

(1)

solutions of very imp questions (Solutions)

1. Oxygen is present in dissolved state in water. As per Henry's law when temperature rises solubility of a gas decreases in solvent, it means solubility of oxygen in warm water is less than cold water. This makes aquatic species respire comfortably in cold water. (1)

2. The mole fraction of a component is the ratio of the number of moles of the component to the total number of moles of all the components present in the solution. (1/2)

$$\text{Mole fraction of a component} = \frac{\text{Number of moles of the component}}{\text{Total number of moles of all the components}}$$

For a binary solution, mole fraction of

$$\text{component A, } \chi_A = \frac{n_A}{n_A + n_B}$$

$$\text{Similarly, for B, } \chi_B = \frac{n_B}{n_A + n_B} \text{ and } \chi_A + \chi_B = 1 \quad (1/2)$$

3. Henry's law states that, the partial pressure of the gas in vapour phase (p) is directly proportional to the mole fraction of the gas (χ) in the solution.

$$p = K_H \cdot \chi$$

Here, K_H = Henry's law constant.

Different gases have different K_H values at the same temperature. (1)

4. Molality does not change with change in temperature while, molarity decreases with rise in temperature. (1)

5. (a) Refer to sol 1. (1)

(b) At higher altitude people suffer from anoxia because at higher altitudes, the partial pressure of oxygen is less than that at ground level. This leads to low concentration of oxygen in the blood and tissues of people. (1)

6. (i) Mole fraction (χ) Refer to solution 2. (1)

(ii) Molality of solution (m) Molality is defined as the number of moles of the solute per kilogram of the solvent. It is represented by m

$$\text{Molality } (m) = \frac{\text{Number of moles of solute}}{\text{Mass of solvent in kg}} \quad (1)$$

7. 9.8% solution of H_2SO_4 means 9.8 g of H_2SO_4 is present in 100 g of the solution. Thus,

$$\text{Mass of } H_2SO_4 \text{ dissolved} = 9.8 \text{ g}$$

$$\text{Mass of solution} = 100 \text{ g}$$

$$\text{Density of solution} = 1.02 \text{ g mL}^{-1}$$

$$\text{Moles of } H_2SO_4 = \frac{9.8 \text{ g}}{98 \text{ g mol}^{-1}} = 0.1 \text{ mol} \quad (1/2)$$

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

$$= \frac{100 \text{ g}}{1.02 \text{ g mL}^{-1}} = \frac{100}{1.02} \text{ mL}$$

$$= 98.04 \text{ mL or } 0.09804 \text{ L} \quad (1/2)$$

$$\text{Molarity} = \frac{\text{Number of moles of the solute}}{\text{Volume of solution (in litres)}}$$

$$= \frac{0.1 \text{ mol}}{0.09804 \text{ L}}$$

$$= 1.019 \text{ mol L}^{-1} \text{ or } 1.02 \text{ M} \quad (1)$$

8. Molality is defined as the number of moles of the solute per kilogram of the solvent. It is represented by m .

$$\text{Molality } (m) = \frac{\text{Number of moles of solute} \times 1000}{\text{Mass of solvent (in g)}}$$

It does not change with change in temperature.

Molarity is defined as the number of moles of solute dissolved in one litre or one cubic decimetre of the solution.

$$\text{Molarity } (M) = \frac{\text{Number of moles of solute} \times 1000}{\text{Volume of solution (in mL)}} \quad (1)$$

It decreases with increase in temperature (as $V \propto T$).

We can change molality value of a solution into molarity value by using following relation:

$$\text{Molality } (m) = \frac{M \times 1000}{(1000 \times d) - (M \times M_2)}$$

where, M is the molarity and M_2 is the molar mass of component 2 (generally solute) and d is the density of solution (in g cm^{-3}). (1)

9. A 10% glucose solution by weight means that 10 g glucose is present in 100 g solution.

$$\begin{aligned} \text{Number of moles of 10 g glucose} \\ = \frac{10}{180} = 0.0555 \text{ mol} \end{aligned} \quad (1)$$

$$\text{Weight of glucose} = 10 \text{ g}$$

$$\text{Weight of water} = 90 \text{ g} = \frac{90}{1000} \text{ kg} = 0.09 \text{ kg}$$

$$\text{Molality } (m) = \frac{\text{Number of moles of solute}}{\text{Mass of solvent (in kg)}}$$

$$= \frac{0.0555 \text{ mol}}{0.09 \text{ kg}}$$

$$= 0.61 \text{ mol kg}^{-1} \text{ or } 0.61 \text{ m.} \quad (1)$$

10. (i) Find volume of solution using the formula $V = \frac{m}{d}$
 (ii) While calculating volume of solution, total mass, i.e. mass of solute + mass of solvent is taken.

Given, $d = 1.25 \text{ g mL}^{-1}$, $W_2 = 92 \text{ g}$,

$$W_1 = 1 \text{ kg or } 1000 \text{ g}, M_2 = 23 \text{ g mol}^{-1}$$

We know that, density (d) of solution

$$= \frac{\text{Mass (m) of solution}}{\text{Volume (V) of solution}}$$

$$\text{or } V = \frac{m}{d} = \frac{(1000 \text{ g} + 92 \text{ g})}{1.25 \text{ g mL}^{-1}}$$

[Mass of solution = mass of solvent + mass of solute]

$$= \frac{1092}{1.25} \text{ mL} = 873.6 \text{ mL}$$

$$= 873.6 \times 10^{-3} \text{ L} \quad (1)$$

$$\text{Moles of solute} = \frac{92 \text{ g}}{23 \text{ g mol}^{-1}} = 4 \text{ mol}$$

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

$$= \frac{4 \text{ mol}}{873.6 \times 10^{-3} \text{ L}}$$

$$= 4.579 \text{ mol L}^{-1} \text{ or } 4.58 \text{ M} \quad (1)$$

11. Refer to solution 8. (2)

12. Refer to solution 1. (2)

13. Henry's law Refer to solution 3. (1)

Applications of Henry's Law

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

(ii) To minimise the painful effects of bends or decompression sickness in deep sea divers, oxygen diluted with less soluble helium gas is used as breathing gas. (1/2 + 1/2 = 1)

14. 10% glucose solution (by mass) in water means 10 g of glucose (solute) is present in 100 g of solution. (1/2)

Thus, mass of solution, $m = 100 \text{ g}$

$W_2 = 10 \text{ g}$ (solute); $W_1 = 90 \text{ g}$ (solvent)

M_2 (glucose) = 180 g mol^{-1}

Density of solution = 1.2 g mL^{-1}

Volume of solution,

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

$$\text{Molarity (M)} = \frac{W_2}{M_2 \times \text{volume}} = \frac{10 \times 12}{180 \times 1}$$

$$= 0.667 \text{ M}$$

$$\text{Molality (m)} = \frac{W_2 \times 1000}{M_2 \times W_1} = \frac{10 \times 1000}{180 \times 90} = 0.617 \text{ M} \quad (1/4)$$

15. According to Henry's law,

$$m = K_H \times p \quad (1)$$

In 1st case, $6.56 \times 10^{-2} \text{ g} = K_H \times 1 \text{ bar}$

$$\text{or } K_H = 6.56 \times 10^{-2} \text{ g bar}^{-1}$$

In 2nd case, $5.00 \times 10^{-2} \text{ g} = (6.56 \times 10^{-2} \text{ g bar}^{-1}) \times p$ (1)

$$\text{or } p = \frac{5.00 \times 10^{-2} \text{ g}}{6.56 \times 10^{-2} \text{ g bar}^{-1}} = 0.762 \text{ bar} \quad (1)$$

16. According to Henry's law,

$$p_{\text{N}_2} = K_H \times \chi_{\text{N}_2}$$

$$\chi_{\text{N}_2} = \frac{p_{\text{N}_2}}{K_H} = \frac{0.987 \text{ bar}}{76480 \text{ bar}} = 1.29 \times 10^{-5} \quad (1)$$

If n moles of N_2 are present in 1L or 1000 g of water (or $\frac{1000 \text{ g}}{18 \text{ g mol}^{-1}} = 55.5 \text{ moles}$)

$$\chi_2 = \frac{n}{n + 55.5} = \frac{n}{55.5} \text{ (as } n \ll 55.5)$$

$$\therefore \frac{n}{55.5} = 1.29 \times 10^{-5}$$

$$\Rightarrow n = 1.29 \times 10^{-5} \times 55.5 \text{ moles} \\ = 71.595 \times 10^{-5} \text{ moles} \\ = 0.716 \text{ m moles} \quad (1)$$

(2)

to the A—A (solute-solute) and B—B type (solvent-solvent) interactions. (1/2)

2. Azeotropes are binary mixtures having the same composition in liquid and vapour phase and boil at constant temperatures. (1)

3. **Raoult's law** For a solution of volatile liquids, the partial vapour pressure of each component of the solution is directly proportional to its mole fraction present in solution. Thus, for any component, partial vapour pressure,

$$p \propto \chi \Rightarrow p = p^\circ \chi$$

where, p° is the vapour pressure of pure component and χ is the mole fraction of that component. (1)

4. The mixture of acetone and chloroform is an example of maximum boiling azeotrope. It shows negative deviation from Raoult's law because of increase in intermolecular forces of attraction between acetone and chloroform, since they form hydrogen bonds between them. (2)

5. Raoult's law states that "at a given temperature, for a solution of volatile liquids, the partial vapour pressure of each component of the solution is directly proportional to its mole fraction present in the solution".

The solutions which obey Raoult's law over the entire range of concentration are known as ideal solutions. (1)

The important properties of these solutions are :

(i) the enthalpy of mixing of pure components to form the solution is zero, i.e. $\Delta_{\text{mix}}H = 0$.

(ii) the volume of mixing is also zero, i.e.

$$\Delta_{\text{mix}}V = 0. \quad (1)$$

6.

Ideal solution	Non-ideal solution
The components of this solution obey Raoult's law at all temperatures and concentrations. i.e. $p_A = p_A^\circ \chi_A$ and $p_B = p_B^\circ \chi_B$	The components of this solution do not obey Raoult's law. They show positive and negative deviations from Raoult's law. i.e. $p_A \neq p_A^\circ \chi_A$ and $p_B \neq p_B^\circ \chi_B$ (1)
On mixing, there is no enthalpy and volume change. i.e. $\Delta_{\text{mix}}H = 0$ and $\Delta_{\text{mix}}V = 0$	On mixing, there is enthalpy and volume change. i.e. $\Delta_{\text{mix}}H \neq 0$ and $\Delta_{\text{mix}}V \neq 0$ (1)

Explanations

1. The solutions which obey Raoult's law over the entire range of concentration are known as ideal solutions. For ideal solutions, ΔH (mixing) = 0 and ΔV (mixing) = 0 e.g. solution of *n*-hexane and *n*-heptane, bromoethane and chloroethane, etc. (1/2)

Or In these solutions (binary solutions), A—B type (i.e. solute-solvent) interactions are nearly equal

7. Refer to notes

Carbon disulphide and acetone form minimum boiling azeotropes. (2)

8. (i) **Ideal solution** Refer to solution 1. (1)

(ii) **Molarity (M)** Molarity is defined as the number of moles of solute dissolved in one litre or one cubic decimetre of the solution.

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

e.g. 0.25 mol L⁻¹ (or 0.25 M) solution of NaOH means that 0.25 mole of NaOH has been dissolved in one litre (or one cubic decimetre) of solution. (1)

9. Solubility is inversely proportional to K_H , i.e. Henry's constant of the gas.

(i) Greater the value of K_H , lower is the solubility of the gas. As gas (A) is more soluble in water than gas (B) at the same temperature, hence the gas (A) has lower value of K_H . In other words, gas (B) has higher value of K_H than gas (A) at the same temperature. (1)

(ii) In non-ideal solutions, the solutions that show large negative deviation from Raoult's law form maximum boiling azeotropes. e.g. Mixture of nitric acid and water. (1)

10. Positive deviation means A—B interactions are weaker than A—A and B—B interactions while, opposite is true in case of negative deviation.

For non-ideal solutions, vapour pressure is either higher or lower than that predicted by Raoult's law. If it is higher, the solution exhibits positive deviation and if it is lower, it exhibits negative deviation from Raoult's law.

In case of **positive deviation**, A—B interactions are weaker than A—A and B—B interactions.

Due to this, vapour pressure increases which results in positive deviation.

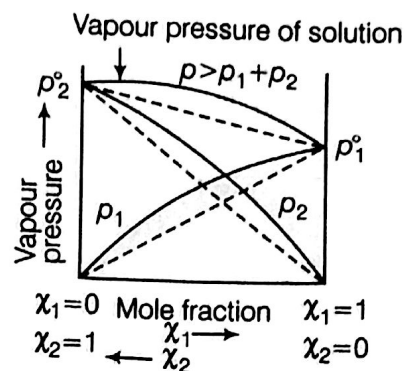
e.g. Ethanol+Acetone and CS₂+Acetone show positive deviation. (1/2)

For positive deviation, ΔH (mixing) = Positive

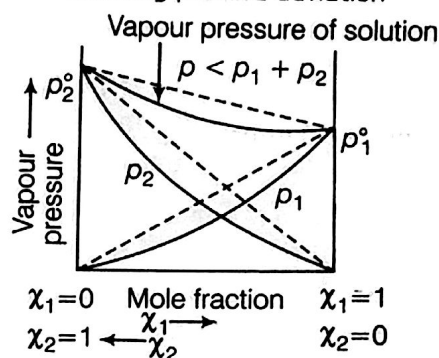
In case of **negative deviation**, A—B interactions are stronger than A—A and B—B interactions.

Due to this, vapour pressure decreases which results in negative deviation. e.g. Phenol + Aniline and Chloroform + Acetone show negative deviation. (1/2)

For negative deviation, ΔH (mixing) = Negative



Plot for non-ideal solution showing positive deviation (1/2)



Plot for non-ideal solution showing negative deviation (1/2)

11. **Azeotropes** Refer to solution 2. (1)

Azeotropes showing negative deviation from Raoult's law form maximum boiling azeotropes at a specific composition, e.g. Azeotrope formed from nitric acid and water.

Azeotropes showing positive deviation from Raoult's law form minimum boiling azeotropes at a specific composition. e.g. Ethanol-water mixture. (1)

12. **Raoult's law** Refer to solution 3. (1)

Raoult's law as a special case of Henry's law

In the solution of a gas in a liquid, one of the components is so volatile that it exists as a gas and its solubility is given by Henry's law which states that, $p = K_H \chi$.

i.e. partial pressure of the volatile component (gas) is directly proportional to the mole fraction of that component (gas) in the solution.

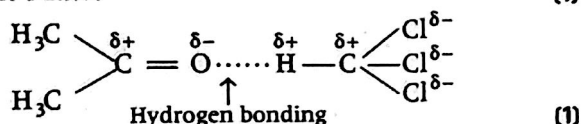
When the equations of Raoult's law and Henry's law are compared, it can be seen that the partial pressure of the volatile component or gas is directly proportional to its mole fraction in solution. Only the proportionality constant K_H differs from p° .

Hence, Raoult's law and Henry's law has been identical except that their proportionality constants are different.

Therefore, Raoult's law becomes a special case of Henry's law in which K_H becomes equal to vapour pressure of pure component p° . (1)

13. Negative deviation means A—B interactions are stronger than A—A and B—B interactions.

A mixture of chloroform and acetone forms a solution which shows negative deviation from Raoult's law because chloroform molecule forms H-bonding with acetone molecule. Here, solute is chloroform and solvent is acetone. As a result of this, A—B interaction becomes stronger than A—A and B—B interactions. This decreases the escaping tendency of molecules for each component which leads to the decrease in vapour pressure and resulting in negative deviation from Raoult's law. (1)



14. Given, $p_A^\circ = 450$ mm of Hg

$$p_B^\circ = 700 \text{ mm of Hg}; p_{\text{Total}} = 600 \text{ mm of Hg}; \chi_A = ?$$

According to Raoult's law,

$$p_A = \chi_A \times p_A^\circ$$

$$p_B = \chi_B \times p_B^\circ = (1 - \chi_A)p_B^\circ$$

$$\begin{aligned}
 p_{\text{Total}} &= p_A + p_B = \chi_A \times p_A^\circ + (1 - \chi_A)p_B^\circ \\
 &= p_B^\circ + (p_A^\circ - p_B^\circ)\chi_A
 \end{aligned}
 \quad (1)$$

On substituting the given values into the above equation, we get

$$\begin{aligned}
 600 &= 700 + (450 - 700)\chi_A \\
 100 &= 250\chi_A \Rightarrow \chi_A = \frac{100}{250} = 0.40
 \end{aligned}$$

Thus, the composition of the liquid mixture will be

$$\begin{aligned}
 \chi_A &= 0.40 \\
 \chi_B &= 1 - 0.40 = 0.60
 \end{aligned}
 \quad (1)$$

Calculation of composition in the vapour phase,

$$\begin{aligned}
 p_A &= \chi_A \times p_A^\circ = 0.40 \times 450 \text{ mm of Hg} \\
 &= 180 \text{ mm of Hg}
 \end{aligned}$$

$$\begin{aligned}
 p_B &= \chi_B \times p_B^\circ = 0.60 \times 700 \text{ mm of Hg} \\
 &= 420 \text{ mm of Hg}
 \end{aligned}$$

Mole fraction of A in the vapour phase

$$\begin{aligned}
 &= \frac{p_A}{p_A + p_B} = \frac{180}{180 + 420} = 0.30
 \end{aligned}
 \quad (1)$$

Mole fraction of B in vapour phase

$$= 1 - 0.30 = 0.70 \quad (1)$$

(3)

Putting values in Eq. (1)

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

Molality $m = 1.33$ (1)

Now, $\Delta T_f = K_f m$, $K_f = 1.86\text{ K kg mol}^{-1}$

$$\Delta T_f = 1.86\text{ K kg mol}^{-1} \times 1.33\text{ m}$$

$$\Delta T_f = 2.47\text{ K}$$

Freezing point of pure water = 273.15 K

$$\therefore \text{freezing point of solution} = 273.15 - 2.47\text{ K} \\ = 270.68\text{ K} \quad (1)$$

Explanations

1. Two solutions having the same osmotic pressure at a given temperature are called isotonic solutions. (1)

2. **Osmotic pressure** is the extra pressure which is applied on the solution just to prevent the flow of solvent into the solution through a semipermeable membrane. (1)

3. If a pressure higher than the osmotic pressure is applied in the solution, the solvent will flow from the solution into the pure solvent through the semi-permeable membrane and the process is called **reverse-osmosis**. (1)

4. (i) Refer to solution 1. (1/2)

(ii) **van't Hoff factor** It is defined as the ratio of the experimental value of colligative property to the calculated value of the colligative property and is used to find out the extent of dissociation or association. Mathematically, it is represented as

$$i = \frac{\text{Observed colligative property}}{\text{Calculated colligative property}} \quad (1/2)$$

5. The boiling point elevation constant is equal to the elevation in boiling point when 1 mole of a solute is dissolved in 1 kg of solvent. It is also called ebullioscopic constant. (1)

6. Molality of solution,

$$m = \frac{w_2}{M_2} \times \frac{1000}{w_1} \quad \dots (i)$$

where, weight of glucose $w_2 = 60\text{ g}$

molar mass of glucose $M_2 = 180\text{ g mol}^{-1}$

weight of solvent (water) $w_1 = 250\text{ g}$

7. (i) The osmotic pressure method has the advantage over other methods as pressure measurement is around the room temperature and the molarity of the solution is used instead of molality. (1)

(ii) Elevation in boiling point is directly proportional to ' i '. $\Delta T_b \propto i$. Now as given in the question, elevation of boiling point of 1 M KCl solution is nearly double than that of 1 M sugar solution. It is because KCl being ionic, dissociates into K^+ and Cl^- and therefore its van't Hoff factor, i is 2 whereas for sugar van't Hoff factor is 1 as it does not undergoes such a dissociation. (1)

8. (i) **Colligative properties** The properties of solutions which depends only on the number of solute particles, irrespective of their nature relative to the total number of particle present in the solution.

There are four important colligative properties.

I. Relative lowering of vapour pressure

II. Elevation of boiling point

III. Depression of freezing point

IV. Osmosis and osmotic pressure (1)

(ii) **Molality (m)** It is defined as the number of moles of the solute per kilogram of the solvent.

$$\text{Molality} = \frac{\text{Moles of solute}}{\text{Mass of solvent (in kg)}}$$

e.g. 1.00 mol kg^{-1} (or 1.00 m) solution of KCl means that 1 mole (74.5 g) of KCl is dissolved in 1 kg of water. (1)

9. (i) **Abnormal molar mass** Molar mass that is either lower or higher than the expected or normal value is called abnormal molar mass, e.g. all the molecules of ethanoic acid associate in benzene, then ΔT_b or ΔT_f for ethanoic acid will be half of the normal value. (1)

(ii) **van't Hoff factor** Refer to solution 4 (ii). (1)

10. Refer to solution 2. (1)

Osmotic pressure (π) related to the concentration (C) of a solute as

$$\pi = CRT; \pi = \frac{n_2}{V} RT = \frac{W_2 RT}{M_2 V}$$

$$\pi V = W_2 \frac{RT}{M_2}; M_2 = \frac{W_2 RT}{\pi V} \quad (1)$$

11. (i) On mixing two liquids X and Y , the decrease in volume of the resulting solution suggests that a non-ideal solution is formed which shows negative deviation from Raoult's law.

In case of the solutions showing negative deviations from Raoult's law, ΔH mixing (i.e. enthalpy of mixture) is negative.

Thus, on mixing X and Y liquids, evolution of heat takes place, i.e. the temperature of the resulting solution increases. (1)

(ii) When we placed the blood cell in hypertonic solution then due to osmosis, water will flow out of the cell and it would shrink. (1)

12. The boiling point of the solution containing a non-volatile solute is always higher than that of the pure solvent because the vapour pressure of such a solution is lower than that of the pure solvent and vapour pressure increases with increase in temperature. Hence, the solution has to be heated more to make the vapour pressure equal to the atmospheric pressure. (1)

Elevation of boiling point is a colligative property because it depends upon the number of solute particles present in a solution. (1)

13. Given that $K_f = 5.12 \text{ K kg mol}^{-1}$, $W_1 = 75 \text{ g}$,

$$\Delta T_f = 0.48 \text{ K}, M_2 = 256 \text{ g mol}^{-1}$$

$$\Delta T_f = \frac{K_f \times W_2 \times 1000}{W_1 \times M_2} \quad (1/2)$$

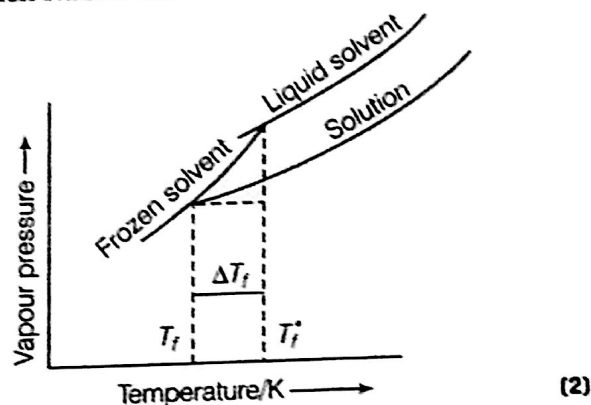
$$\text{or } 0.48 = \frac{5.12 \times W_2 \times 1000}{75 \times 256} \quad (1/2)$$

$$\therefore W_2 = \frac{0.48 \times 75 \times 256}{5.12 \times 1000} = 1.8 \text{ g} \quad (1)$$

14. When a non-volatile solute is added to a solvent, its vapour pressure decreases because some of the surface sites are occupied by solute molecules. Thereby, the fraction of the surface covered by the solvent molecules gets reduced. Thus, less space is available for the solvent molecules to vaporise. Therefore, vapour pressure is also reduced. (2)

15. When a non-volatile solute is added to a solvent, the freezing point of the solution is always lower than that of pure solvent as the vapour pressure of the solvent decreases in the presence of non-volatile solute.

Plot for the lowering in freezing point of water when NaCl is added to it is shown below.



16.

(i) First, find out ΔT_b by using formula.

$$\Delta T_b = \frac{K_b \times W_b \times 1000}{M_b \times W_a}$$

(ii) Then, find out the value of T_b by using formula.
 $\Delta T_b = T_b - T_b^\circ$

Given, $W_a = \text{weight of H}_2\text{O (solvent)}$
 $= 1 \text{ kg} = 1000 \text{ g}$

$W_b = \text{weight of C}_6\text{H}_{12}\text{O}_6 \text{ (glucose-solute)}$
 $= 18 \text{ g}$

$T_b^\circ = 373.15 \text{ K}$

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

$M_b = \text{Molar mass of solute (glucose)}$
 $= 180 \text{ g mol}^{-1}$

$$\Delta T_b = \frac{K_b \times 1000 \times W_b}{M_b \times W_a}$$

$$= \frac{(0.52 \text{ K kg mol}^{-1}) \times 1000 \times 18 \text{ g}}{(180 \text{ g mol}^{-1}) \times 1000 \text{ g}}$$

$$= \frac{9360}{180000} = 0.052 \text{ K} \quad (1)$$

As we know that, $\Delta T_b = T_b - T_b^\circ$

$$\Rightarrow 0.052 = T_b - 373.15$$

$$\Rightarrow T_b = 373.15 + 0.052$$

$$= 373.202 \text{ K}$$

$$= 373.20 \text{ K (approx)} \quad (1)$$

17. Consider the relation, $\Delta T_b = iK_b m$

Molality of solution, $m = 1.00 \text{ m}$

Boiling point of solution,

$$T_b = 100.18^\circ \text{C} = 373.18 \text{ K}$$

Boiling point of water (solvent)

$$T_b^\circ = 100.00^\circ \text{C} = 373 \text{ K}$$

$$\Delta T_b = T_b - T_b^\circ = 373.18 \text{ K} - 373 \text{ K} = 0.18 \text{ K} \quad (1/2)$$

$$\Delta T_b = iK_b m \quad (1/2)$$

$$0.18 \text{ K} = i \times 0.512 \text{ K kg mol}^{-1} \times 1 \text{ mol kg}^{-1}$$

$$i = \frac{0.18 \text{ K}}{0.512 \text{ K kg mol}^{-1} \times 1 \text{ mol kg}^{-1}}$$

$$i = 0.35 \quad (1)$$

18. **Osmosis** The movement of solvent molecules from less concentrated solution to more concentrated solution through semipermeable membrane is called osmosis. (1/2)

Osmotic pressure Refer to solution 2. (1/2)

Yes, osmotic pressure is a colligative property because it depends upon the number of solute particles but not on their nature, e.g. 0.1 molar KCl and NaCl have the same osmotic pressure under same conditions of temperature and pressure. (1)

19. **van't Hoff factor** Refer to solution 4 (ii). (1)

In dissociation, observed molar mass has lesser value than normal, so i is more than one ($i > 1$). e.g. The value of i for ethanoic acid in benzene is nearly 0.5 while for aqueous KCl, NaCl and MgSO_4 solution, it is nearly 2. The value of i for K_2SO_4 is nearly 3. (1)

20. The osmotic pressure method has the advantage over other colligative properties because

(i) pressure measurement is around the room temperature and the molarity of the solution is used instead of molality. (1)

(ii) its magnitude is large as compared to other colligative properties even for very dilute solutions. (1)

21. **For osmosis and osmotic pressure** Refer to solution 18.

For advantages of osmotic pressure Refer to solution 20. (2)

22. Given $K_b = 0.52 \text{ K m}^{-1}$

Mass of solute (W_2) = 0.520 g (glucose)

Mass of solvent (W_1) = 80.20 g (water)

Molar mass of solute (M_2) = 180 g mol⁻¹

Molar mass of solvent (M_1) = 18 g mol⁻¹

$$\therefore \Delta T_b = K_b \times \frac{W_2}{M_2} \times \frac{1000}{W_1}$$

$$\Delta T_b = \frac{0.52 \times 0.52 \times 1000}{180 \times 80.2}$$

$$\Delta T_b = 0.0187 \approx 0.019$$

$$\therefore \text{Boiling point } T_b = 373 + 0.019 = 373.019 \text{ K}$$

$$\text{Hence b.p} \approx 373.02 \text{ K} \quad (1)$$

23. (i) First, find out ΔT_f by using the formula

$$\Delta T_f = \frac{K_f \times W_2 \times 1000}{M_2 \times W_1}$$

(ii) Then, find out the value of T_f by using formula, $\Delta T_f = T_f^\circ - T_f$

Given, W_2 (glucose) = 0.520 g

W_1 (H_2O) = 80.2 g

K_f (H_2O) = 1.86 K m⁻¹

M_2 of $\text{C}_6\text{H}_{12}\text{O}_6$ (glucose) = 180 g mol⁻¹

$$\Delta T_f = \frac{K_f \times W_2 \times 1000}{M_2 W_1}$$

$$= \frac{1.86 \text{ K m}^{-1} \times 0.520 \text{ g} \times 1000}{180 \text{ g mol}^{-1} \times 80.2 \text{ g}} \quad (1)$$

$$= 0.0669 \text{ K} \quad (1/2)$$

Freezing point of solution

$$T_f = 273 \text{ K} - 0.0669 \text{ K}$$

$$= 272.933 \text{ K} \quad (1/2)$$

24. The egg placed in pure water will swell because the concentration of proteins is high inside the egg as compared to water. Therefore, water diffuses through the semi-permeable membrane of egg and egg swells. (1)

On the other hand, the egg placed in sodium chloride solution will shrink due to osmosis, water will move out of the egg membrane, thereby, shrinking the egg. (1)

25. **Given** Mass of glucose (w_B) = 30 g

Volume of solution (V_i) = 1000 mL (= 1 L)

Osmotic pressure (initial) (π_i) = 4.98 bar

Osmotic pressure (final) (π_f) = 1.52 bar

Molar mass of glucose (M_B) = 180 g mol⁻¹

(i.e. of $\text{C}_6\text{H}_{12}\text{O}_6$)

\therefore Osmotic pressure (π) = CRT

(where, C = concentration)

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

and mass of glucose is same for both the solutions i.e., for π_i and π_f

or

$$\pi_i \times V_i = \pi_f \times V_f$$

or

$$4.98 \times 1 = 1.52 \times V_f$$

\therefore

$$V_f = \frac{4.98}{1.52} = 3.28 \text{ L}$$

(1)

Therefore, concentration of final solution (C_f) is

$$C_i \times V_i = C_f \times V_f$$

(where, C_i is initial concentration)

$$\frac{W_B}{M_B} \times 1 = C_f \times 3.28 \text{ L}$$

or

$$C_f = \frac{30}{180} \times \frac{1}{3.28} = 0.05 \text{ M}$$

Hence, concentration of final solution = 0.05 M (1)

26. 4% solution (w/w) of sucrose is given

$$\Rightarrow w_2 = 4 \text{ g}; M_2 = 342 \text{ g/mol and } w_1 = 96 \text{ g}$$

$$\therefore \text{Molality of sucrose} = \frac{w_2 \times 1000}{M_2 \times w_1} = \frac{4 \times 1000}{342 \times 96}$$

$$= 0.122 \text{ mol kg}^{-1} \text{ or } 0.122 \text{ m}$$

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

$$= 273.15 - 271.15 = 2 \text{ K}$$

$$\therefore \Delta T_f = k_f \times m \Rightarrow k_f = \frac{\Delta T_f}{m} = \frac{2}{0.122}$$

(1)

Now, molality of glucose solution

$$\text{Given } w_2 = 5 \text{ g}; M_2 = 180 \text{ g/mol}; w_1 = 95 \text{ g}$$

$$\therefore \text{Molality of glucose} = \frac{w_2 \times 1000}{M_2 \times w_1} = \frac{5}{180} \times \frac{1000}{95}$$

$$= 0.292 \text{ m}$$

$$\therefore \Delta T_f (\text{glucose}) = k_f \times m$$

$$= \frac{2}{0.122} \times 0.292 = 4.8$$

(1)

\therefore Freezing point of glucose solution

$$= 273.15 - 4.8 = 268.35 \text{ K}$$

(1)

27. Apply van't Hoff equation, $\Delta T_f = iK_f \cdot m$, where i = number of ions produced by MgBr_2 .

$$\text{Given, } W_2 = 10.50 \text{ g}, W_1 = 200 \text{ g}$$

$$M_2(\text{MgBr}_2) = 184 \text{ g mol}^{-1}$$

$$K_f = 1.86 \text{ K kg mol}^{-1}$$



$$i = 3$$

(1)

$$\Delta T_f = iK_f \cdot m$$

$$\Delta T_f = \frac{i \cdot K_f \times W_2 \times 1000}{M_2 \times W_1}$$

(1/2)

$$\Delta T_f = \frac{3 \times 1.86 \text{ K kg mol}^{-1} \times 10.50 \text{ g} \times 1000}{184 \text{ g mol}^{-1} \times 200 \text{ g}}$$

$$= 1.592 \text{ K}$$

(1/2)

$$\text{Freezing point of solution} = 273 \text{ K} - 1.592 \text{ K}$$

$$T_f = 271.408 \text{ K}$$

(1)

28.

First, calculate the value of molality (m) of sucrose, using $m = \frac{W_{\text{solute}} \times 1000}{M_{\text{solute}} \times W_{\text{solvent}}}$

then, calculate the cryoscopic constant (K_f) by using depression in freezing point, $\Delta T_f = K_f \cdot m$. Finally calculate the ΔT_f of glucose solution followed by freezing point of glucose solution $T_f = 273.15 - \Delta T_f$.

For sucrose solution,

10% solution by mass means 10 g of sucrose dissolved in 90 g of water.

$$\text{Molality of sucrose solution} = \frac{W_2 \times 1000}{M_2 \times W_1}$$

$$\text{Given, } W_2 = 10 \text{ g}$$

$$W_1 = 90 \text{ g}$$

$$M_2 = 342 \text{ g mol}^{-1}$$

$$\text{Molality } (m) = \frac{10}{342} \times \frac{1000}{90} = 0.324 \text{ mol kg}^{-1}$$

$$\Delta T_f \text{ for sucrose solution} = 273.15 \text{ K} - 269.15 \text{ K} = 4 \text{ K}$$

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

$$K_f = \frac{4}{0.324} \text{ K kg mol}^{-1}$$

(1)

For glucose solution

$$W_2 = 10 \text{ g}, W_1 = 90 \text{ g}, M_2 = 180 \text{ g mol}^{-1}$$

$$\text{Molality } (m) = \frac{10}{180} \times \frac{1000}{90} = 0.617 \text{ mol kg}^{-1}$$

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

$$\therefore \Delta T_f (\text{glucose}) = \frac{4}{0.324} \times 0.617 = 7.617 \text{ K}$$

(1)

Hence, freezing point of glucose solution

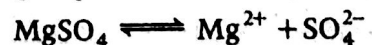
$$= 273.15 \text{ K} - 7.617 \text{ K} = 265.53 \text{ K}$$

(1)

29. Given, weight of solute, $W_2 = 4 \text{ g}$

weight of solvent, $W_1 = 100 \text{ g}$

$i = 2$ (as MgSO_4 dissociates completely into 2 ions)



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

$$M_2 = 120 \text{ g mol}^{-1}$$

(1)

∴ The elevation in boiling point of solution,

$$\Delta T_b = \frac{i \times K_b \times W_2 \times 1000}{M_2 \times W_1}$$

where,

i = van't Hoff factor

W_2 = weight of solute

W_1 = weight of solvent

M_2 = molar mass of solute

T_b° = boiling point of pure solvent

$$\Delta T_b = \frac{2 \times 0.52 \times 4 \times 1000}{120 \times 100} = 0.346 \text{ K}$$

(1)

Boiling point of pure water is 100°C or 373 K.

$$T_b = \Delta T_b + T_b^\circ$$

$$\therefore T_b = 373 + 0.346$$

$$= 373.346 \text{ K}$$

(1)

30. (i) Apply the formula,

$$\Delta T_f = \frac{iK_f \times W_2 \times 1000}{M_2 \times W_1} \text{ and find } W_2.$$

(ii) Since, NaCl and KCl are strong electrolytes,
∴ $\alpha = 1$ and $i = 2$ (if not given in question)

Given, $W_1 = 37.2 \text{ g}$, $\Delta T_f = 2^\circ\text{C} = 2\text{K}$

$$\begin{aligned} \therefore \Delta T_f &= T_f - T_f^\circ \\ \Delta T_f &= 2^\circ\text{C} - 0^\circ\text{C} = 2^\circ\text{C} \\ \text{or } \Delta T_f &= 275\text{K} - 273\text{K} = 2\text{K} \end{aligned}$$

$K_f = 1.86 \text{ K kg mol}^{-1}$, $i = 2$

[for complete dissociation]

$M_2(\text{NaCl}) = 23 + 35.5 = 58.5 \text{ g mol}^{-1}$

$$\Delta T_f = \frac{iK_f \times W_2 \times 1000}{M_2 \times W_1} \quad (1)$$

$$W_2 = \frac{\Delta T_f \times M_2 \times W_1}{i \times K_f \times 1000}$$

$$= \frac{2\text{K} \times 58.5 \text{ g mol}^{-1} \times 37.2 \text{ g}}{2 \times 1.86 \text{ K kg mol}^{-1} \times 1000}$$

$$W_2 = 1.17 \text{ g} \quad (2)$$

Or

Refer to the above method to obtain the weight of NaCl.

31. (i) Apply the formula, $\Delta T_f = \frac{K_f \times W_2 \times 1000}{M_2 \times W_1}$ and

calculate ΔT_f .

(ii) $\Delta T_f = T_f^\circ - T_f$, from then calculate T_f .

Given, $W_1 = 600 \text{ g}$, $K_f = 1.86 \text{ K kg mol}^{-1}$

$W_2 = 45 \text{ g}$, $M_2 = 62.0 \text{ g mol}^{-1}$,

T_f° (water) = 273 K

$$(i) \quad \Delta T_f = \frac{K_f \times W_2 \times 1000}{M_2 \times W_1} \quad (1)$$

$$= \frac{1.86 \text{ K kg mol}^{-1} \times 45 \text{ g} \times 1000}{62 \text{ g mol}^{-1} \times 600 \text{ g}}$$

$$\Delta T_f = 2.25 \text{ K} \quad (1)$$

$$(ii) \quad \Delta T_f = T_f^\circ - T_f$$

$$T_f = 273 \text{ K} - 2.25 \text{ K} = 270.75 \text{ K} \quad (1)$$

32. Isotonic solutions have same osmotic pressure at a given temperature.

Given, $W(\text{cane sugar}) = 5 \text{ g}$

$W(X) = 0.877 \text{ g}$

$M(\text{cane sugar}) = 342 \text{ g mol}^{-1}$ (1)

$\pi(\text{cane sugar}) = \pi(X)$

[∵ solution is isotonic]

$$\frac{W(\text{cane sugar}) \times 1000}{M(\text{cane sugar}) \times V} = \frac{W(X) \times 1000}{M(X) \times V} \quad (1)$$

$$\frac{5 \text{ g}}{342 \text{ g mol}^{-1}} = \frac{0.877 \text{ g}}{M(X)}$$

$$M(X) = 59.9 \text{ g mol}^{-1} \quad (1)$$

33. Calculate 'i' using formula

$$\Delta T_f = \frac{iK_f \times W_2 \times 1000}{M_2 \times W_1}$$

Given, $W_2 = 3.9 \text{ g}$, $W_1 = 49 \text{ g}$; $\Delta T_f = 1.62 \text{ K}$

$M_2(\text{benzoic acid}) = 122 \text{ g mol}^{-1}$

$K_f(\text{benzene}) = 4.9 \text{ K kg mol}^{-1}$

$$\Delta T_f = \frac{i \times K_f \times W_2 \times 1000}{M_2 \times W_1} \quad (1)$$

$$i = \frac{\Delta T_f \times M_2 \times W_1}{K_f \times W_2 \times 1000}$$

$$i = \frac{1.62 \text{ K} \times 122 \text{ g mol}^{-1} \times 49 \text{ g}}{4.9 \text{ K kg mol}^{-1} \times 3.9 \text{ g} \times 1000}$$

$$i = 0.50 \quad (1/2)$$

Since, $i < 1$, therefore solute (benzoic acid) undergoes association. (1/2)

34. Apply formula, $\frac{p^\circ - p}{p^\circ} = \frac{n_2}{n_1}$

Given, $W_2 = 10 \text{ g}$, $W_1 = 200 \text{ g}$.

$$p = 31.84 \text{ mm of Hg}$$

$$p^\circ = 32 \text{ mm of Hg}; M_1 = 18 \text{ g mol}^{-1} \quad (1)$$

$$\frac{p^\circ - p}{p^\circ} = \frac{W_2 \times M_1}{M_2 \times W_1} \quad (1)$$

$$\frac{32 - 31.84}{32} = \frac{10 \times 18}{M_2 \times 200}$$

$$M_2 = 180 \text{ g mol}^{-1} \quad (1)$$

35. Mass of CaCl_2 (W_2) = 10 g

Mass of water (W_1) = 200 g

Molar mass of CaCl_2 (M_2) = 111 g mol⁻¹ (1)

$$K_b = 0.512 \text{ K kg mol}^{-1}$$

i for $\text{CaCl}_2 = 3$

$$m = \frac{W_2 \times 1000}{M_2 \times W_1} \Rightarrow m = \frac{10}{111} \times \frac{1000}{200}$$

$$m = 0.450 \text{ kg mol}^{-1}, \Delta T_b = iK_b \times m$$

$$= 3 \times 0.512 \text{ K kg mol}^{-1} \times 0.450 \text{ m} = 0.6912 \text{ K} \quad (2)$$

36. (i) First, find out m by using, $\Delta T_f = K_f m$.
 (ii) Then, find out ΔT_b by using, $\Delta T_b = K_b m$.
 (iii) Then, find out the value of T_b by using formula,
 $T_b = \Delta T_b + T_b^\circ$

$$\text{Given, } \Delta T_f = T_f^\circ - T_f = 0 - (-15.0^\circ\text{C}) = 15^\circ\text{C}$$

$$\Delta T_f = 15.0^\circ\text{C}$$

$$K_f = 1.86 \text{ K/m} = 1.86^\circ\text{C/m}$$

$$\text{Molality } (m) \text{ of HOCH}_2\text{CH}_2\text{OH} = \frac{\Delta T_f}{K_f} \quad (1)$$

$$= \frac{15.0^\circ\text{C}}{1.86^\circ\text{C/m}} = 8.06 \text{ m}$$

$$\Delta T_b = K_b \times \text{molality } (m) \text{ of HOCH}_2\text{CH}_2\text{OH} \quad (1)$$

$$= 0.52^\circ\text{C/m} \times 8.06 \text{ m} = 4.19^\circ\text{C}$$

Boiling point of pure water is 100°C .

$$T_b = \Delta T_b + T_b^\circ$$

$$T_b = 4.19^\circ\text{C} + 100.00^\circ\text{C}$$

$$= 104.19^\circ\text{C} \quad (1)$$

37. Apply $\pi = i \frac{W_b RT}{M_b V}$ to find out the value of π .

Given, mass of K_2SO_4 , $W_b = 2.5 \times 10^{-2} \text{ g}$

Molar mass of K_2SO_4 , $M_b = 174 \text{ g mol}^{-1}$

$i = n = 3$ (\because for complete dissociation, $i = n$)

$$V = 2 \text{ L}, T = 25^\circ\text{C} = 298 \text{ K}$$

$$R = 0.0821 \text{ L atm K}^{-1} \text{ mol}^{-1} \quad (1)$$

We know, osmotic pressure

$$\pi = i \frac{W_b RT}{M_b V} \Rightarrow \pi = \frac{3 \times 2.5 \times 10^{-2} \times 0.0821 \times 298}{174 \times 2} \quad (1)$$

$$\pi = 52.7 \times 10^{-4} \text{ atm} \quad (1)$$

38. Given, $W_2 = 1.00 \text{ g}$, $W_1 = 50 \text{ g}$, $K_f = 512 \text{ K kg mol}^{-1}$ (1)

$$\Delta T_f = 0.40 \text{ K}, \Delta T_f = \frac{K_f \times W_2 \times 1000}{M_2 \times W_1} \quad (1)$$

$$M_2 = \frac{K_f \times W_2 \times 1000}{W_1 \times \Delta T_f} = \frac{512 \times 1 \times 1000}{50 \times 0.40}$$

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

39. Freezing point of pure water is 273.15 K (0°C) and that of given solution is 271 K , i.e. we have depression in freezing point. So,

- (i) apply the formula of depression in freezing point for cane sugar and find the value of K_f .
 (ii) use this value of K_f to find out the value of ΔT_f for glucose solution. Then, find the freezing point of solution.

Given, 5% cane-sugar solution means, $W_2 = 5 \text{ g}$,
 $W_1 = 95 \text{ g}$, $M_2 = 342 \text{ g mol}^{-1}$

Similarly, for 5% glucose solution,

$$W_2' \text{ (glucose)} = 5 \text{ g}; W_1' = 95 \text{ g}$$

$$M_2' \text{ (glucose)} = 180 \text{ g mol}^{-1}$$

$$\Delta T_f \text{ (cane sugar)} = 273.15 \text{ K} - 271 \text{ K} = 2.15 \text{ K}$$

$$\Delta T_f \text{ (cane sugar)} = \frac{K_f \times W_2 \times 1000}{M_2 W_1}$$

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

$$K_f = \frac{2.15 \times 342 \times 95}{5 \times 1000} = 13.9707 \quad (1)$$

$$\Delta T_f \text{ (glucose)} = \frac{K_f \times W_2' \times 1000}{M_2' W_1'}$$

$$\Delta T_f \text{ (glucose)} = \frac{13.9707 \times 5 \times 1000}{180 \times 95}$$

$$= 4.085 \text{ K} \quad (1)$$

$$\therefore \text{Freezing point of the solution}$$

$$= 273.15 \text{ K} - 4.085 \text{ K} = 269.065 \text{ K} \quad (1)$$

Alternate method

\therefore Mass of solute and solvent are same.

$$\therefore \Delta T_f \text{ (cane-sugar)} = K_f \times m$$

$$= K_f \times \frac{W_{\text{(cane-sugar)}}}{M_{\text{(cane-sugar)}}} \times \frac{1000}{W_{\text{(water)}}} \quad \dots(i)$$

$$\Delta T_{f(\text{glucose})} = K_f \times m = K_f \times \frac{W_{(\text{glucose})}}{M_{(\text{glucose})}} \times \frac{1000}{W_{(\text{water})}} \quad \dots (ii)$$

On comparing (i) and (ii),

$$\frac{\Delta T_{f(\text{glucose})}}{\Delta T_{f(\text{cane-sugar})}} = \frac{\text{Molar mass(cane-sugar)}}{\text{Molar mass(glucose)}}$$

$$\therefore \Delta T_{f(\text{glucose})} = \frac{2.15 \times 342}{180} = 4.08 \text{ K} \quad (3)$$

40. Apply formula, $\frac{p^\circ - p}{p^\circ} = \frac{n_2}{n_1}$

$$\frac{p^\circ - p}{p^\circ} = \chi_2 = \frac{n_2}{n_1}$$

[for a dilute solution, $n_2 \ll n_1$]

$$\frac{p^\circ - p}{p^\circ} = \frac{W_2 \times M_1}{M_2 \times W_1} \quad (1)$$

Given, $p^\circ = 3.165 \text{ kPa}$,

$$W_2 = 5 \text{ g}, W_1 = 95 \text{ g}$$

$$M_2 = 60.05 \text{ g mol}^{-1}$$

$$M_1 = 18 \text{ g mol}^{-1}$$

$$\frac{3.165 - p}{3.165} = \frac{5 \times 18}{60.05 \times 95} = 0.0158 \quad (1)$$

$$3.165 - p = 0.050$$

$$p = 3.115 \text{ k Pa} \quad (1)$$

41. Given, mass of solute (W_2) = 15.0 g
Mass of solvent (water) (W_1) = 450 g
 $\Delta T_f = 0^\circ\text{C} - (-0.34^\circ\text{C}) = 0.34^\circ\text{C} = 0.34 \text{ K}$
 $K_f = 1.86 \text{ K kg mol}^{-1}$

To find molar mass of solute (M_2) = ?

$$\therefore \Delta T_f = K_f \times \frac{W_2}{M_2} \times \frac{1000}{W_1} \quad (1)$$

$$\therefore M_2 = \frac{K_f \times W_2 \times 1000}{\Delta T_f \times W_1}$$

$$M_2 = \frac{1.86 \times 15 \times 1000}{0.34 \times 450} \quad (1)$$

$$M_2 = \frac{27900}{153} = 182.35 \text{ g mol}^{-1} \quad (1)$$

42. Given, Mass of solute (glycerol) (W_2) = ?

Molar mass of solute (M_2) = 92 g mol^{-1}

Mass of solvent (water) (W_1) = 500 g.

$$\Delta T_b = 100.42^\circ\text{C} - 100^\circ\text{C}$$

$$= 0.42^\circ\text{C} = 0.42 \text{ K}$$

$$K_b = 0.512 \text{ K kg mol}^{-1}$$

$$\therefore \Delta T_b = K_b \times \frac{W_2}{M_2} \times \frac{1000}{W_1}$$

$$\therefore W_2 = \frac{\Delta T_b \times M_2 \times W_1}{K_b \times 1000} \quad (1)$$

$$W_2 = \frac{0.42 \times 92 \times 500}{0.512 \times 1000} \quad (1)$$

$$W_2 = 37.73 \text{ g}$$

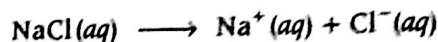
Hence, mass of glycerol dissolved = 37.73 g. (1)

43. Refer to sol 27.

44. Apply van't Hoff equation, $\Delta T_b = iK_b m$, where i = number of ions produced by NaCl.

Given, $W_2 = 15.00 \text{ g}$, $W_1 = 250.0 \text{ g}$

$$M_2 = 58.44 \text{ g mol}^{-1}, K_b = 0.512 \text{ K kg mol}^{-1}$$



$$i = 2 \quad (1)$$

$$\Delta T_b = iK_b \cdot m$$

$$\Delta T_b = \frac{i \times K_b \times W_2 \times 1000}{M_2 \times W_1} \quad (1/2)$$

$$\Delta T_b = \frac{2 \times 0.512 \text{ K kg mol}^{-1} \times 15.0 \text{ g} \times 1000}{58.44 \text{ g mol}^{-1} \times 250 \text{ g}}$$

$$\Delta T_b = 1.051 \text{ K} \quad (1/2)$$

$$\text{Boiling point of solution} = 373 \text{ K} + 1.051 \text{ K} = 374.051 \text{ K} \quad (1)$$

45. Given, $W_2 = 6.21 \text{ g}$, $W_1 = 24.0 \text{ g}$

$$T_b = 68.04^\circ\text{C}$$

$$T_b^\circ = 61.7^\circ\text{C}$$

$$\text{and } K_b = 3.63^\circ\text{C/m}; \Delta T_b = \frac{K_b \times W_2 \times 1000}{M_2 \times W_1} \quad (1)$$

$$\text{or } M_2 = \frac{K_b \times W_2 \times 1000}{\Delta T_b \times W_1}$$

$$\Delta T_b = T_b - T_b^\circ = 68.04^\circ\text{C} - 61.7^\circ\text{C} = 6.34^\circ\text{C} \quad (1)$$

$$M_2 = \frac{3.63^\circ\text{C m}^{-1} \times 6.21 \text{ g} \times 1000}{6.34^\circ\text{C} \times 24.0 \text{ g}}$$

$$= 148.15 \text{ g mol}^{-1} \quad (1)$$

46. Given, $W_2 = 8.95 \text{ mg} = 8.95 \times 10^{-3} \text{ g}$,

$$V = 35.0 \text{ mL} = \frac{35}{1000} \text{ L}$$

$$\pi = 0.335 \text{ torr} = \frac{0.335}{760} \text{ atm}$$

($\because 1 \text{ atm} = 760 \text{ torr}$)

$$T = 273 + 25 = 298 \text{ K} \quad (1)$$

$$\pi V = nRT \quad \text{or} \quad \pi V = \frac{W_2 RT}{M_2}$$

$$\Rightarrow M_2 = \frac{W_2 RT}{\pi V}$$

$$= \frac{8.95 \times 10^{-3} \text{ g} \times 0.082 \text{ L atm mol}^{-1} \text{ K}^{-1} \times 298 \text{ K}}{\frac{0.335}{760} \text{ atm} \times \frac{35.0}{1000} \text{ L}} \quad (1)$$

$$M_2 = 14174 \text{ g mol}^{-1} \quad (1)$$

$$M_2 = 1.4174 \times 10^4 \text{ g mol}^{-1} \quad (1)$$

47. Given, $m = 0.561 \text{ m}$, $\Delta T_f = 2.93^\circ \text{C}$ and

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

$$\Delta T_f = i K_f m \quad (1)$$

$$i = \frac{\Delta T_f}{K_f m} = \frac{2.93^\circ \text{C}}{1.86^\circ \text{C kg mol}^{-1} \times 0.561 \text{ m}} \quad (1)$$

$$= 2.807 \quad (1)$$

48. (i) First calculate M_2 (observed) by using the formula,

$$M_2 = \frac{K_f \times W_2 \times 1000}{\Delta T_f \cdot W_1}$$

(ii) Calculate 'i' by using the formula,

$$i = \frac{M_2 \text{ (Calculated)}}{M_2 \text{ (Observed)}}$$

(iii) Calculate α by using the formula,

$$\alpha = \frac{i - 1}{\left(\frac{1}{n} - 1\right)}$$

Here, $n = 2$ because phenol forms dimer on association.

Given, $W_2 = 20 \text{ g}$, $W_1 = 1 \text{ kg} = 1000 \text{ g}$
 $\Delta T_f = 0.69 \text{ K}$, $K_f = 5.1 \text{ K kg mol}^{-1}$

$$\Delta T_f = \frac{K_f \times W_2 \times 1000}{M_2 W_1}$$

$$M_2 = \frac{K_f \times W_2 \times 1000}{\Delta T_f \times W_1}$$

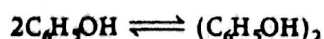
$$M_2 = \frac{5.1 \text{ K kg mol}^{-1} \times 20 \text{ g} \times 1000}{0.69 \text{ K} \times 1000 \text{ g}}$$

$$M_2 \text{ (Observed)} = 147.82 \text{ g mol}^{-1} \quad (1)$$

$$M_2 \text{ (Calculated)} \text{ C}_6\text{H}_5\text{OH} = 6 \times 12 + 6 \times 1 + 16$$

$$= 94 \text{ g mol}^{-1}$$

$$i = \frac{M_2 \text{ (Calculated)}}{M_2 \text{ (Observed)}} = \frac{94}{147.82} = 0.635 \quad (1)$$



$$\alpha = \frac{i - 1}{\left(\frac{1}{n} - 1\right)} = \frac{0.635 - 1}{\frac{1}{2} - 1} = \frac{0.365}{0.5} = 0.73 \Rightarrow \alpha = 73\% \quad (1)$$

49. (i) First calculate M_2 (observed) by using the

$$\text{formula, } M_2 = \frac{K_b \times W_2 \times 1000}{\Delta T_b \times W_1}$$

(ii) Calculate i by using the formula,

$$i = \frac{M_2 \text{ (Calculated)}}{M_2 \text{ (Observed)}}$$

(iii) Calculate α by using the formula, $\alpha = \frac{i - 1}{m - 1}$

Given, $W_2 = 12.48 \text{ g}$, $W_1 = 1.0 \text{ kg} = 1000 \text{ g}$,

$$T_b \text{ (solution)} = 373.0832 \text{ K}$$

$$K_b \text{ for H}_2\text{O} = 0.52 \text{ K m}^{-1}$$

and $M_2(\text{BaCl}_2) = 208.34 \text{ g mol}^{-1}$

$$\Delta T_b = T_b - T_b^\circ = 373.0832 \text{ K} - 373 \text{ K}$$

$$= 0.0832 \text{ K}$$

$$M_2 \text{ (Observed)} = \frac{K_b \times W_2 \times 1000}{\Delta T_b \times W_1}$$

$$= \frac{0.52 \text{ K m}^{-1} \times 12.48 \text{ g} \times 1000}{0.0832 \text{ K} \times 1000 \text{ g}}$$

$$M_2 \text{ (Observed)} = 78 \text{ g mol}^{-1} \quad (1)$$

$$i = \frac{M_2 \text{ (Calculated)}}{M_2 \text{ (Observed)}} = \frac{208.34 \text{ g mol}^{-1}}{78 \text{ g mol}^{-1}} = 2.67 \quad (1)$$

For BaCl_2 , $m = 3$ as it gives 3 ions on dissociation.

$$\alpha = \frac{i - 1}{m - 1} = \frac{2.67 - 1}{3 - 1} = \frac{1.67}{2} = 0.835$$

$$\alpha = 83.5\% \quad (1)$$

50. Apply $\pi = CRT$ and $C = \frac{n}{V} = \frac{W_2}{M_2 V}$

$$\pi = CRT = \frac{W_2 \times R \times T}{M_2 \times V}$$

For both solutions, R , T and V are constant.

For first solution,

$$(4.98 \text{ bar}) = \frac{(36 \text{ g}) \times R \times T}{(180 \text{ g mol}^{-1}) \times V} \quad \dots(i)$$

For second solution,

$$(1.52 \text{ bar}) = \frac{W_2 \times R \times T}{M_2 \times V} \quad \dots(ii) \quad (1)$$

On dividing Eq. (ii) by Eq. (i), we get

$$\frac{(1.52 \text{ bar})}{(4.98 \text{ bar})} = \frac{W_2 \times R \times T}{M_2 \times V} \times \frac{180 \times V}{36 \times R \times T} \quad (1)$$

$$\frac{W_2}{M_2} = \frac{1.52}{4.98 \times 5} = 0.0610 \text{ mol} \quad (1)$$

51. (i) Calculate the molality of solution by using the formula,

$$m = \frac{M \times 1000}{(1000 \times d) - (M \times M_2)}$$

(where, M = molarity, d = density and M_2 = molar mass of solute)

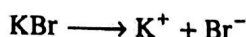
- (ii) Calculate ΔT_b by using the formula, $\Delta T_b = iK_b m$
 (iii) Calculate T_b (boiling point of solution) by using the formula, $T_b^\circ + \Delta T_b = T_b$

Given, concentration of the solution = 1 molar

Density of the solution = 1.06 g mL^{-1}

M_2 , molar mass of KBr = $39 + 80 = 119 \text{ g mol}^{-1}$

K_b for $\text{H}_2\text{O} = 0.52 \text{ K kg mol}^{-1}$



i.e. ions produced = 2

$\therefore i = 2$

$$\text{Molality, } m = \frac{M \times 1000}{(1000 \times d) - (M \times M_2)} \quad (1/2)$$

$$m = \frac{1 \times 1000}{(1000 \times 1.06) - (1 \times 119)}$$

$$= 1.0626 \text{ mol kg}^{-1} \quad (1/2)$$

$$\Delta T_b = iK_b m$$

$$= 2 \times 0.52 \text{ K kg mol}^{-1} \times 1.0626 \text{ mol kg}^{-1} \quad (1/2)$$

$$\Delta T_b = 1.105 \text{ K} \quad (1/2)$$

$$T_b = 373 \text{ K} + 1.105 \text{ K} = 374.105 \text{ K} \quad (1)$$

52. Given, $W_2 = 1.25 \text{ g}$

$$W_1 = 99.0 \text{ g}$$

$$K_b = 2.53^\circ\text{C kg mol}^{-1}$$

$$\Delta T_b = T_b - T_b^\circ = 80.31 - 80.10 = 0.21^\circ\text{C}$$

Using the formula,

$$M_2 = \frac{K_b \times W_2 \times 1000}{\Delta T_b \times W_1} = \frac{2.53 \times 1.25 \times 1000}{0.21 \times 99.0}$$

$$M_2 = 152 \text{ g mol}^{-1} \text{ approx} \quad (3)$$

53. Given, M_2 (ethylene glycol) = 62 g mol^{-1} ,

$$W_1 = 5.50 \text{ kg} = 5500 \text{ g}, \Delta T_f = 10 \text{ K}$$

$$[0^\circ\text{C} - (-10^\circ\text{C}) = 10^\circ\text{C} = 10 \text{ K}]$$

and $K_f = 1.86 \text{ K kg mol}^{-1}$

$$\Delta T_f = \frac{K_f \cdot W_2 \cdot 1000}{M_2 \cdot W_1} \quad (1)$$

$$W_2 = \frac{\Delta T_f \cdot M_2 \cdot W_1}{K_f \cdot 1000}$$

$$= \frac{10 \text{ K} \times 62 \text{ g mol}^{-1} \times 5500 \text{ g}}{1.86 \text{ K kg mol}^{-1} \times 1000} \quad (1)$$

$$W_2 = 1833.33 \text{ g} = 1.833 \text{ kg} \quad (1)$$

54. (i) First find M_2 (observed) by using the formula,

$$M_2 = \frac{K_f \times W_2 \times 1000}{\Delta T_f \times W_1}$$

- (ii) Compare it with calculated M_2 to know whether it is associated or dissociated.

Given, $W_1 = 1 \text{ kg} = 1000 \text{ g}$ (benzene)

$$\Delta T_f = 0.256 \text{ K}, K_f = 5.12 \text{ K kg mol}^{-1}$$

0.1 mol of acetic acid = $0.1 \times 60 = 6.0 \text{ g}$ (W_2)

[\therefore Molar mass of $\text{CH}_3\text{COOH} = 60 \text{ g mol}^{-1}$] (1/2)

$$M_2 = \frac{K_f \times W_2 \times 1000}{\Delta T_f \times W_1} \quad (1/2)$$

$$= \frac{5.12 \text{ K kg mol}^{-1} \times 6.0 \text{ g} \times 1000}{0.256 \text{ K} \times 1000 \text{ g}}$$

$$= 120 \text{ g mol}^{-1} \quad (1/2)$$

$$i = \frac{M_2 \text{ (Calculated)}}{M_2 \text{ (Observed)}}$$

$$= \frac{60}{120} = \frac{1}{2} = 0.5 \quad (1/2)$$

The value of i is 0.5. It is less than 1. Hence, the solute, i.e. CH_3COOH gets dimerise in benzene. (1)

55. Lowering in melting point (ΔT_f) = 1.5°C

Mass of solvent (CH_3COOH), $W_1 = 75 \text{ g}$

Molar mass of solvent (CH_3COOH),

$$M_1 = 60 \text{ g mol}^{-1}$$

$$[\text{as } \text{CH}_3\text{COOH} = 12 + 3 + 12 + 16 + 16 + 1 = 60 \text{ g mol}^{-1}]$$

Molar mass of solute ($\text{C}_6\text{H}_8\text{O}_6$),

$$M_2 = 72 + 8 + 96 = 176 \text{ g mol}^{-1}$$

$$[\text{as, } \text{C}_6\text{H}_8\text{O}_6 = 6 \times 12 + 8 \times 1 + 6 \times 16 = 176]$$

For acetic acid, $K_f = 3.9 \text{ K kg mol}^{-1}$ [Given]

Applying the formula,

$$M_2 = \frac{1000 K_f W_2}{W_1 \Delta T_f}, \text{ we get} \quad (1)$$

$$W_2 = \frac{M_2 \times W_1 \times \Delta T_f}{1000 \times K_f}$$

$$= \frac{(176 \text{ g mol}^{-1}) (75 \text{ g}) (1.5 \text{ K})}{(1000) (3.9 \text{ K kg mol}^{-1})} \quad (1)$$

$$= 5.077 \text{ g} \quad (1)$$

56. (i) Refer to solution 28. (1)
 (ii) (a) Refer to solution 8(ii) (1)
 (b) Refer to solution 9(i) (1)

57. (i) $\text{MgCl}_2 \longrightarrow \text{Mg}^{2+} + 2\text{Cl}^-$
 1 mol of MgCl_2 gives 3 moles of particles.
 $\therefore i = 3$

$$\Delta T_f = iK_f m$$

Given, W_a = Weight of H_2O (solvent) = 50 g

W_b = Weight of MgCl_2 (solute) = 1.9 g

$T_f^\circ = 273.15 \text{ K}$

$K_f = 1.86 \text{ K kg mol}^{-1}$

M_b = Molar mass of solute = 95 g mol^{-1}

$$\Delta T_f = \frac{iK_f \times 1000 \times W_b}{M_b \times W_a}$$

$$= \frac{3 \times 1.86 \text{ K kg mol}^{-1} \times 1000 \times 1.9 \text{ g}}{95 \text{ g mol}^{-1} \times 50 \text{ g}}$$

$$\Delta T_f = 2.232 \text{ K}$$

Also, $\Delta T_f = T_f^\circ - T_f$;

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

$$= 273.15 - 2.232$$

$$= 270.918 \text{ K} \quad (3)$$

- (ii) (a) 2M glucose has higher boiling point because more the concentration, more is the elevation in boiling point. (1)
 (b) When the external pressure applied becomes more than the osmotic pressure of solution, reverse osmosis takes place. (1)

58. (i) Given, Weight of solvent (W_a) = 100g

Weight of solute (W_b) = 2.56 g

$$\Delta T_f = 0.383 \text{ K}$$

$$K_f = 3.83 \text{ K kg mol}^{-1}$$

$$\Delta T_f = K_f m$$

$$\Delta T_f = \frac{K_f \times 1000 \times W_b}{M_b \times W_a}$$

$$0.383 \text{ K} = \frac{3.83 \text{ K kg mol}^{-1} \times 1000 \times 2.56 \text{ g}}{M_b \times 100 \text{ g}}$$

$$M_b = \frac{3.83 \text{ K kg mol}^{-1} \times 1000 \times 2.56 \text{ g}}{0.383 \text{ K} \times 100 \text{ g}}$$

$$M = 256 \text{ g/mol}$$

Molecular mass = $n \times$ Atomic mass

$$n = \frac{\text{Molecular mass}}{\text{Atomic mass}} = \frac{256}{32} = 8$$

- \therefore Formula of sulphur is S_8 . (3)

- (ii) (a) If we place the blood cells in a solution containing more than 0.9% (mass/volume) sodium chloride solution, water will flow out of the cells and they would shrink. This process is called **plasmolysis**. (1)
 (b) If the salt concentration is less than 0.9% (mass/volume), then the water will flow into the cells and they would swell. (1)

objectives answers

$$\text{Volume of the solution} = 100 \text{ mL} = \frac{100}{1000} \text{ L} = 0.1 \text{ L}$$

Concentration of urea solution (in mol L⁻¹)

$$= \frac{1 \times 10^{-3}}{0.1} = 1 \times 10^{-2} \text{ mol L}^{-1} = 0.01 \text{ mol/L or M}$$

2. (a) Orthophosphoric acid is H₃PO₄. It is a tribasic acid

$$\text{Normality} = \text{molarity} \times \text{basicity} = 3 \times 3 = 9 \text{ N}$$

3. (c) 1 molal solution means 1 mole of the solute is present in 1000 g of water.

$$\text{Mole of water} = \frac{1000}{18} = 55.55$$

$$\text{Mole of solute} = 1$$

$$\therefore \text{mole fraction of solute} = \frac{1}{56.55} = 0.0177$$

4. (a) Molarity = normality \times $\frac{\text{equivalent weight}}{\text{molecular weight}}$

Given, normality of Na₂CO₃ solution = 0.2 N

Equivalent weight = M

Molecular weight = 2M (\because Na₂CO₃ is dipositive)

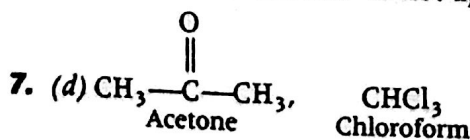
$$\therefore \text{Molarity} = 0.2 \times \frac{M}{2M} = 0.1 \text{ M}$$

5. (b) Molarity = $\frac{\text{number of moles of solute}}{\text{volume of solution (in L)}}$

$$= \frac{5 \times 1000}{40 \times 250} = 0.5 \text{ M}$$

$$\left[\because \text{Moles of NaOH} = \frac{5}{40} \right]$$

6. (a) Raoult's law is not applicable, if the total number of particles of solute changes in the solution due to association or dissociation. Among the given compounds NaCl undergoes dissociation and forms Na⁺ and Cl⁻ ions. Therefore, Raoult's law is not applicable to NaCl.



Acetone and chloroform will show a negative deviation due to their association after mixing.

8. (a) One molar (1 M) aqueous solution is more concentrated than one molal aqueous solution of the same solute. In solution, H₂SO₄ provides three ions, while NaCl provides two ions.

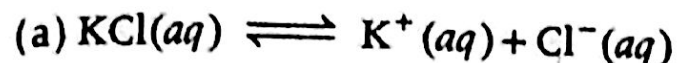
Hence, vapour pressure of solution of NaCl is higher (as it gives less ions). Thus, 1 molal NaCl will have the maximum vapour pressure.

Explanations

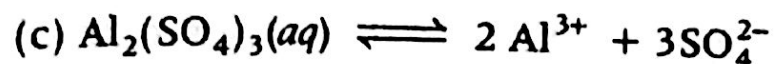
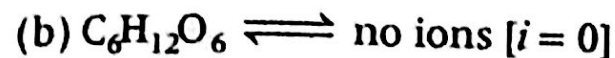
1. (b) Given, number of molecules of urea
 = 6.02×10^{20}

$$\therefore \text{Number of moles} = \frac{6.02 \times 10^{20}}{6.02 \times 10^{23}} \\ = 1 \times 10^{-3} \text{ mol}$$

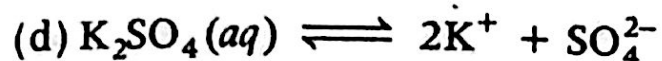
9. (d) As we know, $\Delta T_f \propto i$



(Total ions = 2 thus, $i = 2$)



(Total ions = 5, thus, $i = 5$)



(Total ions = 3, thus, $i = 3$)

Hence, $\text{Al}_2(\text{SO}_4)_3$ will exhibit largest freezing point depression due to the highest value of i .

10. (c) Elevation of boiling point,

$$\Delta T_b = \frac{w \times K_b \times 1000}{M \times W(g)}$$

(Here, w and W = weights of solute and solvent respectively.)

M = molecular weight of solute and

K_b = constant.

On substituting values, we get

$$0.05 = \frac{w \times 0.5 \times 1000}{100 \times 100}$$

or
$$w = \frac{0.05 \times 100 \times 100}{0.5 \times 1000} = 1 \text{ g}$$

11. (a) Ebullioscopic constant, $K_b = \frac{\Delta T_b}{\text{molality}}$

Its unit will be K kg mol^{-1} .

12. (d) Colligative properties are those properties which depend on the number of solute particles and not on the nature of solute. The colligative properties are depression in freezing point, elevation in boiling point, osmotic pressure and relative lowering of vapour pressure.

13. (b) A solution having lower or higher osmotic pressure than the other is said to be hypotonic or hypertonic respectively.

14. (c) Depression in freezing point is a colligative property (depends only upon the number of particles of solutes). Thus, the compound which produces maximum ions has the least freezing point.

\therefore Concentration is same

Sucrose \longrightarrow No ions

$\text{NaCl} \longrightarrow \underbrace{\text{Na}^+ + \text{Cl}^-}_{\text{Two ions}}$

$\text{CaCl}_2 \longrightarrow \underbrace{\text{Ca}^{2+} + 2\text{Cl}^-}_{\text{Three ions}}$

Glucose \longrightarrow No ions

Thus, 1% CaCl_2 has the least freezing point.