SOLUTIONS

2.1 Types of Solutions :

Q. Define homogeneous mixture or solution. Also give examples of solution in everyday life.

Solution : A solution is a homogeneous mixture of two or more chemically non-reacting substances whose composition can be varied within certain limits.

Importance of solutions. The use of particular solution in everyday life depends upon its composition. For example,

(i) Brass is a homogeneous mixture of copper and zinc, Germen silver is that of copper, zinc and nickel while bronze is that of copper and tin. They have different properties and hence are put to different uses.

(ii) 1 part per million parts (1 ppm) of fluoride ions in water prevents tooth decay, 1.5 ppm causes the teeth to become mottled (coloured) and still higher concentration can be used as poison, e,g., for rats in the form of sodium fluoride.

(iii) Solutions of intravenous injections should have the same ionic concentration as that of the blood plasma.

Q. What are the different types of solutions on the basis of different physical state of solute and solvent.

Solution : Depending upon the physical state of solvent and solute, there are nine type of solutions. They

Number	Solute (S_2)	Solvent (S_1)	Examples
1	Gas	Gas	Mixture of oxygen and nitrogen gases
2	Liquid	Gas	Chloroform mixed with nitrogen gas
3	Solid	Gas	Camphor in nitrogen gas
4	Gas	Liquid	Oxygen dissolved in water
5	Liquid	Liquid	Ethanol dissolved in water
6	Solid	Liquid	Glucose dissolved in water
7	Gas	Solid	Solution of hydrogen in palladium
8	Liquid	Solid	Amalgam of mercury with sodium
9	Solid	Solid	Copper dissolved in gold

2.2 Expressing Concentration of Solution :

Q. Calculate the mole fraction of ethylene glycol ($C_2H_6O_2$) in a solution containing 20% of C_2H_6O by mass. Also calculate mole fraction of H_2O. [NCERT Solved Example]

Solution : X_{glycol} = 0.068, x_{water} = 0.932

Q. Calculate the molarity of a solution containing 5 g of NaOH in 450 mL solution. [NCERT Solved Example]

Solution : 0.278 mol dm^{-3}

Q. 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.

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

Q. 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.

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

Solution : 16.23 M

Q. Calculate (a) molality (b) molarity and (c) mole fraction of KI if the density of 20% (mass/mass) aqueous KI is 1.202 g mL^{-1}.

Solution : 0.617 m, 0.01 and 0.99, 0.67

Q. How is the molality of a solution different from its molarity ?

Solution : Molality is defined as the number of moles of the solute dissolved in 1000 g of the solvent. Molarity is defined as the number of moles of the solute dissolved in one litre of the solution.

Q. Why does molality of a solution remain unchanged with change in temperature while its molarity changes ?

Solution : Molarity is dependent on volume of the solution, which changes with temperature. Molality is independent of volume.

Q. Distinguish between molarity and molality.

Solution : Molarity is the number of moles of the solute per litre of solution. Molality is the number of moles of the solute in 1000 g of solvent.

Q. What is the molarity of acetic acid in a solution containing 6 g of acetic acid per litre of the solution ?

Solution : Number of moles of acetic acid/litre = 6/60 = 0.1. Hence molarity = 0.1 M.

Q. What is the molality of ammonia in a solution containing 0.85 g of NH_3 in 100 mL of a liquid of density 0.85 g cm^{-3} ?

Solution : 0.588 m

Q. Calculate the volume of 80% (by mass) of H_2SO_4 [density = 1.80 g/mL] required to prepare 1 litre of 0.2 molar H_2SO_4.

Solution : 13.6 mL

Q. Calculate molarity and molality of a 13% solution (by weight) of sulphuric acid. Its density is 1.020 g cm^{-3}.

Solution : 1.353 M, 1.524 m.

Q. The solubility of $Ba(OH)_2 \cdot 8H_2O$ in water at 288 K is 5.6 g per 100 g of water. What is the molality of the hydroxide ions in saturated solution of $Ba(OH)_2 \cdot 8H_2O$ at 288 K ? [At. mass of Ba = 137, O = 16, H = 1]

Solution : 0.356 m

Q. Calculate the molality of K_2CO_3 solution which is formed by dissolving 2.5 g of it in one litre of solution. Density of solution is 0.85 g mL^{-1}.

Solution : 0.0213 m

Q. The molality of an aqueous solution is 1.002 mol/kg. What is the mole-fraction of solute ?

Solution : 0.0177

Q. A 6.90 M solution of KOH in water contains 30% by mass of KOH. Calculate the density of the KOH solution.

Solution : 1.288 g cm^{-3}

2.3   Solubility :

Q. Define solubility of a substance in a solvent and on what factors it depends ?

Solution : 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.

Q. Why NaCl and sugar dissolves readily in H_2O whereas napthalene and anthracene do not ?

Solution : Napthalene and anthracene dissolve readily in benzene but sodium chloride and sugar do not. It is observed that polar solutes dissolve in polar solvents and non polar solutes in non-polar solvents. In general, a solute dissolves in a solvent if the intermolecular interactions are similar in the two or we may say like dissolved like.

Q. Define saturated solution.

Solution : Solute + Solvent $\rightleftharpoons$ Solution

The stage in which concentration of solute in solution will remain constant under the given conditions, i.e., temperature and pressure. Such a solution in which no more solute can be dissolved at the same temperature and pressure is called a saturated solution.

Q. What is the effect of temperature and pressure on solubility of solid in liquid solution ?

Solution : The solubility of a solid in a liquid is significantly affected by temperature changes. Solute + Solvent $\rightleftharpoons$ Solution. This, being dynamic equilibrium, must follow **Le Chateliers Principle.** In general, if in a nearly saturated solution, the dissolution process is endothermic ($\Delta_{sol} H > 0$), the solubility should increase with rise in temperature and if it is exothermic ($\Delta_{sol} H < 0$) the solubility should decrease.

Pressure does not have any significant effect on solubility of solids in liquids. It is so because solids and liquids are highly incompressible and practically remain unaffected by changes in pressure.

Q. Define Henry's Law with its applications.

Solution : The partial pressure of the gass in vapour phase (p) is proportional to the mole fraction of the gas (x) in the solution.

$$P_{gas} \propto \chi_{gas}$$

or $\qquad P_{gas} = K_H \chi_{gas}$ where K_H = Henry's constant.

Here χ_{gas} and P_{gas} represent the mol fraction of the dissolved gas and pressure respectively. Higher the value of K_H at a given pressure lower the solubility of gas in liquid.

Applications of Henry's Law :

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

2. The partial pressure of oxygen at high altitudes is smaller than at the seal level. This results in low concentration of oxygen in the blood and tissues. Low blood oxygen causes climbers to become weak and unable to think. Such symptoms are known as anoxia.

3. Scuba divers face the problems of high concentration of dissolved gases while breathing air at high pressure underwater. When the divers reach the surface, the pressure gradually decreases. This releases the dissolved gases and leads to the formation of bubbles of nitrogen in blood. This blocks capillaries and creates a medical condition known as bends which are painful and dangerous to life. To avoid bends, tanks used by scuba divers are filled with air diluted with helium (11.7% helium, 56.2% nitrogen and 32.1% oxygen).

Q. What is the effect of increase of temperature on solubility of gas in a given solvent and on aquatic species.

Solution : Solubility of gases increases with decrease of temperature. It is due to this reason that aquatic species are more comfortable in cold waters rather than in warm waters.

Q. 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 at 293 K is 76.48 kbar. [NCERT Solved Example]

Solution : 0.716 m mol.

Q. Why solubility of gases decreases with increase of temperature ?

Solution : Solubility of gases in liquids decreases with rise in temperature. When dissolved, the gas molecules are present in liquid phase and the process of dissolution can be considered similar to condensation and heat is evolved in this process. Dissolution process involves dynamic equilibrium and thus must follow Le Chatelier's Principle. As dissolution is an exothermic process, the solubility should decrease with increase of temperature.

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

Solution : 282 bar.

Q. 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.

Solution : 1.854 g

2.4 **Vapour Pressure of Liquid Solutions :**

**Q. Define Raoult's law for a solution of volatile liquids ?**

Solution : It is stated as, "At a given temperature, for a solution of volatile liquids, the partial vapour pressure of each component is directly proportional to their mole fraction".

Q. If in a binary solution of two liquids, two components A and B are present in a closed vessel. Then find the relation between P_{total}, P_A^0, P_B^0 and x_A also show them graphically.

Solution : For Volatile solutions : $P_A = P^0_A X_A$ and $P_B = P^0_B X_B$

(Total vapour pressure of solution) $P_{total} = P_A + P_B$

$\therefore P_{total} = (P^0_A - P^0_B)X_A + P^0_B$
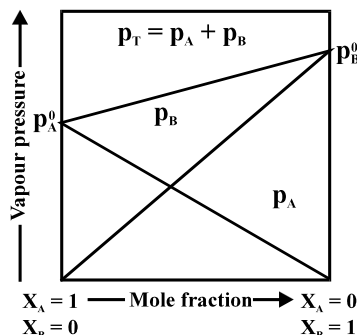
Q. Vapour pressure of chloroform ($CHCl_3$) and dichloromethane (CH_2Cl_2) at 298 K are 200 mm Hg and 415 mm Hg respectively. (i) Calculate the vapour pressure of the solution prepared by mixing 25.5 g of $CHCl_3$ and 40 g of CH_2Cl_2 at 298 K and, (ii) mole fractions of each component in vapour phase.

Solution : (i) 347.9 mm Hg (ii) 0.82, 0.18

Q. Justify the statement that Raoult's law as a special case of Henry's Law.

Solution : If we compare the equations for Raoult's law and Henry's law, 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_1^0. Thus, Raoult's law becomes a special case of Henry's law in which K_H becomes equal to p_1^0.

Q. Define Vapour Pressure of Liquid.

Solution : Liquids at a given temperature vapourise and under equilibrium conditions the pressure exerted by the vapours of the liquid over the liquid phase is called vapour pressure.

Q. Why vapour pressure of liquid solvent decreases on adding non-volatile solute.

Solution : In a pure liquid the entire surface is occupied by the molecules of the liquid. If a non-volatile solute is added to a solvent to give a solution the vapour pressure of the solution is solely from the solvent alone. In the solution, the surface has both solute and solvent molecules; thereby the fraction of the surface covered by the solvent molecules gets reduced. Consequently, the number of solvent molecules escaping from the surface is correspondingly reduced, thus, the vapour pressure is also reduced.

2.5   Ideal and Non-Ideal Solution :

Q. Define Ideal Solution and what are the condition for ideal solution obeying Raoult's law. Also give the examples of solutions showing ideal behaviour.

Solution : The solution which obey Raoult's law over the entire range of concentration are known as ideal solution. The enthalpy of mixing of the pure components to form the solution is zero and the volume of mixing is also zero, i.e., $\Delta_{mix}H = 0$, $\Delta_{mix}V = 0$

It means that no heat is absorbed or evolved when the components are mixed. Also, the volume of solution would be equal to the sum of volumes of the two components.

The intermolecular attractive forces between the A-A and B-B are nearly equal to those between A-B. for e.g., ideal solution are n-hexane and n-heptane, bromoethane and chloroethane, benzene and toluene.

Q. What are non-ideal solution. Explain graphically with example.

Solution : When a solution does not obey Raoult's law over the entire range of concentration, then it is called non-ideal solution. The vapour pressure of such a solution 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 from Raoult's law, A-B interactions are weaker than those between A-A or B-B, i.e., in this case the intermolecular attractive forces between the solute-solvent molecules are weaker than those between the solute-solute and solvent-solvent molecules. This means that in such solutions, molecules of A (or B) will find it easier to escape than in pure state. This will increase the vapour pressure and result in positive deviation. For e.g., CH_3COCH_3 and CS_2 mixture, Acetone (CH_3COCH_3) and C_2H_5OH mixture.
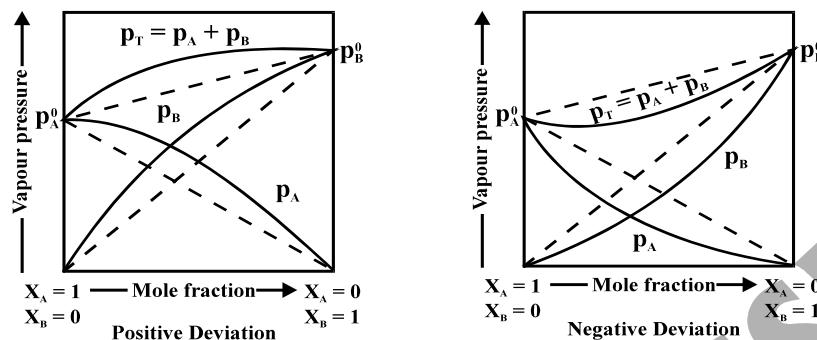
In case of negative deviations from Raoult's law, the intermolecular attractive forces between A-A and B-B are weaker than those between A-B and leads to decrease in vapour pressure resulting in negative deviations for e.g., aniline and phenol mixture, chloroform and acetone mixture.

Q. Why the mixture of aniline and phenol, chloroform and acetone shows the negative deviation from ideal behaviour ?

Solution : An example of this type is a mixture of phenol and aniline. In this case the intermolecular hydrogen bonding between phenolic proton and lone pair on nitrogen atom of aniline is stronger than the respective intermolecular hydrogen bonding between similar molecules. Similarly, a mixture of chloroform and acetone forms a solution with negative deviation from Raoult's law. This is because chloroform molecules is able to form hydrogen bond with acetone molecule.

Q. What type of deviation is shown by mixtures of ethanol and acetone ? Give reason.

Solution : It shows positive deviation. 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.

Q. What are azeotropes ? Is it possible to separate the components of azeotropes by fractional distillation.

Solution : Some liquids on mixing, form azeotropes which are binary mixtures having the same composition in liquid and vapour phase and boil at a constant temperature. In such cases, it is not possible to separate the components by fractional distillaltion.

Q. What are different types of azeotropes ? Explain briefly.

Solution : There are two types of azeotropes called minimum boiling azeotrope and maximum boiling azeotrope. The solutions which show a large positive deviation from Raoult's law form minimum boiling azeotrope at a specific composition. For example, ethanol water mixture (obtained by fermentation of sugars) on fractional distillation gives a solution containing approximately 95% by volume of ethanol. Once this composition, known as azeotrope composition, has been achieved, the liquid and vapour have the same composition, and no further separation occurs.

The solution that show large negative deviation from Raoult's law form maximum boiling azeotrope at a specific composition. Nitric acid and water is an example of this class of azeotrope. This azeotrope has the approximate composition, 68% nitric acid and 32% water by mass.

Q. 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 total vapour pressure is 600 mm Hg. Also find the composition of the vapour phase.

Solution : 17.95 m and 8.70 M

2.6 Colligative Properties and Determination of Molar Mass :

Q. What are colligative properties and what are different types of colligative properties ?

Solution : All these properties depend on the number of solute particles irrespective of their nature relative to the total number of particles present in the solution. Such properties are called colligative properties. These are (i) relative lowering of vapour pressure of the solvent (2) depression of freezing point of the solvent (iii) elevation of boiling point of the solvent and (iv) osmotic pressure of the solution.

Q. What is relation between relative lowering in vapour pressure and mole fraction of solute ?

Solution : $\dfrac{\Delta p}{p^0} = X_{solute}$ **.........** [X_{solute} is mole fraction of solute, $\Delta p = (p^0 - p)$ is lowering in vapour pressure]

$\dfrac{\Delta p}{p^0} = \dfrac{in_B}{in_B + n_A}$ **.....** [n_B and n_A are no. of moles of solutes and solvent respectively]

Q. 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 ?

Solution : 170 g mol^{-1}

Q. Define boiling point of a liquid.

Solution : Vapour pressure of a liquid increases with increase of temperature. It boils at the temperature at which its vapour pressure is equal to the atmospheric pressure.

Q. Show the variation of vapour pressure of pure solvent and solution as a function of temperature, also give the relation between elevation of boiling point and molality.

Solution : $\Delta T_b = T_b - T_b^0 = iK_b.m$ .....

[K_b is called as molal elevation constant, m is the molality of solution]

In elevation of b.Pt : b.Pt of solution $(T_b) > (T_b^0)$ b.Pt of solvent
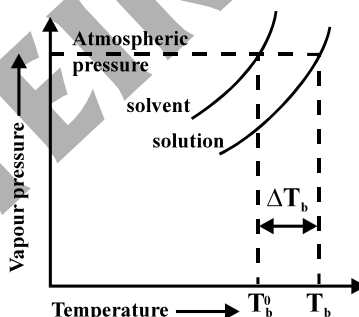
Q. 18 g of glucose, $C_6H_{12}O_6$, is dissolved in 1 kg of water in a saucepan. At what temperature will water boil at 1.013 bar ? K_b for water is 0.52 K kg mol^{-1}. [NCERT Solved Example]

Solution : 373.202 K

Q. The boiling point of benzene is 353.23 K. When 1.80 g of a non-volatile solute was dissolved in 90 g of benzene, the boiling point is raised to 354.11 K. Calculate the molar mass of the solute, K_b for benzene is 2.53 K kg mol^{-1}. [NCERT Solved Example]

Solution : 58 g mol^{-1}

Q. Define freezing point. Show the variation of vapour pressure with freezing temperature graphically.

Solution : At the freezing point of a substance, the solid phase is in dynamic equilibrium with the liquid phase. Thus, the freezing point of a substance may be defined as the temperature at which the vapour pressure of the substance in its liquid phase is equal to its vapour pressure in the soild phase.

$\Delta T_f = T_f^0 - T_f = iK_f m$....   [$K_f$ is molal depression constant]

F.Pt of solution $(T_f) < (T_f^0)$ F.Pt of solvent
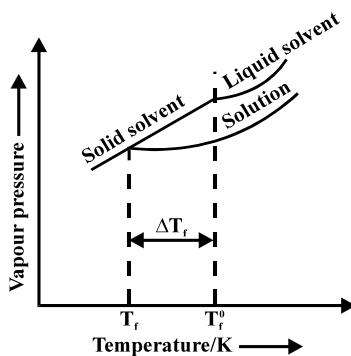
Q. What is relation between K_f, K_b with $\Delta_{fus}H$ and $\Delta_{vap}H$.

Solution : $K_b = \dfrac{R(T_b^0)^2 M_{solvent}}{1000\Delta H_{vap.}}$ .....   [ΔH_v is the enthalpy of vaporisation per mole of solvent]

$K_f = \dfrac{R(T_f^0)^2 M_{solvent}}{1000 \times \Delta H_{fus.}}$ .....   [ΔH_{fus} is the enthalpy of fusion per mole of solvent]

Q. 45 g of ethylene glycol ($C_2H_6O_2$) is mixed with 600 g of water. Calculate (a) the freezing point depression and (b) the freezing point of the solution. [NCERT Solved Example]

Solution : (a) 2.2 K (b) 270.95 K

Q. 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.

Solution : 256 g mol^{-1}

Q. What are the properties of semipermeable membrane ?

Solution : These membranes can be of animal or vegetable origin and these occur naturally such as pig's bladder or parchment or can be synthetic such as cellophane. These membranes appear to be continuous sheets or films, yet they contain a network of submicroscopic holes or pores. Small solvent molecules, like water, can pass through these holes but the passage of bigger molecules like solute is hindered. Membranes having this kind of properties are known as semipermeable membranes (SPM).

Q. Define osmosis and osmotic pressure. Give some examples of osmosis.

Solution : Assume that only solvent molecules can pass through these semipermeable membranes. If this membrane is placed between the solvent and solution, the solvent molecules will flow through the membrane from pure solvent to the solution. This process of flow of the solvent is called **osmosis**.

The flow will continue till the equilibrium is attained. The flow of the solvent from its side to solution side across a semipermeable membrane can be stopped if some extra pressure is applied on the solution. This pressure that just stops the flow of solvent is called **osmotic pressure** of the solution.

Examples of osmosis : Water movement from soil into plant roots and subsequently into upper portion of the plant is partly due to osmosis. The preservation of meat by salting and of fruits by adding sugar protects against bacterial action. Through the process of osmosis, a bacterium on salted meat or candid fruit loses water, shrivels and dies.

Q. What is relation between osmotic pressure with molarity of solution ?

Solution : $\pi = iCRT$ .....   [C is the molarity of the solution at temperature 'T' K]

Q. Which method is used for determination of molar masses of protein, polymer and other macromolecules and why ?

Solution : Measurement of osmotic pressure provides another method of determining molar masses of proteins, polymers and other macromolecules.

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.

The technique of osmotic pressure for determination of molar mass of solutes is particularly useful for biomolecules as they are generally not stable at higher temperatures and polymers have poor solubility.

Q. What are isotonic solution ?

Solution : Two solutions having same osmotic pressure at a given temperature are called isotonic solutions. When such solutions are seperated by semipermeable membrane no osmosis occurs between them. For e.g., the osmotic pressure associated with the fluid inside the blood cell is equivalent to that of 0.9% (mass/volume) sodium chloride solution, called normal saline solution and it is safe to inject intravenously. For isotonic solution $\pi_1 = \pi_2$.

Q. What will happen if we place cells in a solution containing more than 0.9% (w/v) NaCl solution and less than 0.9% (w/v) NaCl solution.

Solution : 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. 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. 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. [NCERT Solved Example].

**Solution :** 61.022 g mol^{-1}

Q. What is edema ?

Solution : Prople 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. What is Reverse Osmosis ? Explain its application.

Solution : The direction of osmosis can be reversed if a pressure larger than the osmotic pressure is applied to the solution side. That is, now the pure solvent flows out of the solution through the semi permeable membrane. This phenomenon is called **reverse osmosis**.

Reverse osmosis is used in desalination of sea water.
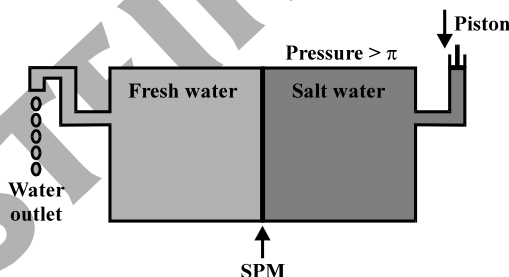
When pressure more than osmotic pressure is applied, pure water is squeezed out of the sea water through the membrane. The pressure required for the reverse osmosis is quite high. A workable porous membrane is a film of cellulose acetate placed over a suitable support. Cellulose acetate is permeable to water but impermeable to impurities and ions present in sea water.

Q. 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.

Solution : $\sim 15 \times 10^{-4}$ g, 1.25×10^{-4} m

Q. Boiling point of water at 750 mm Hg is 99.63^{0}C. How much sucrose is to be added to 500 g of water such that it boils at 100^{0}C.

Q. 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^{0}C. K_f = 3.9 K kg mol^{-1}.

Q. 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^{0}C.

2.7 **Abnormal Molar Masses :**

Q. Define Van't Hoff Factor 'i'.

Solution : There may be change in number of mol of solute due to ionisation or association hence these properties are also affected. Number of mol of the product is related to degree of ionisation or association by van't Hoff Factor 'i' is given by

Q. When a solute dissociates with a degree of dissociation α. What is its relation with Van't Hoff Factor 'i'. Similarly when a solute associates with a degree of association α then also write its relation with 'i'.

Solution : In case of dissociation : $i = [1 + (n - 1)\alpha]$

where n is the number of products (ions or molecules) obtained per mol of the reactant.

In case of association : $i = [1 + (\frac{1}{n} - 1)\alpha]$

where 'n' is the no. of moles of solute undergoes association and α is degree of association

Q. How the Van't Hoff Factor 'i' is calculated ?

Solution : $i = \dfrac{\text{normal molar mass}}{\text{abnormal molar mass}}$

$i = \dfrac{\text{Observed value of colligative property due to diss. or asso.}}{\text{Theoretical value of colligative property without diss. or asso.}}$

$i = \dfrac{\text{no. of moles of solute at time 't'}}{\text{initial no. of moles of solute added}}$

if i = 1 (no change), i > 1 (dissociation), i < 1 (association)

Q. 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 ?

Solution : 99.2 %

Q. 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 0.0205⁰C. Calculate the van't Hoff factor and the dissociation constant of acid.

Solution : 1.041, 1.86×10^{-5}

NCERT EXERCISE

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

2.2 **Give an example of a solid solution in which the solute is a gas.**

2.3 **Define the following terms :**

 (i) **Mole fraction**   **(ii)** **Molality**   **(iii)** **Molarity**

 (iv) **Mass percentage**

2.4 **Concentrated nitric acid used in the laboratory work 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 solution is 1.504 g mL⁻¹ ?**

2.5 **A solution of glucose in water is labelled as 10% w/w, what would be the molality and mole fraction of each component in the solution ? If the density of the solution is 1.2 g mL⁻¹, then what shall be the molarity of the solution ?**

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

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

2.8 An antifreeze solution is prepared from 222.6 g of ethylene glycol, ($C_2H_6O_2$), 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 ?

2.9 A sample of drinking water was found to be severely contaimed with chloroform ($CHCl_3$), supposed to be carcinogen. The level of contamination was 15 ppm (by mass) :

    (i) Express this in per cent by mass.

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

2.10 What role does the molecular interaction play in a solution of alcohol and water ?

2.11 Why do gases always tend to be less soluble in liquids as the temperature is raised ?

2.12 State Henry's law and mention some important applications.

2.13 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 ?

2.14 What is meany by positive and negative deviations from Raoult's law and how is the sign of ΔH_{mix} related to positive and negative deviations from Raoult's law ?

2.15 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 ? [$P^0 = 1.013$ bar]

2.16 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 g of octane ?

2.17 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.

2.18 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%.

2.19 A solution containing 30 g of 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 and 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.

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

2.21 Two elements A and B form compounds having 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 molar depression constant for benzene is 5.1 K kg mol^{-1}. Calculate atomic masses of A and B.

2.22 At 300 K, 36m 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 bars at the same temperature, what would be its concentration ?

2.23 Suggest the most important type of intermolecular attractive 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)

2.24 Based on solute-solvent interactions, arrange the following in order of increasing solubility in n-octane and explain : Cyclohexane, KCl, CH_3OH, CH_3CN.

2.25 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

2.26 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 molarity of Na$^+$ ions in the lake.

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

2.28 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.

2.29 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.

2.30 Calculate the amount of benzoic acid (C_6H_5COOH) required for preparing 250 mL of 0.15 M solution in methanol.

2.31 The depression in freezing point of water observed for the same amount of acetic acid, trichloroacetic acid and trifluoroacetic acid increases in the order given above. Explain, briefly.

2.32 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}.

2.33 19.5 g of CH_2FCOOH is dissolved in 500 g of water. The depression in the freezing point observed is 1.0^0C. Calculate the van't Hoff factor and dissociation constant of fluroacetic acid.

2.34 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.

2.35 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 of 298 K under 760 mm Hg.

2.36 100 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.

2.37 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 x $x_{acetone}$	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

2.38 Benzene and toluene form ideal solution over the entire range of composition. The vapour pressure of pure benzene and toluene at 300 K are 50.71 mm Hg and 32.06 mm Hg, respectively. Calculate the mole fraction of benzene in vapour phase if 80 g of benzene is mixed with 100 g of toluene.

2.39 The air is a mixture of a number of gases. The major components are oxygen and nitrogen with approximately 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.

2.40 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 27^0C. [Molar mass $CaCl_2$ = 111 g/mol]

2.41 Determine the osmotic pressure of a solution prepared by dissolving 25 mg of K_2SO_4 in 2 litre of water at 25^0C, assuming that is completely dissociated. [Molar mass K_2SO_4 = 174 g/mol]

ANSWERS

2.4	16.23 M	2.5	0.617 m, 0.01, 0.99, 0.67 M
2.6	157.8 mL of HCl	2.7	33.5%, 66.5%
2.8	17.95 m, 9.11 M	2.9	15×10^{-4}, 1.25×10^{-4} m
2.13	0.762 bar	2.15	41.35 g mol^{-1}
2.16	73.43 kPa	2.17	p_s = 12.08 kPa
2.18	w = 10 g	2.19	(i) 23 g mol^{-1} (ii) 3.53 kPa
2.20	269.06 K	2.21	A = 25.59 u, B = 42.64 u
2.22	0.061 M	2.24	KCl, CH$_3$OH, CH$_3$CN, Cyclohexane
2.25	Toluene, chloroform, Phenol, Pentanol; Formic acid, ethylene glycol		
2.26	Molarity = 5 M.	2.27	2.45×10^{-8} mol L^{-1}
2.28	1.424 %	2.29	3.21 g
2.30	4.575 g benzoic acid.	2.32	0.65^0
2.33	1.0753, 3.07×10^{-3}	2.34	17.44 mm
2.35	1.78×10^{-3}	2.36	280.7 torr, 32 torr
2.38	0.60	2.39	$x_{O_2} = 4.61 \times 10^{-5}$, $x_{N_2} = 9.22 \times 10^{-5}$
2.40	3.42 g	2.41	5.27×10^{-3} atm

ADDITIONAL QUESTIONS AND PROBLEMS

Q. How is it that the boiling points of the following solutions in water are different :

(a)   0.1 M NaCl solution

(b)   0.1 M sugar solution.

Q. Calculate the osmotic pressure of a solution obtained by mixing 100 cm³ of 0.25 M solution of urea and 100 cm³ of 0.1 M solution of cane-sugar at 293 K. (R = 0.082 L atm mol^{-1} K^{-1})

Q. 1.0 g of a non-volatile solute was dissolved in 100 g of acetone (mol. mass = 58 g) at 298 K. The vapour pressure of solution was found to be 192.5 mm of Hg. Calculate the molar mass of solute. [The vapour pressure of pure acetone at 298 K is 195 mm Hg].

Q. Give an example of a solution containing a solid solute in a solid solvent.

Q. On mixing equal volumes of water and ethanol, what type of deviation would you expect from Raoult's law ?

Q. An aqueous solution of sodium chloride freezes below 273 K. Explain the lowering in freezing point of water with the help of suitable diagram.

Q. Calculate the volume of 80% (by mass) of H$_2$SO$_4$ (density = 1.80 g/ml) required to prepare 1 litre of 0.2 molar H$_2$SO$_4$. (Relative atomic masses : H = 1, O = 15, S = 32).

Q. What is meant by Van't Hoff factor ? The osmotic pressure of a 0.0103 molar solution of an electrolyte is found to be 0.70 atm at 27⁰C. Calculate the Van't Hoff factor.

[R = 0.082 L atm-mol^{-1}K^{-1}]

What conclusion do you draw about the molecular state of the solution in the solution ?

Q. Define osmotic pressure.

Q. State Raoult's Law for a binary solution containing volatile components.

Q. Mention a large scale use of the phenomena of reverse osmosis.

Q. What happens when blood cells are placed in pure water.

Q. Why does molality of a solution remains unchanged with change in temperature while its molarity changes.

Q. State any two characteristics of ideal solution.

Q. Why is an increase in temperature observed on mixing chloroform and acetone ?

Q. State Henry's Law and mention two applications of this law.

Q. The solution of non-volatile solute boils at a higher temperature then the pure solvent. Show this relationship on graphic diagram.

Q. With the help of neat diagram indicate why the solution of a non-volatile solute should freeze at a temperature lower than the freezing point of pure solvent.

Q. Give one example each of miscible liquid pairs showing positive and negative deviations from Raoult's Law. Give one reason each for such deviations.

Q. Look at the following figure and answer the question given below :
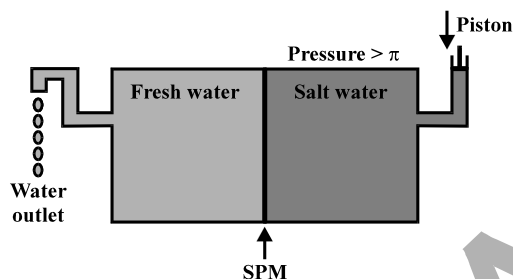
(a) What is the process known as ?

(b) What will happen if the pressure applied on the piston is less than P ?

(c) Which SPM is used in the above process ?

Q. The osmotic pressure of an aqueous solution at 300 K is 120 kPa. Calculate the freezing point of the solution. [Given : $k_f = 1.84$ K m^{-1}, m $\approx$ M].

Q. The vapour pressure of a solution containing 6.69 g of $Mg(NO_3)_2$ dissolved in 100 g of water is 747 torr at 373 K. Calculate the degree of dissociation of the salt in the solution.

Q. A current of dry air was bubbled through a bulb containing 26.66 g of an organic substance in 200 g of water, then through a bulb at the same temperature containing pure water and finally through a tube containing fused calcium carbide. The loss in weight of water bulb = 2.0870 g and the gain in weight of calcium carbide tube = 2.036 g. Calculate the molecular weight of organic substance in solution.