500 \text{ mL} = 500 \text{ g}$

$$\text{Moles of water, } n = \frac{\text{Mass of water}}{\text{Molar mass}} = \frac{500 \text{ g}}{18 \text{ g mol}^{-1}} = 27.78 \text{ mol}$$

$$x_{CO_2} = \frac{n_{CO_2}}{n_{H_2O} + n_{CO_2}} = \frac{n_{CO_2}}{n_{H_2O}} \text{ or } n_{CO_2} = x_{CO_2} \times n_{H_2O}$$

$$n_{CO_2} = 1.51 \times 10^{-3} \times 27.78 \text{ mol} = \mathbf{0.042\ mol}$$

Q. 3. **(*i*) Define the following terms:**

(*a*) Azeotrope

(*b*) Osmotic pressure

(*c*) Colligative properties

(*ii*) Calculate the molarity of 9.8% (w/w) solution of H_2SO_4 if the density of the solution is 1.02 g mL^{-1}.
(Molar mass of H_2SO_4 = 98 g mol^{-1}) **[*CBSE (F) 2014*]**

Ans. (*i*) (*a*) The binary mixtures of liquids having same composition in liquid and vapour phase and boil at a constant temperature are called azeotropes.

(*b*) The excess of pressure which must be applied to the solution side to prevent the passage of solvent into it through a semipermeable membrane is called osmotic pressure.

(*c*) The properties of solutions which depend only on the number of solute particles in the solution but independent of their nature are called colligative properties.

(*ii*) Let the mass of solution = 100 g

∴ Mass of H_2SO_4 = 9.8 g

$$\text{Number of moles of } H_2SO_4 = \frac{\text{Mass of } H_2SO_4}{\text{Molar Mass}} = \frac{9.8 \text{ g}}{98 \text{ g mol}^{-1}} = 0.1 \text{ mol}$$

$$\text{Volume of solution} = \frac{\text{Mass of solution}}{\text{Density of solution}} = \frac{100 \text{ g}}{1.02 \text{ g mL}^{-1}} = \frac{100}{1.02} \text{mL}$$

$$= \frac{100}{1.02} \text{mL} \times \frac{1}{1000 \text{ mL L}^{-1}} = \frac{1}{10.2} \text{L}$$

$$\text{Molarity} = \frac{\text{Moles of solute}}{\text{Volume of solution (in L)}}$$

$$= \frac{0.1 \text{ mol}}{\frac{1 \text{ L}}{10.2}}$$

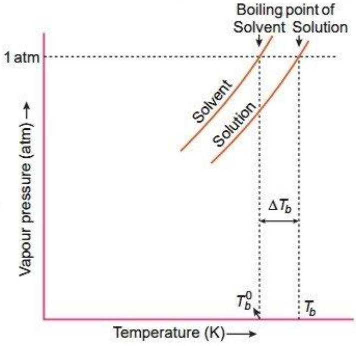
$$= \mathbf{1.02 \text{ mol L}^{-1} \text{ or } 1.02 \text{ M}}$$

Q. 4. **(*i*) Draw the graph between vapour pressure and temperature and explain the elevation in boiling point of a solvent in solution.**

(*ii*) Determine the osmotic pressure of a solution prepared by dissolving 25 mg of K_2SO_4 in 2 litres of water at 25°C assuming it to be completely dissociated.
(Atomic masses K = 39 u, S = 32 u, O = 16 u) **[*CBSE 2019 (56/5/1)*]**

Ans. (*i*) When a non-volatile solute is added to a volatile solvent, then the vapour pressure of the solvent in the solution becomes less than that of pure solvent. In order to make this solution boil, its vapour pressure must be increased to 1 atm by raising the temperature above the boiling point of the pure solvent. In other words, there is increase in the boiling point of the solvent in the solution.

Elevation of boiling point (ΔT_b) = Boiling point of solution (T_b) – Boiling point of solvent (T_b^0)



(*ii*) K_2SO_4 dissolved = 25 mg = 0.025 g

Volume of solution = 2 L, T = 25°C = 298 K

Molar mass of K_2SO_4 = 2 × 39 + 32 + 4 × 16
= 174 g mol^{-1}

Since K_2SO_4 dissociates completely as $K_2SO_4 \longrightarrow 2K^+ + SO_4^{2-}$

$$i = \frac{\text{Number of moles of particles after dissociation}}{\text{Number of moles of particles before dissociation}} = \frac{3}{1} = 3$$

Applying van't Hoff equation,

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

$$= \frac{3 \times 0.025\ \text{g} \times 0.0821\ \text{L atm K}^{-1}\ \text{mol}^{-1} \times 298\ \text{K}}{174\ \text{g mol}^{-1} \times 2\ \text{L}}$$

$$\mathbf{= 5.27 \times 10^{-3}\ atm}$$

Q. 5. **(*i*) Why is the value of Van't Hoff factor for ethanoic acid in benzene close to 0.5?**

(*ii*) Determine the osmotic pressure of a solution prepared by dissolving 2.32×10^{-2}g of K_2SO_4 in 2L of solution at 25°C, assuming that K_2SO_4 is completely dissociated.

($R = 0.082$ L atm K^{-1} mol^{-1}, Molar mass $K_2SO_4 = 174$g mol^{-1})

(*iii*) When 25.6g of Sulphur was dissolved in 1000g of benzene, the freezing point lowered by 0.512 K. Calculate the formula of Sulphur (S_x).

(K_f for benzene = 5.12 K kg mol^{-1}, Atomic mass of Sulphur = 32g mol^{-1}) [*CBSE 2023 (56/5/2)*]

Ans. (*i*) $2CH_3COOH \xrightleftharpoons{\text{Benzene}} (CH_3\text{—}COOH)_2$

Molecules of ethanoic acid dimerise in benzene due to hydrogen bonding. The number of particles reduced to nearly half of initial value due to dimerisation. Therefore value of Van't Hoff factor for ethanoic acid in benzene is close to 0.5.

(*ii*) $K_2SO_4 \longrightarrow 2K^+ + SO_4^{2-}, \quad i = \frac{3}{1} = 3$

Here $W_B = 2.32 \times 10^{-2}$ g, $i = 3$, R = 0.0821 L atom K^{-1} mol^{-1}, T = 298 K $M_B = 174$ g mol^{-1}, $V = 2L$.

Substituting the values in the expression, $\pi = \dfrac{i \square W_B \square R \square T}{M_B \square V}$

$$\text{We get, } \pi = \frac{3 \times 2.32 \times 10^{-2}\ \text{g} \times 0.0821\ \text{L atom K}^{-1}\text{mol}^{-1} \times 298\text{K}}{174\ \text{g mol}^{-1} \times 2\text{L}}$$

$$\pi = 4.89 \times 10^{-3}\ \text{atm.}$$

(*iii*) $W_B = 25.6$ g, $W_A = 1000$ g, $\Delta T_f = 0.512$ K, $K_f = 5.12$ K kg mol^{-1}

Substitution these values in the expression, we get

$$M_B = \frac{K_f \times W_B \times 1000}{\Delta T_f \times W_A}\text{, we get}$$

$$M_B = \frac{5.12\ \text{K kg mol}^{-1} \times 25.6\ \text{g} \times 1000\ \text{g kg}^{-1}}{0.512\ \text{K} \times 1000\ \text{g}}$$

$$= 256\ \text{g mol}^{-1}$$

Molecular mass of $S_x = 32x$

Now, $\quad 32x = 256$ or $x = \dfrac{256}{32} = 8$

Therefore, formula of sulphur = S_8

Q. 6. **(*i*) Why a person suffering from high blood pressure is advised to take minimum quantity of common salt?**

(*ii*) 2 g of benzoic acid (C_6H_5COOH) dissolved in 25 g of benzene shows a depression in freezing point equal to 1.62 K. Molal depression constant for benzene is 4.9 K kg mol^{-1}. What is the percentage association of acid if it forms dimer in solution? **[*CBSE 2019 (56/5/2)*]**

Ans. (*i*) Osmotic pressure is directly proportional to the concentration of the solutes. Our body fluid contains a number of solutes. On taking large amount of common salt, Na^+ and Cl^- ions enter into the body fluid thereby raising the concentration of the solutes. As a result, osmotic pressure increases which may rupture the blood cells.

(*ii*) The given quantities are

$W_B = 2$ g, $W_A = 25$ g, $\Delta T_f = 1.62$ K, $K_f = 4.9$ K kg mol^{-1}

Substituting these values in equation $M_B = \dfrac{K_f \times W_B \times 1000}{\Delta T_f \times W_A}$, we get

$$M_B = \frac{4.9 \times 2 \times 1000}{1.62 \times 25} = 241.98 \text{ g mol}^{-1}$$

Thus, observed molecular mass of benzoic acid in benzene = 241.98 g mol^{-1}

Normal molecular mass of C_6H_5COOH = 122 g mol^{-1}

$$\therefore \qquad i = \frac{\text{Normal molecular mass}}{\text{Observed molecular mass}} = \frac{122 \text{ g mol}^{-1}}{241.98 \text{ g mol}^{-1}} = 0.504$$

$$i = 0.504 \qquad \ldots(i)$$

If α represents the degree of association of solute then we would have $(1 - \alpha)$ mole of benzoic acid left in unassociated form and corresponding $\dfrac{\alpha}{2}$ as associated moles of benzoic acid at equilibrium.

Now, consider the following equilibrium for the acid:

$$\begin{array}{ccc} 2(C_6H_5COOH) & \rightleftharpoons & (C_6H_5COOH)_2 \\ 1 \text{ mol} & & 0 \\ (1-\alpha) \text{ mol} & & \frac{\alpha}{2} \text{ mol} \end{array}$$

Thus, total number of moles of particles at equilibrium

$$= 1 - \alpha + \frac{\alpha}{2} = 1 - \frac{\alpha}{2}$$

$$i = \frac{\text{Total number of moles of particles after association}}{\text{Number of moles of particles before association}}$$

$$i = \frac{1 - \frac{\alpha}{2}}{1} = 1 - \frac{\alpha}{2} \qquad \ldots(ii)$$

From (*i*) and (*ii*), we have

$$0.504 = 1 - \frac{\alpha}{2}$$

$$\frac{\alpha}{2} = 1 - 0.504 = 0.496$$

or $\quad \alpha = 0.496 \times 2 = \mathbf{0.992}$

Therefore, degree of association of benzoic acid in benzene is **99.2%**.

Q. 7. **(*i*) Give reasons for the following:**

(*a*) At higher altitudes, people suffer from a disease called anoxia. In this disease, they become weak and cannot think clearly. **[*CBSE 2019 (56/4/1)*]**

(*b*) When mercuric iodide is added to an aqueous solution of KI, the freezing point is raised.

(*ii*) 0.6 mL of acetic acid (CH_3COOH), having density 1.06 g mL^{-1}, is dissolved in 1 litre of water. The depression in freezing point observed for this strength of acid was 0.0205°C. Calculate the van't Hoff factor and the dissociation constant of acid.

Ans. (*i*) (*a*) At higher altitudes, partial pressure of oxygen is less than that at ground level, so that oxygen concentration becomes less in blood or tissues. Hence, people suffer from anoxia.

(*b*) Due to the formation of complex $K_2[HgI_4]$, number of particles in the solution decreases and hence the freezing point is raised.

(*ii*) Mass = Density × Volume

$\therefore$ Mass of acetic acid $= 1.06 \text{ g mL}^{-1} \times 0.6 \text{ mL} = 0.636 \text{ g}$

$$\text{Number of moles of acetic acid} = \frac{\text{Mass of acetic acid}}{\text{Molar mass}} = \frac{0.636 \text{ g}}{60 \text{ g mol}^{-1}} = 0.0106 \text{ mol}$$

Mass of water $= 1 \text{ g mL}^{-1} \times 1000 \text{ mL} = 1000 \text{ g}$

$$\text{Molality} = \frac{\text{Number of moles of acetic acid}}{\text{Mass of water in grams}} \times 1000$$

$$= \frac{0.0106}{1000} \times 1000 = 0.0106 \text{ mol kg}^{-1}$$

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

$$= 1.86 \text{ K kg mol}^{-1} \times 0.0106 \text{ mol kg}^{-1}$$

$$= 0.0197 \text{ K}$$

$$\text{van't Hoff Factor } (i) = \frac{\text{Observed freezing point}}{\text{Calculated freezing point}} = \frac{0.0205 \text{ K}}{0.0197 \text{ K}}$$

$$i = \mathbf{1.041} \qquad ...(i)$$

If α is the degree of dissociation of acetic acid, then we would have $n(1-\alpha)$ moles of undissociated acid, $n\alpha$ moles of CH_3COO^- and $n\alpha$ moles of H^+ ions at equilibrium.

$$\begin{array}{cccc} CH_3COOH & \rightleftharpoons & H^+ & + \quad CH_3COO^- \\ n \text{ mol} & & 0 & 0 \\ n(1-\alpha) & & n\alpha \text{ mol} & n\alpha \text{ mol} \end{array}$$

Thus, total moles of particles $= n - n\alpha + n\alpha + n\alpha = n(1+\alpha)$

$$i = \frac{\text{Total number of moles of particles after dissociation}}{\text{Number of moles of particles before dissociation}}$$

$$i = \frac{n(1+\alpha)}{n} = 1+\alpha \qquad ...(ii)$$

From (*i*) and (*ii*), we have

$$1.041 = 1+\alpha \quad \Rightarrow \quad \alpha = 1.041 - 1 = 0.041$$

$$K_a = \frac{[CH_3COO^-][H^+]}{[CH_3COOH]}$$

$$[CH_3COO^-] = n(1-\alpha) = 0.0106\,(1-0.041) = 0.0106 \times 0.959$$

$$[H^+] = n\alpha = 0.0106 \times 0.041$$

$$[CH_3COO^-] = n\alpha = 0.0106 \times 0.041$$

$$\therefore \quad K_a = \frac{0.0106 \times 0.041 \times 0.0106 \times 0.041}{0.0106 \times 0.959}$$

$$= \mathbf{1.86 \times 10^{-5}}$$

Questions for Practice

Choose and write the correct answer for each of the following.

1. **The value of van't Hoff factor for ethanoic acid in benzene is**

   (*a*) 1.0 (*b*) 1.5

   (*c*) 0.5 (*d*) 2

2. **Which of the following aqueous solutions should have the highest boiling point?** [*NCERT Exemplar*]

   (*a*) 1.0 M NaOH (*b*) 1.0 M Na_2SO_4

   (*c*) 1.0 M NH_4NO_3 (*d*) 1.0 M KNO_3

3. **An unknown gas 'X' is dissolved in water at 2.5 bar pressure and has mole fraction 0.04 in solution. The mole fraction of 'X' gas when the pressure of gas is doubled at the same temperature is** [*CBSE 2022 (56/3/4)*]

   (*a*) 0.08 (*b*) 0.04

   (*c*) 0.02 (*d*) 0.92

4. **An azeotropic solution of two liquids has a boiling point lower than either of the two when it** [*CBSE 2022 (56/3/4)*]

   (*a*) shows a positive deviation from Raoult's law.

   (*b*) shows a negative deviation from Raoult's law.

   (*c*) shows no deviation from Raoult's law.

   (*d*) is saturated.

5. **Which one of the following pairs will form an ideal solution?**

   (*a*) Chloroform and acetone

   (*b*) Ethanol and acetone

   (*c*) *n*-hexane and *n*-heptane

   (*d*) Phenol and aniline

In the following questions, two statements are given—one labeled Assertion (A) and the other labeled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below:

(a) Both Assertion (A) and Reason (R) are correct statements, and Reason (R) is the correct explanation of the Assertion (A).

(b) Both Assertion (A) and Reason (R) are correct statements, but Reason (R) is not the correct explanation of the Assertion (A).

(c) Assertion (A) is correct, but Reason (R) is incorrect statement.

(d) Assertion (A) is incorrect, but Reason (R) is correct statement.

6. **Assertion** (*A*) : Molarity of a solution in liquid state changes with temperature.

   Reason (*R*) : The volume of a solution changes with change in temperature.

7. **Assertion** (*A*) : Osmotic pressure is a colligative property.

   Reason (*R*) : Osmotic pressure is proportional to the molality.

8. **Assertion** (*A*) : If more volatile liquid is added to another liquid, vapour pressure of solution will be greater than that of pure solvent.

Reason (*R*) : Vapour pressure of solution is entirely due to solvent molecules.

9. **Assertion** (*A*) : The boiling point of pure solvent is always higher than the boiling point of solution.

Reason (*R*) : The vapour pressure of the solvent decreases in the presence of non-volatile solute.

10. **Assertion** (*A*) : The boiling point of 0.1 M urea solution is less than that of 0.1 M KCl solution.

Reason (*R*) : Elevation of boiling point is directly proportional to the number of species present in the solution.

Answer the following questions:

11. What type of deviation is shown by a mixture of ethanol and acetone? What type of azeotrope is formed by mixing ethanol and acetone? [*CBSE (F) 2013*]

12. Derive the relationship between relative lowering of vapour pressure and molar mass of the solute. [*CBSE Chennai 2015*]

13. Give reasons: [*CBSE 2019 (56/2/1)*]

    (*i*) Cooking is faster in pressure cooker than in cooking pan.

    (*ii*) Red Blood Cells (RBC) shrink when placed in saline water but swell in distilled water.

14. Calculate the mass of a non-volatile solute (molar mass 40 g mol^{-1}) which should be dissolved in 114 g octane to reduce its vapour pressure to 80%.

15. Henry's law constant for the molality of methane in benzene at 298 K is 4.27×10^5 mm Hg. Calculate the solubility of methane in benzene at 298 K under 760 mm Hg.

16. At 25°C the saturated vapour pressure of water is 3.165 kPa (23.75 mm Hg). Find the saturated vapour pressure of a 5% aqueous solution of urea (carbamide) at the same temperature.

    (Molar mass of urea = 60.05 g mol^{-1})

17. Calculate the freezing point of a solution when 3 g of $CaCl_2$ (M = 111 g mol^{-1}) was dissolved in 100 g of water, assuming $CaCl_2$ undergoes complete ionisation. (K_f for water = 1.86 K kg mol^{-1}).

18. Calculate the mass of NaCl (molar mass = 58.5 g mol^{-1}) to be dissolved in 37.2 g of water to lower the freezing point by 2°C, assuming that NaCl undergoes complete dissociation.

    (K_f for water = 1.86 K kg mol^{-1})

19. (*i*) When 2.56 g of sulphur was dissolved in 100 g of CS_2, the freezing point lowered by 0.383 K. Calculate the formula of sulphur (S_x).

    [K_f for CS_2 = 3.83 K kg mol^{-1}, Atomic mass of Sulphur = 32 g mol^{-1}]

    (*ii*) Blood cells are isotonic with 0.9 % sodium chloride solution. What happens if we place blood cells in a solution containing

    (*a*) 1.2% sodium chloride solution?

    (*b*) 0.4% sodium chloride solution?

20. (*i*) Why is boiling point of 1M NaCl solution more than that of 1M glucose solution?

    (*ii*) A non-volatile solute 'X' (molar mass = 50g mol^{-1}) when dissolved in 78 g of benzene reduced its vapour pressure to 90%. Calculate the mass of X dissolved in the solution.

(*iii*) Calculate the boiling point elevation for a solution prepared by adding 10g of $MgCl_2$ to 200g of water assuming $MgCl_2$ is completely dissociated.

(K_b for water = 0.512 K kg mol^{-1}, Molar mass $MgCl_2$ = 95g mol^{-1})

[*CBSE 2023 (56/5/2)*]

21. (*i*) Calculate the molality of a sulphuric acid solution in which the mole fraction of water is 0.85.

(*ii*) The graphical representation of vapour pressures of two component system as a function of composition is given alongside.

By graphic inspection, answer the following questions:

(*a*) Are the A–B interactions weaker, stronger or of the same magnitude as A–A and B–B?

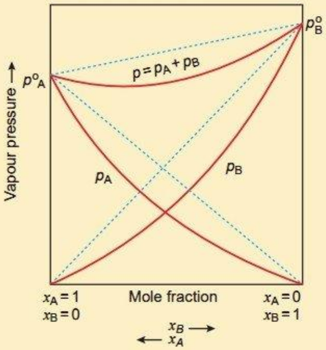
(*b*) Name the type of deviation shown by this system from Raoult's law.

(*c*) Predict the sign of $\Delta_{mix}H$ for this system.

(*d*) Predict the sign of $\Delta_{mix}V$ for this system.

(*e*) Give an example of such a system.

(*f*) What type of azeotrope will this system form, if possible?



Answers

1. (*c*) **2.** (*b*) **3.** (*a*) **4.** (*a*) **5.** (*c*) **6.** (*a*) **7.** (*c*) **8.** (*c*) **9.** (*a*) **10.** (*a*)

14. 8 g **15.** 1.78×10^{-3} **16.** 3.118 kPa **17.** 271.642 K **18.** 1.17 g

19. (*i*) 256 g mol^{-1} (*ii*) S_8

20. (*ii*) 5.56 g (*iii*) 273.958 K

21. (*i*) 0.98 m

(*ii*) (*a*) stronger, (*b*) Negative deviation (*c*) –ve, (*d*) –ve,

(*e*) A mixture of 20% acetone and 80% chloroform by mass, (*f*) maximum boiling azeotrope