



INDIAN SCHOOL AL WADI AL KABIR

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SUMMARY NOTES	Chapter: SOLUTIONS	Note: A4 FILE FORMAT
NAME OF THE STUDENT	CLASS & SEC:	ROLL NO.

SOLUTIONS: These are homogeneous mixtures of two or more than two components.

SOLVENT: The component that is present in the largest quantity is known as solvent.

SOLUTE: One or more components present in the solution other than solvent are called solutes.

BINARY SOLUTION: A solution consisting of two components.

TYPES OF SOLUTIONS

Type of Solution	Solute	Solvent	Common Examples
Gaseous Solutions	Gas	Gas	Mixture of oxygen and nitrogen gases
	Liquid	Gas	Chloroform mixed with nitrogen gas
	Solid	Gas	Camphor in nitrogen gas
Liquid solutions	Gas	Liquid	Oxygen dissolved in water
	Liquid	Liquid	Ethanol dissolved in water
	Solid	Liquid	Glucose dissolved in water
Solid solutions	Gas	Solid	Solution of hydrogen in palladium
	Liquid	Solid	Amalgam of mercury with sodium
	Solid	Solid	Copper dissolved in gold

EXPRESSING CONCENTRATION OF A SOLUTION

Concentration - The amount of solute present in a given amount of solvent at a given temperature is called concentration.

Concentration can be expressed in terms of the following.

1. Mass percentage (w/w)

$$\text{Mass \% of a component} = \frac{\text{Mass of the component in the solution} \times 100}{\text{Total mass of the solution}}$$

2. Volume percentage (V/V)

$$\text{Volume \% of a component} = \frac{\text{Volume of the component} \times 100}{\text{Total volume of solution}}$$

3. Parts per million (ppm)

$$\text{Parts per million} = \frac{\text{Number of parts of the component}}{\text{Total number of parts of all components of solution}} \times 10^6$$

4. Mole fraction (χ)

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

For example, in a binary mixture, if the number of moles of components A and B are n_A and n_B respectively, then

the mole fraction of A will be $\chi_A = \frac{n_A}{n_A + n_B}$

the mole fraction of B will be $\chi_B = \frac{n_B}{n_A + n_B}$

Note – In a given solution, the sum of all the mole fractions is unity.

5. Molarity (M)

Molarity: Molarity (M) is defined as number of moles of solute dissolved in one litre (or one cubic decimetre) of solution. Its unit is molL^{-1}

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

6. Molality (m)

Molality: Molality (m) is defined as the number of moles of the solute per kilogram (kg) of the solvent. Its unit is molkg^{-1}

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

Q. 1 Which among the following is temperature dependent and why?

Molarity, Molality, Mole fraction, Mass%, ppm

Ans. Molarity. This is because volume depends on temperature and the mass does not.

Q. 2 Calculate the mole fraction of ethylene glycol ($C_2H_6O_2$) in a solution containing 20% of $C_2H_6O_2$ by mass.

Assume that we have 100 g of solution.

Solution will contain 20 g of ethylene glycol and 80 g of water.

Molar mass of $C_2H_6O_2 = 12 \times 2 + 1 \times 6 + 16 \times 2 = 62 \text{ g mol}^{-1}$

Moles of $C_2H_6O_2 = \frac{20 \text{ g}}{62 \text{ g mol}^{-1}} = 0.322 \text{ mol}$

Moles of water = $\frac{80 \text{ g}}{18 \text{ g mol}^{-1}} = 4.444 \text{ mol}$

$$\begin{aligned} \chi_{\text{ethylene glycol}} &= \frac{\text{moles of } C_2H_6O_2}{\text{moles of } C_2H_6O_2 + \text{moles of } H_2O} \\ &= \frac{0.322 \text{ mol}}{0.322 \text{ mol} + 4.444 \text{ mol}} \end{aligned}$$

$$= 0.068$$

Mole fraction of water can be calculated as: $1 - 0.068 = 0.932$

Q. 3 Calculate the molarity of a solution containing 5 g of NaOH in 450 mL solution.

Moles of NaOH = $\frac{5 \text{ g}}{40 \text{ g mol}^{-1}} = 0.125 \text{ mol}$

Volume of the solution in litres = $450 \text{ mL} / 1000 \text{ mL L}^{-1}$

Molarity = $\frac{0.125 \text{ mol} \times 1000 \text{ mL L}^{-1}}{450 \text{ mL}} = 0.278 \text{ M}$

$$= 0.278 \text{ mol L}^{-1}$$

Q. 4 Calculate molality of 2.5 g of ethanoic acid (CH_3COOH) in 75 g of benzene.

Molar mass of $C_2H_4O_2 : 12 \times 2 + 1 \times 4 + 16 \times 2 = 60 \text{ g mol}^{-1}$

Moles of $C_2H_4O_2 = \frac{2.5 \text{ g}}{60 \text{ g mol}^{-1}} = 0.0417 \text{ mol}$

Mass of benzene in kg = $75 \text{ g} / 1000 \text{ g kg}^{-1} = 75 \times 10^{-3} \text{ kg}$

$$\begin{aligned} \text{Molality of C}_2\text{H}_4\text{O}_2 &= \frac{\text{Moles of C}_2\text{H}_4\text{O}_2}{\text{Mass of benzene (kg)}} \\ &= \frac{0.0417 \text{ mol}}{0.075 \text{ kg}} \\ &= \boxed{0.556 \text{ mol kg}^{-1}} \end{aligned}$$

Solubility

- Solubility of a substance is its maximum amount that can be dissolved in a specified amount of solvent at a specified temperature.
- It depends upon the nature of solute and solvent as well as temperature and pressure.

Solubility of a Solid in a Liquid

Dissolution: When a solid solute is added to the solvent, some solute dissolves and its concentration increases in solution. This process is known as dissolution.

Crystallisation: Some solute particles in solution collide with the solid solute particles and get separated out of solution. This process is known as crystallisation.

An equilibrium is reached when the number of solute particles going into solution will be equal to the solute particles separating out.



Saturated solution: A solution in which no more solute can be dissolved at the same temperature and pressure is called a saturated solution

Unsaturated solution: An unsaturated solution is one in which more solute can be dissolved at the same temperature.

Effect of pressure on solubility of solid in liquid

- Pressure has no effect on solubility of solids in liquids.
- It is because solids and liquids are highly incompressible and remain unaffected by changes in pressure.

Effect of temperature on solubility of solid in liquid

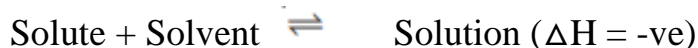
Solubility of solid can be exothermic or endothermic.

- If dissolution is endothermic



High temperature will favour dissolution according to Le Chatelier's principle.

- If dissolution is exothermic



Low temperature will favour dissolution according to Le Chatelier's principle.

Solubility of gas in liquid

Gases are soluble in liquids.

The solubility of gas in liquid is greatly influenced by pressure and temperature.

Effect of pressure

Solubility of gases increases with pressure.

Solubility can be expressed in terms of mole fraction.

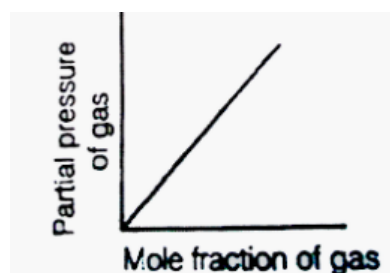
Henry's law

The partial pressure of the gas in vapour phase (p) is proportional to the mole fraction of the gas (χ) in the solution.

$$p = K_H \chi$$

K_H is the Henry's law constant

GRAPHICAL REPRESENTATION



The slope of the line is the Henry's Law constant, K_H

$$p = K_H \chi$$

Higher the value of K_H at a given pressure, the lower is the solubility of the gas in the liquid.

Q. 5 If N_2 gas is bubbled through water at 293 K, how many millimoles of N_2 gas would dissolve in 1 litre of water? Assume that N_2 exerts a partial pressure of 0.987 bar. Given that Henry's law constant for N_2 at 293 K is 76.48 kbar

$$\chi (\text{Nitrogen}) = \frac{p (\text{nitrogen})}{K_H} = \frac{0.987 \text{ bar}}{76480 \text{ bar}} = 1.29 \times 10^{-5}$$

As 1 litre water contains 55.55 mol of it, therefore if n represents number of moles of

$$\chi(\text{Nitrogen}) = \frac{n \text{ mol}}{n \text{ mol} + 55.5 \text{ mol}} = \frac{n}{55.5} = 1.29 \times 10^{-5}$$

(n in denominator is neglected as it is $\ll 55.5$)

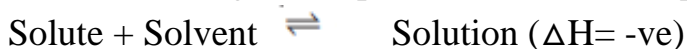
$$\text{Thus } n = 1.29 \times 10^{-5} \times 55.5 \text{ mol} = 7.16 \times 10^{-4} \text{ mol} = \boxed{0.716 \text{ mmol}}$$

APPLICATIONS OF HENRY'S LAW

- To increase the **solubility of CO₂ in soft drinks** and soda water, the bottle is sealed under high pressure.
- Increased pressure under water increases the solubility of atmospheric gases in blood. When the scuba divers come towards surface, the pressure gradually decreases. This releases the dissolved gases and leads to the formation of bubbles of nitrogen in the blood. This blocks capillaries and creates a medical condition known as **bends**, which are painful and dangerous to life.
- At high altitudes the partial pressure of oxygen is less than that at the ground level. This leads to low concentrations of oxygen in the blood and tissues of people living at high altitudes or climbers. Low blood oxygen causes climbers to become weak and unable to think clearly, a condition known as **anoxia**.

Effect of temperature on solubility of gas in liquid

Dissolution of gas in liquid is an exothermic process



Low temperature favours dissolution (forward reaction) according to Le Chatelier's principle.

Q. 6 Aquatic species are more comfortable in cold waters rather than in warm waters. Give reason.

Ans. Solubility of gases increases with decrease in temperature.

VAPOUR PRESSURE OF LIQUID SOLUTIONS

There are two types of liquid solutions.

- Liquid in liquid solution
- Solid in liquid solution

Liquid in liquid solutions

Consider a binary solution of two volatile liquids denoted by 1 and 2.

When taken in a closed vessel, both the components would evaporate and eventually an equilibrium would be established between vapour phase and the liquid phase.

Let the total vapour pressure at this stage be p_{total} and p_1 and p_2 be the partial vapour pressures of the two components 1 and 2 respectively.

Raoult's law states that 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.

Then,

$$p_1 \propto \chi_1$$

$$p_1 = p_1^\circ \chi_1$$

$$p_2 \propto \chi_2$$

$$p_2 = p_2^\circ \chi_2$$

p_1° and p_2° are vapour pressure of pure components 1 and 2.

According to Dalton's law of partial pressures, the total pressure (p_{total}) over the solution phase will be the sum of the partial pressures of the components of the solution and is given as

$$p_{\text{total}} = p_1 + p_2$$

Substituting the values of p_1 and p_2 , we get

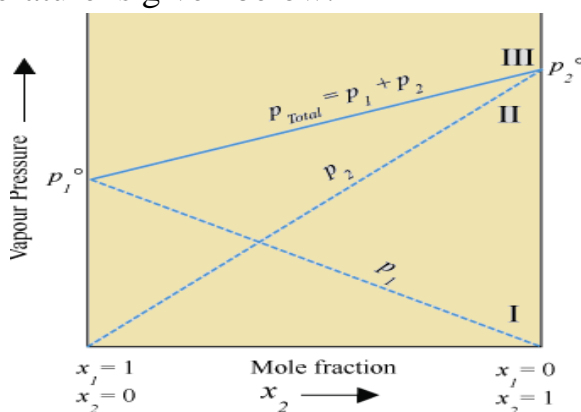
$$p_{\text{total}} = p_1^\circ \chi_1 + p_2^\circ \chi_2$$

$$= (1 - \chi_2) p_1^\circ + \chi_2 p_2^\circ$$

$$= p_1^\circ + (p_2^\circ - p_1^\circ) \chi_2$$

Graphical representation

- ❖ A plot of p_1 or p_2 versus the mole fractions χ_1 and χ_2 for a solution gives a linear plot.
- ❖ The minimum value of p_{total} is p_1° and the maximum value is p_2° , assuming that component 1 is less volatile than component 2, i.e., $p_1^\circ < p_2^\circ$
- ❖ The plot of vapour pressure and mole fraction of an ideal solution at constant temperature is given below.



Note:

If y_1 and y_2 are the mole fractions of the components 1 and 2 respectively in the vapour phase then, using Dalton's law of partial pressures.

$$p_1 = y_1 p_{\text{total}}$$

$$p_2 = y_2 p_{\text{total}}$$

In general $p_i = y_i p_{\text{total}}$

Q.7 Vapour pressure of chloroform (CHCl_3) and dichloromethane (CH_2Cl_2) at 298 K are 200 mm Hg and 415 mm Hg respectively. (i) Calculate the vapour pressure of the solution prepared by mixing 25.5 g of CHCl_3 and 40 g of CH_2Cl_2 at 298 K and, (ii) mole fractions of each component in vapour phase.

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

$$p = K_H \chi \text{ (Henry's law)}$$

$$p_1 = p_1^\circ \chi_1 \text{ (Raoult's law)}$$

Raoult's law is a special case of Henry's law in which K_H becomes equal to p_1°

Vapour Pressure of Solutions of Solids in Liquids

Q.8 The vapour pressure of the solution at a given temperature is found to be lower than the vapour pressure of the pure solvent at the same temperature. Explain

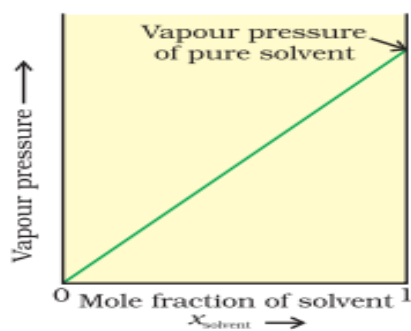
Ans. This is because the surface has both solute and solvent molecules; thereby the fraction of the surface covered by the solvent molecules gets reduced.

Thus, the number of solvent molecules escaping from the surface is correspondingly reduced, thus, the vapour pressure is also reduced.

When the solute is non-volatile, only the solvent molecules are present in vapour phase and contribute to vapour pressure

$$p_1 = p_1^\circ \chi_1 \text{ (Raoult's law)}$$

The graphical representation of such a solution is given as:



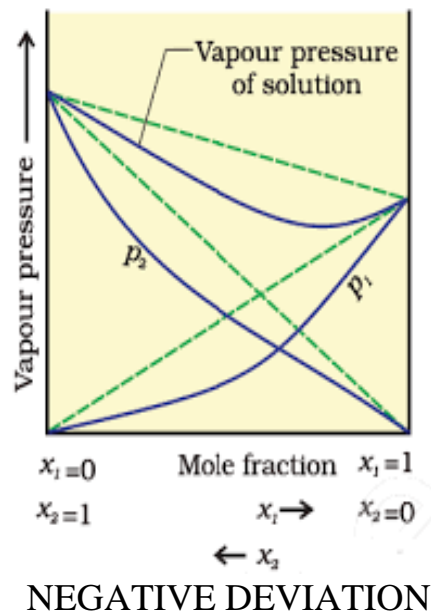
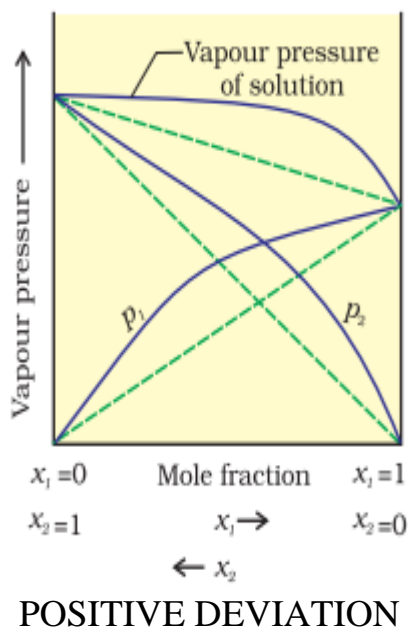
IDEAL AND NON-IDEAL SOLUTIONS

On the basis of Raoult's law, solutions are classified as ideal and non-ideal solutions.

Ideal solution	Non-ideal solution
The solutions which obey Raoult's law over the entire range of concentration are known as ideal solutions.	The solutions which do not obey Raoult's law over the entire range of concentration are called non-ideal solutions.
$\Delta_{\text{mix}} H = 0, \Delta_{\text{mix}} V = 0$	$\Delta_{\text{mix}} H \neq 0, \Delta_{\text{mix}} V \neq 0$
For a solution containing A and B, If the intermolecular attractive forces between A-A and B-B are nearly equal to those between A-B, this leads to the formation of ideal solution.	For a solution containing A and B, If the intermolecular attractive forces between A-A and B-B are not equal to those between A-B, this leads to the formation of non-ideal solution.
The vapour pressure of such a solution is same as that predicted by Raoult's law.	The vapour pressure of such a solution is either higher or lower than that predicted by Raoult's law.
Examples: Solution of n-hexane and n-heptane, bromoethane and chloroethane, benzene and toluene	Examples: Solutions of ethanol and acetone, ethanol and chloroform

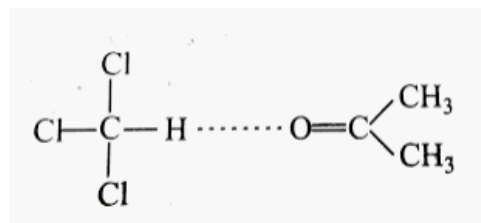
NON-IDEAL SOLUTIONS – They are classified based on deviation from Raoult's law.

Positive deviation from Raoult's law	Negative deviation from Raoult's law
A-B interactions are weaker than those between A-A or B-B	A-B interactions are stronger than those between A-A or B-B
The vapour pressure of the solution is much higher than that predicted by Raoult's law.	The vapour pressure of the solution is lesser than that predicted by Raoult's law.
Volume of the mixture increases when solute and solvent are mixed. $\Delta_{\text{mix}} V = +ve$	Volume of the mixture decreases when solute and solvent are mixed. $\Delta_{\text{mix}} V = -ve$
$\Delta_{\text{mix}} H = +ve$	$\Delta_{\text{mix}} H = -ve$
Example: Mixtures of ethanol and acetone, carbon disulphide and acetone	Example: Mixtures of phenol and aniline, chloroform and acetone



Q. 9 A mixture of chloroform and acetone forms a solution with negative deviation from Raoult's law. Explain.

Ans. This is because chloroform molecule is able to form hydrogen bond with acetone molecule. This decreases the escaping tendency of molecules for each component and consequently, the vapour pressure decreases resulting in negative deviation from Raoult's law.



Q. 10. A mixture of ethanol and acetone forms a solution with positive deviation from Raoult's law. Explain.

Ans. In pure ethanol, molecules are hydrogen bonded. On adding acetone, its molecules get in between the host molecules and break some of the hydrogen bonds between them. Due to weakening of interactions, the solution shows positive deviation from Raoult's law.

AZEOTROPES

Binary mixtures having the same composition in liquid and vapour phase and boil at a constant temperature are called **azeotropes**.

The components cannot be separated by fractional distillation.

The two types are:

MINIMUM BOILING AZEOTROPE	MAXIMUM BOILING AZEOTROPE
The solutions which show a large positive deviation from Raoult's law form minimum boiling azeotrope at a specific composition.	The solutions that show large negative deviation from Raoult's law form maximum boiling azeotrope at a specific composition.
Example: Ethanol (95.63%)-water (4.37%) mixture	Example: Nitric acid (68%) – water (32%) mixture

COLLIGATIVE PROPERTIES

Those properties which depend on the number of solute particles irrespective of their nature relative to the total number of particles present in the solution are called colligative properties.

The four colligative properties are:

1. Relative lowering of vapour pressure of the solvent
2. Elevation of boiling point of the solvent
3. Depression of freezing point of the solvent
4. Osmotic pressure of the solution

RELATIVE LOWERING OF VAPOUR PRESSURE

The vapour pressure of a solvent in solution is less than that of the pure solvent.

Consider a non-volatile solute '2' added to a volatile solvent '1'

According to Raoult's law,

$$p_1 = p_1^\circ \chi_1 \quad - (1)$$

The reduction in the vapour pressure of solvent (Δp_1) is given as

$$\Delta p_1 = p_1^\circ - p_1 \quad - (2)$$

$$= p_1^\circ - p_1^\circ \chi_1 \quad (\text{Substituting from 1})$$

$$= p_1^\circ (1 - \chi_1)$$

$$\Delta p_1 = \chi_2 p_1^\circ \quad - (3) \quad (\chi_1 + \chi_2 = 1)$$

$$\frac{\Delta p_1}{p_1^\circ} = \frac{p_1^\circ - p_1}{p_1^\circ} = \chi_2 \quad - (4)$$

$$\frac{\Delta p_1}{p_1^\circ} = \chi_2$$

The relative lowering of vapour pressure ($\frac{\Delta p_1}{p_1^\circ}$) is equal to the mole fraction of the solute.

$$\frac{p_1^\circ - p_1}{p_1^\circ} = \frac{n_2}{n_1 + n_2} \quad \left(\text{Since } \chi_2 = \frac{n_2}{n_1 + n_2} \right)$$

Here n_1 and n_2 are the number of moles of solvent and solute respectively present in the solution. For dilute solutions $n_2 \ll n_1$, hence neglecting n_2 in the denominator.

$$\frac{p_1^\circ - p_1}{p_1} = \frac{n_2}{n_1}$$

$$\frac{p_1^\circ - p_1}{p_1} = \frac{w_2 \times M_1}{M_2 \times w_1}$$

Here w_1 and w_2 are the masses and M_1 and M_2 are the molar masses of the solvent and solute respectively.

Thus, molar mass of a solute (M_2) can be calculated.

Q. 11 The vapour pressure of pure benzene at a certain temperature is 0.850 bar.

A non-volatile, non-electrolyte solid weighing 0.5 g when added to 39.0 g of benzene (molar mass 78 g mol^{-1}). Vapour pressure of the solution, then, is 0.845 bar. What is the molar mass of the solid substance?

$$p_1^\circ = 0.850 \text{ bar}; p_1 = 0.845 \text{ bar}; M_1 = 78 \text{ g mol}^{-1}; w_2 = 0.5 \text{ g}; w_1 = 39 \text{ g}$$

$$\frac{p_1^\circ - p_1}{p_1^\circ} = \frac{w_2 \times M_1}{M_2 \times w_1}$$

$$\frac{0.85 \text{ bar} - 0.845 \text{ bar}}{0.85 \text{ bar}} = \frac{0.5 \text{ g} \times 78 \text{ g mol}^{-1}}{M_2 \times 39 \text{ g}}$$

$$M_2 = 170 \text{ g mol}^{-1}$$

ELEVATION IN BOILING POINT

- ❖ The boiling point of a solution is always higher than that of the boiling point of the pure solvent in which the solution is prepared.
- ❖ Let T_b° be the boiling point of pure solvent and T_b be the boiling point of solution. The increase in the boiling point $\Delta T_b = T_b - T_b^\circ$ is known as **elevation of boiling point**.
- ❖ For dilute solutions, the elevation of boiling point (ΔT_b) is directly proportional to the molal concentration of the solute in a solution.

$$\Delta T_b \propto m$$

$$\Delta T_b = K_b m \quad - (1)$$

K_b is called Boiling Point Elevation Constant or Molal Elevation Constant or Ebullioscopic Constant. The unit of K_b is K kg mol^{-1} .

Ebullioscopic Constant is defined as the elevation in the boiling point of a 1 molal solution.

If w_2 gram of solute of molar mass M_2 is dissolved in w_1 gram of solvent, then molality, m of the solution is given by the expression

$$m = \frac{w_2 / M_2}{w_1 / 1000} = \frac{1000 \times w_2}{M_2 \times w_1}$$

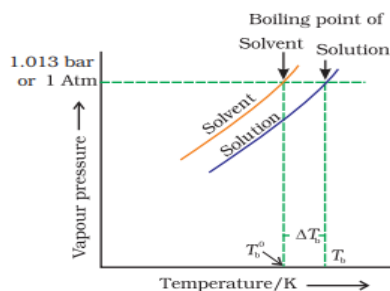
Substituting the value of molality in equation (1)

$$\Delta T_b = K_b \times 1000 \times \frac{w_2}{M_2 \times w_1}$$

$$M_2 = \frac{1000 \times w_2 \times K_b}{\Delta T_b \times w_1} \quad \text{Thus molar mass of a solute can be calculated.}$$

Graphical representation

A plot of T vs vapour pressure.



Q. 12. 18 g of glucose, $C_6H_{12}O_6$, is dissolved in 1 kg of water in a saucepan. At what temperature will water boil at 1.013 bar? K_b for water is $0.52 \text{ K kg mol}^{-1}$

Moles of glucose = $18 \text{ g} / 180 \text{ g mol}^{-1} = 0.1 \text{ mol}$

Number of kilograms of solvent = 1 kg

Thus, molality of glucose solution = 0.1 mol kg^{-1}

$$\Delta T_b = K_b \times m = 0.52 \text{ K kg mol}^{-1} \times 0.1 \text{ mol kg}^{-1} = 0.052 \text{ K}$$

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

$$0.052 = T_b - T_b^\circ$$

$$0.052 = T_b - 373.15$$

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

Q. 12 The boiling point of benzene is 353.23 K. When 1.80 g of a non-volatile solute was dissolved in 90 g of benzene, the boiling point is raised to 354.11 K.

Calculate the molar mass of the solute. K_b for benzene is $2.53 \text{ K kg mol}^{-1}$

The elevation (ΔT_b) in the boiling point = $354.11 \text{ K} - 353.23 \text{ K} = 0.88 \text{ K}$

$$M_2 = \frac{2.53 \text{ K kg mol}^{-1} \times 1.8 \text{ g} \times 1000 \text{ g kg}^{-1}}{0.88 \text{ K} \times 90 \text{ g}} = 58 \text{ gmol}^{-1}$$

DEPRESSION OF FREEZING POINT

- ❖ The addition of a non-volatile solute lowers the freezing point of a solvent in a solution.
- ❖ Let T_f° be the freezing point of pure solvent and T_f be the freezing point of solution.
- ❖ The decrease in the freezing point $\Delta T_f = T_f^\circ - T_f$ is known as depression in freezing point.
- ❖ For dilute solutions, the depression in freezing point (ΔT_f) is directly proportional to the molal concentration of the solute in a solution.

$$\Delta T_f \propto m$$

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

K_f is called Freezing Point Depression Constant or Molal Depression Constant or Cryoscopic Constant. The unit of K_f is K kg mol^{-1}

Cryoscopic Constant is defined as the depression in freezing point of a 1 molal solution.

If w_2 gram of solute having molar mass M_2 is dissolved in w_1 gram of solvent, then molality, m of the solution is given by the expression

$$m = \frac{w_2 / M_2}{w_1 / 1000} = \frac{1000 \times w_2}{M_2 \times w_1}$$

Substituting the value of molality in equation (1)

$$\Delta T_f = \frac{K_f \times 1000 \times w_2}{M_2 \times w_1}$$

$$M_2 = \frac{1000 \times w_2 \times K_f}{\Delta T_f \times w_1} \quad \text{Thus molar mass of a solute can be calculated.}$$

Q. 13. 45 g of ethylene glycol ($\text{C}_2\text{H}_6\text{O}_2$) is mixed with 600 g of water. Calculate
(a) the freezing point depression b) the freezing point of the solution

Depression in freezing point is related to the molality, therefore,
the molality of the solution = $\frac{\text{moles of ethylene glycol}}{\text{kg of water}}$

mass of water in kilogram

$$\text{Moles of ethylene glycol} = \frac{45 \text{ g}}{62 \text{ g mol}^{-1}} = 0.73 \text{ mol}$$

$$\text{Mass of water in kg} = \frac{600 \text{ g}}{1000 \text{ g kg}^{-1}} = 0.6 \text{ kg}$$

$$\text{Hence molality of ethylene glycol} = \frac{0.73 \text{ mol}}{0.60 \text{ kg}} = 1.2 \text{ mol kg}^{-1}$$

$$\text{Therefore, freezing point depression, } \Delta T_f = 1.86 \text{ K kg mol}^{-1} \times 1.2 \text{ mol kg}^{-1} = 2.2 \text{ K}$$

$$\text{Freezing point of the aqueous solution} = 273.15 \text{ K} - 2.2 \text{ K} = \boxed{270.95 \text{ K}}$$

Q. 14. 1.00 g of a non-electrolyte solute dissolved in 50 g of benzene lowered the freezing point of benzene by 0.40 K. The freezing point depression constant of benzene is 5.12 K kg mol⁻¹. Find the molar mass of the solute

$$M_2 = \frac{5.12 \text{ K kg mol}^{-1} \times 1.00 \text{ g} \times 1000 \text{ g kg}^{-1}}{0.40 \times 50 \text{ g}} = \boxed{256 \text{ g mol}^{-1}}$$

OSMOTIC PRESSURE

Osmosis – The flow of solvent molecules from less concentrated region to more concentrated region through a semi permeable membrane.

Osmotic pressure - The pressure which is applied on the solution side to just stop the flow of solvent is called osmotic pressure of the solution.

- ❖ Osmotic pressure is a colligative property as it depends on the number of solute molecules and not on their identity.
- ❖ For dilute solutions, it has been found experimentally that osmotic pressure is proportional to the molarity, C of the solution at a given temperature T.

$$\pi = C R T \quad - (1)$$

Here π is the osmotic pressure and R is the gas constant, C = Molarity

$$\pi = \frac{n_2 R T}{V}$$

Here V is volume of a solution in litres containing n_2 moles of solute. If w_2 grams of solute, of molar mass, M_2 is present in the solution, then $n_2 = w_2 / M_2$ and we can write,

$$\pi = \frac{w_2 R T}{M_2 V}$$

$$\text{Therefore } M_2 = \frac{w_2 R T}{\pi V}$$

Q. 15. 200 cm³ of an aqueous solution of a protein contains 1.26 g of the protein. The osmotic pressure of such a solution at 300 K is found to be 2.57×10^{-3} bar. Calculate the molar mass of the protein.

$$\pi = 2.57 \times 10^{-3} \text{ bar} \quad V = 200 \text{ cm}^3 = 0.200 \text{ litre} \quad T = 300\text{K} \quad R = 0.083 \text{ L bar mol}^{-1} \text{ K}^{-1}$$

$$M_2 = \frac{1.26 \text{ g} \times 0.083 \text{ L bar K}^{-1} \text{ mol}^{-1} \times 300 \text{ K}}{2.57 \times 10^{-3} \text{ bar} \times 0.200 \text{ L}}$$
$$= 61,022 \text{ g mol}^{-1}$$

Q. 16 Why is osmotic pressure method preferred over other colligative properties to calculate molar mass of a solute?

- ❖ Pressure measurement is around the room temperature.
- ❖ Molarity of the solution is used instead of molality.
- ❖ Its magnitude is large even for very dilute solutions.

Isotonic solutions: Two solutions having same osmotic pressure at a given temperature are called isotonic solutions.

Case 1: if we place the cells in a solution containing more than 0.9% (mass/volume) sodium chloride, water will flow out of the cells and they would shrink. Such a solution is called **hypertonic**.

Case 2: If the salt concentration is less than 0.9% (mass/volume), the solution is said to be **hypotonic**. In this case, water will flow into the cells if placed in this solution and they would swell.

Q.17 What is edema?

People taking a lot of salt or salty food experience water retention in tissue cells and intercellular spaces because of osmosis. The resulting puffiness or swelling is called **edema**.

Q. 18 Meat is preserved by salting. Explain.

This is done to prevent bacterial action.

Through the process of osmosis, a bacterium on salted meat loses water, shrivels and dies

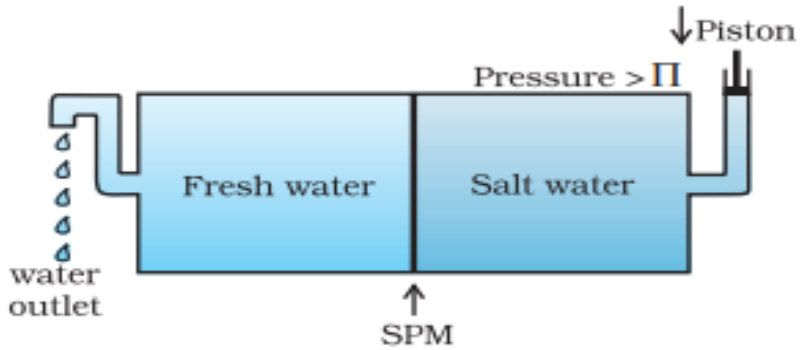
REVERSE OSMOSIS

When a pressure larger than the osmotic pressure is applied to the solution side, the direction of osmosis is reversed. Then the pure solvent flows out of the solution through the semi permeable membrane. This phenomenon is called reverse osmosis.

APPLICATION OF REVERSE OSMOSIS

Desalination of sea water

When pressure more than osmotic pressure is applied on the solution side, pure water is squeezed out of the sea water through the membrane.



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