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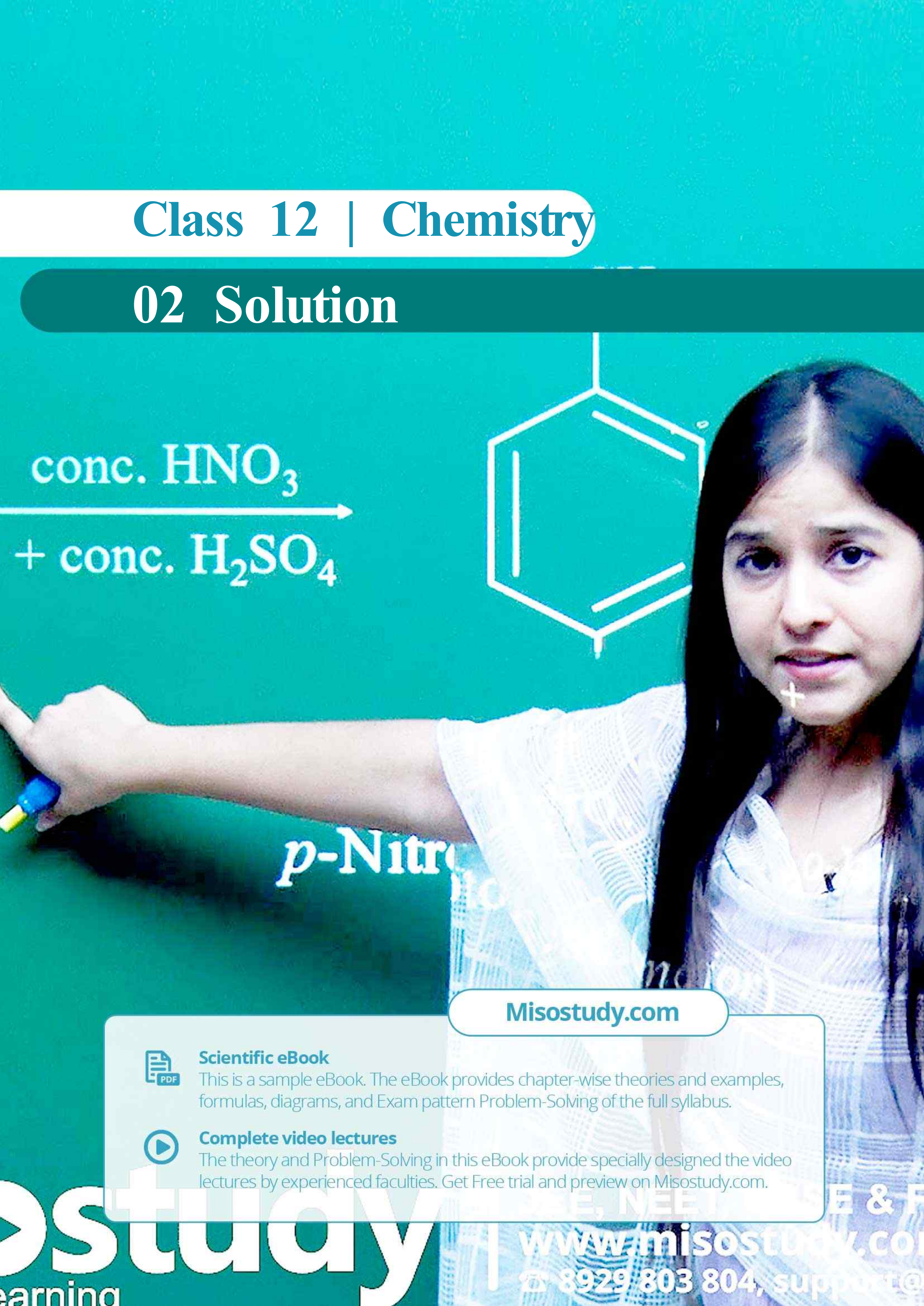
Class 12 | Chemistry

02 Solution



01. Introduction

When two or more chemically non-reacting substances are mixed and form homogeneous mixture it is called solution.

02. Types of Solution

	Solvent	Solute	Examples
1.	Gas	Gas	Mixture of gases, eg. air
2.	Gas	Liquid	Water vapour in air, mist. $CHCl_3(l) + N_2(g)$
3.	Gas	Solid	Smoke, camphor (s) + $N_2(g)$
4.	Liquid	Gas	CO_2 gas dissolve in water (aerated drink), soda water.
5.	Liquid	Liquid	Mixture of miscible liquids e.g. alcohol in water.
6.	Liquid	Solid	Salt in water, sugar in water.
7.	Solid	Gas	hydrogen over palladium.
8.	Solid	Liquid	Mercury in zinc, mercury in gold i.e. all amalgams.
9.	Solid	Solid	Alloys e.g. copper in gold. zinc in copper.

03. Mass Percentage

It may be defined as the number of parts of mass of solute per hundred parts by mass of solution.

$$\% \text{ by mass } \left(\frac{w}{W}\right): = \frac{\text{Wt. of solute}}{\text{Wt. of solution}} \times 100$$

[X % by mass means 100 gm solution contains X gm solute; (100−X) gm solvent]

04. Mass-Volume Percentage (W/V %) :

It may be defined as the mass of solute present in 100 cm^3 of solution. For example, If 100 cm^3 of solution contains 5 g of sodium hydroxide, than the mass-volume percentage will be 5% NaOH solution.

$$\%\left(\frac{w}{V}\right) = \frac{\text{wt. of solute (in gm)}}{\text{volume of solution (in mL)}}\times 100$$

$$[X\%\left(\frac{w}{V}\right)\text{ means 100 ml solution contains X gm solute}]$$

05. Volume Percent

It can be represented as % v/v or % volume and used to prepare such solutions in which both components are in liquids state. It is the number of parts of by volume of solute per hundred parts by volume of solution

Therefore,

$$\%\left(\frac{v}{V}\right) = \frac{\text{volume of solute}}{\text{volume of solution}}\times 100$$

06. Parts Per Million (ppm)

This method is used for expressing the concentration of very dilute solutions such as hardness of water, air pollution etc.

$$\text{ppm of substance} = \frac{\text{Mass of solute}\times 10^6}{\text{Mass of solution}} = \frac{\text{Volume of solute}\times 10^6}{\text{Volume of solution}}$$

07. Mole Fraction:

The ratio of the number of moles of one component to the total number of all the components present in the solution, is called the mole fraction of that component.

Mole fraction of solute X_A is given by $X_A = \frac{n_A}{n_A + n_B} = \frac{n_A}{\sum n}$

Mole fraction of solvent X_B is given by $X_B = \frac{n_B}{n_A + n_B} = \frac{n_B}{\sum n}$

where n_A is moles of solute A and n_B is moles of solvent B.

For binary solution of A & B $X_A + X_B = 1$

08. Molarity (Molar Concentration) :

It is defined as the number of moles of the solute dissolved in per litre of the solution, i.e.,

$$\text{Molarity (M)} = \frac{\text{Number of moles of solute}}{\text{Volume of solution (in } l)} = \frac{w_A}{m_A \times V} = \frac{c(gm/l)}{m_A} = \frac{\%\frac{W}{W} \times d \times 10}{m_A}$$

where let w_A g of the solute of molecular mass m_A be dissolved in V litre of solution, d = density of solution in g/mL.

09. Molarity of Dilute Solution :

Before dilution		After dilution
M_1V_1	=	M_2V_2

Molarity of mixing :

Let there be three samples of solution (containing same solvent and solute) with their molarity M_1, M_2, M_3 and volumes V_1, V_2, V_3 respectively. These solutions are mixed; molarity of mixed solution may be given as:

$M_1V_1 + M_2V_2 + M_3V_3 = M_R (V_1 + V_2 + V_3)$
where, M_R = Resultant molarity
$V_1 + V_2 + V_3$ = Resultant volume after mixing

10. Some Important Point :

[Note : Molarity is dependent on volume, therefore, it depends on temperature.]

1 M	Molar solution, i.e., molarity is 1
0.5 M or M/2	Semimolar
0.1 M or M/10	Decimolar
0.01 M or M/100	Centimolar
0.001 M or M/1000	Millimolar

11. Molality (m) :

The number of moles or gram-mole of solute dissolve in 1000 gram of the solvent is called molality of the solution.

$$\text{Molality of a solution} = \frac{\text{Number of moles of solute}}{\text{Amount of solvent in kg.}} = \frac{\text{Number of moles of solute} \times 1000}{\text{Amount of solvent in grams.}}$$

12. Normality (N) :

The number of equivalents or gram equivalents of solute dissolved in one litre of the solution is known as normality (N) of the solution.

$$\text{Normality (N)} = \frac{\text{Number of gram equivalents of solute}}{\text{volume of solution in litre}} = \frac{\text{weight of solute in gram}}{\text{equivalent weight} \times \text{volume of sol}}$$

$$= \frac{\text{strength of solution in gram/litre}}{\text{Equivalent weight of solute}}$$

Equivalent weight of a substance is that weight which reacts with or displaces one gram of hydrogen, 8 grams of oxygen or 35.5 grams of chlorine.

13. Solubility of Gases

Gases dissolve in liquids in solids. For example, soda-water contains carbon dioxide dissolved in water under high pressure. Oxygen is sufficiently soluble in water to allow survival of aquatic life in lakes, rivers and oceans.
The solubility of a gas in a liquid is determined by several factors. In addition to the nature of the gas and the liquid, solubility of the gas depends on the temperature and pressure of the system. The solubility of a gas in a liquid is governed by Henry's Law which states that the solubility of a gas in a liquid is directly proportional to the pressure of the gas.

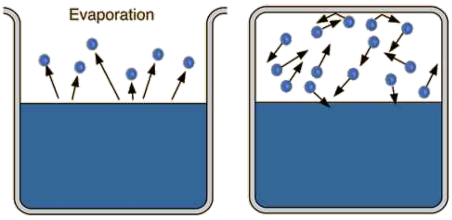
Mole fraction of the gas in a solution is proportional to the partial pressure of the gas. Or, partial pressure of the gas in solution = K_H × mole fraction of the gas in solution. Here K_H is Henry's law constant.

14. Vapour Pressure :

The Evaporation of a Liquid in a Closed Container

When a liquid is taken in a closed vessel at constant temperature, then there are two process which takes place.

(i) **evaporation**
(ii) **condensation**



In the constant evaporation from the surface particles continue to break away from the surface of the liquid.

As the gaseous particles bounce around, some of them will hit the surface of the liquid again, and will be trapped there. This is called condensation. The rate of condensation increases with time, but rate of evaporation remain constant. There will rapidly be an equilibrium set up in which the number of particles leaving the surface is exactly balanced by the number rejoining it.

This pressure at equilibrium is called the saturated vapour pressure (also known as saturation vapour pressure).

15. Effect of Temperature on Vapour Pressure

When the space above the liquid is saturated with vapour particles, you have this equilibrium occuring on the surface of the liquid :

$$\text{liquid} \rightleftharpoons \text{vapour}, \quad \Delta H > 0$$

The forward change (liquid to vapour) is endothermic. It needs heat to convert the liquid into the vapour. According to Le Chatelier, increasing the temperature of a system in a dynamic equilibrium favours the endothermic change. That means increasing the temperature increase the amount of vapour present, and so increases the saturated vapour pressure.

16. Raoult's Law for Volatile Solute :

For a two component solution A (volatile) and B (volatile) the vapour pressure of solution is given by.

Vapour pressure of solution = Vapour pressure of solvent in solution + Vapour pressure of solute

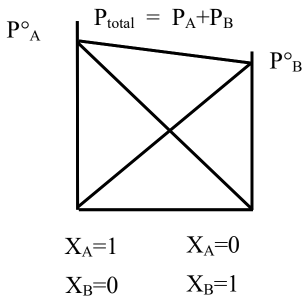
According to Raoult's Law partial. pressure of a component is equal to its mole fraction in solution multiplied with partial pressure in pure state

Thus $P_A = P°_A X_A$

$P°_A$ = vapour pressure in pure state of A

X_A = Mole fraction of A in solution

P_A = Partial pressure of A in solution



Total vapour pressure of solution $P = P°_A X_A + P°_B X_B$

17. Types of Solutions :

(a) **Ideal Solution :** An ideal solution may be defined as the one which obeys Raoult's law over all concentration ranges at a given temperature. The total vapour pressure of an ideal solution containing liquids A and B is given by the following equation.

$$P = P_A + P_B = P^\circ_A X_A + P^\circ_B X_B$$

Example		
	benzene + toluene	chlorobenzene + bromobenzene
	ethyl bromide + ethyl iodide	n-butyl chloride + n-butyl bromide
	ethyl alcohol + methyl alcohol	

(b) **Non-ideal solutions :** Solutions which do not over Raoult's law over all concentration ranges at constant temperature are called non-ideal solutions.

18. Distinction Between Ideal & Non Ideal Solutions

S.No.	Ideal Solution	Non Ideal Solution
1.	They obey Raoult's Law	They do not obey Raoult's Law
2.	$\Delta H_{mixing} = 0 \Rightarrow$ no heat is absorbed or released during dissolution	$\Delta H_{mixing} \neq 0 \Rightarrow$ no heat is absorbed or released during dissolution
3.	$\Delta V_{mixing} = 0 \Rightarrow$ the total volume of the solution is equal to the sum of the volume of the pure liquids mixed to form the solution	$\Delta V_{mixing} \neq 0 \Rightarrow$ the total volume of the solution is not equal to the sum of the volume of the pure liquids mixed to form the solution
4.	In ideal solution $P_A = P_A{}^0 X_A$	In non ideal solution $P_A \neq P_A{}^0 X_A$
5.	Components of ideal solution can be separated in pure form by fractional distillation	Components of non ideal solution can not be separated in pure form by fractional distillation

19. Types of Non – Ideal Solutions

(I) Non ideal solutions showing positive deviation.
(II) Non ideal solutions showing negative deviation.

20. Non Ideal Solutions Showing Positive Deviation

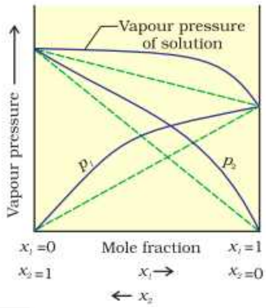
Condition for forming non-ideal solution showing positive deviation from Raoult's law. Two liquids A and B on mixing form this type of solution when

(i) A—B attractive force should be weaker than A—A and B—B attractive forces.
(ii) 'A' and 'B' have different shape, size and character.
(iii) 'A' and 'B' escape easily showing higher vapour pressure than the expected value.

Example

acetone + ethanol
water + ethanol
acetone + benzene
acetone + CS_2
CCl_4 + toluene
CCl_4 + CH_3OH
water + methanol
CCl_4 + $CHCl_3$
cyclohexane + ethanol

21. Graphical Representation of Vapour Pressure of Non-Ideal Solution Showing Positive Deviation



22. Non Ideal Solutions Showing Negative Deviation.

Condition for forming non-ideal solution showing negative deviation from Raoult's law.

Two liquids A and B on mixing from this type of solution when

(i) A—B attractive force should be greater than A—A and B—B attractive forces.

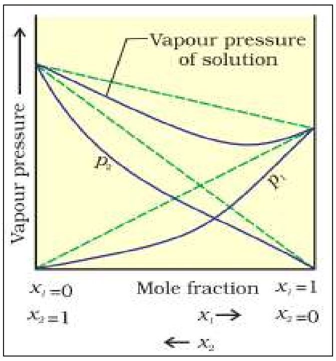
(ii) 'A' and 'B' have different shape, size and character.

(iii) Escaping tendency of both components 'A' and 'B' is lowered showing lower vapour pressure then expected ideally.

Example

acetone + aniline;
chloroform + diethyl ether,
chloroform + benzene
water + HCl
CH_3OH + CH_3COOH;
acetic acid + pyridine;
H_2O +HNO_3;

23. Graphical Representation of Vapour of non-ideal Solution Showing Negative Deviation



24. Distinction Between Non Ideal Solutions Showing Positive Deviation & Negative Deviation

S.NO.	Showing positive deviation	Showing negative deviation
1.	$\Delta H_{mix} > 0$. (endothermic dissolution i.e. heat is absorbed)	$\Delta H_{mix} < 0$. (Exothermic dissolution i.e. heat is evolved)
2.	$\Delta V_{mix} > 0$. (Volume is increased after dissolution)	$\Delta V_{mix} > 0$. (Volume is decreased after dissolution)
3.	$p_A > p_A^oX_A$; $p_B > p_B^oX_B$, $\therefore p_A + p_B > p_A^oX_A + p_B^oX_B$	$p_A < p_A^oX_A$; $p_B < p_B^oX_B$, $\therefore p_A + p_B < p_A^oX_A + p_B^oX_B$

25. Colligative Properties

The properties of dilute solutions containing nonvolatile solute, which depends upon relative number of solute and solvent particles but do not depend upon their nature are called colligative properties.

Some of the colligative properties are

(i) Relative lowering of vapour pressure
(ii) Elevation in boiling point
(iii) Depression in freezing point and
(iv) Osmotic pressure.

26. Factor that Affect the Colligative Property

The number of solute particles in solution. To be more accurate, the colligative property depends upon the fraction of solute and solvent particles in solution.

(1) Nature of the solvent
(2) Independent of the nature of the solute
(3) Extent of association and dissociation of solute particles in solution.

27. Relative Lowering of Vapour Pressure

As shown earlier the mathematical expression for relative lowering of vapour pressure is as follows

$$\frac{\Delta P}{P^o_A} = X_B = \text{mole fraction of solute}$$

$\Delta P = P^o_A - P_A$ = lowering of vapour pressure
P_A = vapour pressure of pure solvent

Molecular mass of non-volatile substance can be determined from relative lowering of vapour pressure

$$\frac{P^o_A - P}{P^o_A} = \frac{W_B/M_B}{W_A/M_A + W_B/M_B}$$

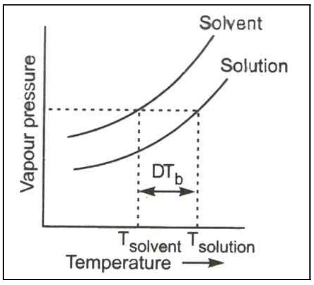
For dilute solution $W_B/M_B < W_A/M_A$ and hence W_B/M_B may be neglected in the denominator. So

$$\frac{P^o_A - P_A}{P^o_A} = \frac{W_B/M_B}{W_A/M_A} = \frac{W_B}{W_A} \times \frac{M_A}{M_B} \text{ or } M_B = \frac{W_B/M_A}{W_A}\left(\frac{P^o_A}{P^o_A - P_A}\right)$$

28. Elevation in Boiling Point

The boiling points elevates when a non-volatile solute is added to a volatile solvent. Which occurs due to lowering of vapour pressure. The boiling point of a liquid may be defined as the temperature at which its vapour pressure becomes equal to atmospheric pressure.

So when a non-volatile solute is added to a volatile solvent results lowering of vapour pressure and consequent elevation of boiling point.
where



$\Delta T_b = T_b - T^o_b$
ΔT_b =elevation in B.P.
ΔP =lowering of V.P.
X_B =mole fraction of solute
K = elevation constant
T^o_b = boiling point of solvent
T_b =boiling point of solution

It is found that elevation of boiling point is directly proportional to the number of moles of the solute in given amount of the solvent(m).

$$\Delta T_b \propto m$$

$$\Delta T_b \propto K_b m$$

Where 'm' is the molality of solution.

Where K_b is ebullioscopic or boiling point elevation constant. When molality of the solution is equal to one. Then

$$\Delta T_b = K_b$$

Determination of K_b of solvent:

$$K_b = \frac{RT_b^2}{1000L_v}$$

where R is molar gas constant, T_b is the boiling point of the solvent on Kelvin scale and L_v the latent heat of vaporization of solvent in calories per gram.

For water $K_b = \frac{2\times(373)^2}{1000\times540} = 0.515$ K-kg/mol

29. Depression in Freezing Point

The freezing point of a pure liquid is fixed. If a non-volatile solute is dissolved in a liquid the freezing point of the solution is lowered. The freezing point is that temperature at which the solvent has the same vapour pressure in two phases liquid solution and solid solvent. Since the solvent vapour pressure in solution is depressed. Its vapour pressure will become equal to that of the solid solvent at a lower temperature.

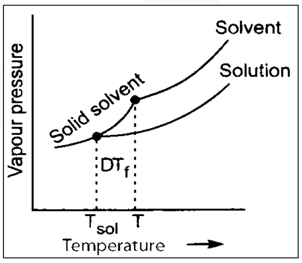
$$\Delta Tf = T^o_f - T_f$$

It is found that depression in freezing point is directly proportional to the number of moles of the solute in given amount of the solvent(m).

Hence $\Delta T_f \propto m$

$$\Delta T_f \propto K_f\ m$$

Where m = molarity of the solution.



K_f = molal depression constant

When molarity (m) of the solution is one. then

$$\Delta T_f = K_f$$

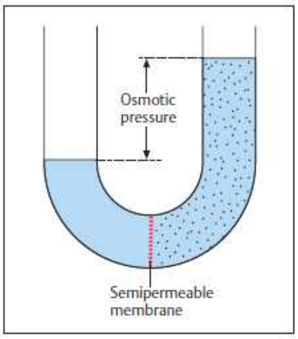
Hence molal depression constant or molal cryoscopic constant may be defined as "the depression in freezing point when one mole of non-volatile solute is dissolved per kilogram (1000 gm) of solvent" and molal depression constant is defined as "the depression in freezing point when one mole of non-volatile solute is dissolved per litre (1000 ml) of solvent."
The molecular mass of the non-volatile solute may be calculated by the use of following mathematical equation

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

Where W_A = mass of solvent, W_B = mass of solute,
M_A = Molar mass of solvent, M_B = Molar mass of solute.

30. Osmotic Pressure

(i) Osmosis : Spontaneous flow of solvent molecules through a semipermeable membrane from a pure solvent to the solution (or from a dilute solution to a concentrated solution) is termed as osmosis.



(ii) Osmotic Pressure :
When a solution is separated from the pure solvent with the help of a semipermeable membrane. There occurs the flow of solvent molecules from the pure solvent to the solution side. The flow of solvent molecules from a region of higher concentration of solvent to the region of lower concentration of solvent is termed as the phenomenon of osmosis. This also happens when two solution of different concentrations are separated by s semipermeable membrane.
The excess pressure that must be applied to the solution side to prevent the passage of solvent into it through a semipermeable membrane.

(iii) Theory of Dilute Solutions :
The osmotic pressure of dilute solution was the same as the solute would have exerted if it were a gas at the same temperature as of the solution and occupied a volume equal to that of the solution. This generalization is known as Van't Hoff theory of dilute solutions. The osmotic pressure is a colligative property. So the osmotic pressure is related to the number of moles of the solute by the following relation
$\pi V = nRT$

$$\pi = \frac{n}{V} RT \qquad (\therefore \frac{n}{V} = C)$$

$\pi = CRT$

Here C = concentration of solution in miles per litre;
R = solution constant;
T = temperature in Kelvin degree;
n = number of moles of solute; and
V = volume of solution.

This equation is called Van't Hoff's equation.

31. Type of Solution :

(i) **Isotonic solution :**
The two solutions having equal osmotic pressure are termed as isotonic solution.

(ii) **Hypertonic solution :**
A solution having higher osmotic pressure than some other solution is said to be called hypertonic solution.

(iii) **Hypotonic solution :**
A solution having a lower osmotic pressure relative to some other solution is called hypotonic solution.

Semipermeable membrane :

A membrane which allows the passage of solvent molecules but not that of solute. When a solution is separated from the solvent by it is known as semipermeable membrane.
Some example of it are as follows
(a) Copper ferrocyanide $Cu_2[Fe(CN)_6]$
(b) Calcium phosphate membrane and
(c) Phenol saturated with water.

Reverse Osmosis :

If a pressure greater than the osmotic pressure is applied on the concentrated solution, the solvent starts to flow concentrated solution to dilute solution (or pure solvent). This is reverse osmosis. One of its chief uses is desalination of sea water to get pure drinking water.

32. Abnormal Molecular Masses

Vapour pressure lowering, boiling point elevation, freezing point depression and osmotic pressure are colligative properties which depend upon the fraction of solute and solvent particles in solution and not upon the chemical nature of the solute. If solute molecules dissociates in solution, there are more particles in solution and therefore, lowering of vapour pressure shows an increased effect.

$$NaCl_{(s)} \rightleftharpoons Na^{+}_{(aq)} + Cl^{-}_{(aq)}$$

If the solute molecules associates in solution, there are less particles in solution, and therefore lowering of vapour pressure shows a decreased effect.

$$nAB \rightleftharpoons (AB)_n$$

$$2C_6H_5COOH \rightleftharpoons (C_6H_5COOH)_2$$

33. Vant Hoff Factor

In 1886, Van't Hoff, Jacobs Henricus (Dutch chemist, 1859,-1911) introduced a factor 'i' known as Van't Hoff factor to express the extent to association or dissociation of a solute in solution. It can be calculated as:

$$i = \frac{\text{number of solute particles actually present in solution}}{\text{number of solute particles dissolved}}$$

$$= \frac{\text{Observed colligative property}}{\text{normal colligative property}} = \frac{\text{observed molality}}{\text{normal molality}} = \frac{\text{normal molecular weight of solute}}{\text{observed molecular weight of solut}}$$

The Van't Hoff factor for a solute can be calculated by the following modified equations:

(i) $\dfrac{P_A^o - P_A}{P_A^o} = iX_B$

(ii) $\Delta T_f = iK_f m$

(iii) $\Delta T_b = iK_b m$

(iv) $\pi = iCRT$

where C is molarity of the solution.

NOTE ☞ For non-electrolytes; $i = 1$
For electrolytes; $i > 1$ (If solute particles undergo Dissociation in the solution)
$i < 1$ (If solute particles undergo Association in the solution)

34. Application of Van't Hoff Factor :

(a) **Calculation of Degree of Dissociation of solute particles:**

	A_n	$\rightleftharpoons$	nA
No. of moles dissolved	1 mol		0
No. of moles after dissociation	$1 - \alpha$		$n\alpha$

Total number of moles present in solution = $(1 - \alpha) + n\alpha$

(b) Calculation of Degree of Dissociation of solute particles:

	A_n $\rightleftharpoons$	nA
No. of moles dissolved	1 mol	0
No. of moles after dissociation	$1-\alpha$	$n\alpha$

Total number of moles present in solution = $(1-\alpha)+n\alpha$

$$\text{Van't Hoff factor, } \mathbf{i} = \frac{\text{Moles of solute actually present in solution}}{\text{Moles of solute dissolved}}$$

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

(c) Calculation of Degree of Association of solute particles:

Let n moles of the solute, A, associate to form $(A)_n$. If α is the degree of association.

	nA $\rightleftharpoons$	A_n
No. of moles dissolved	1 mol	0
No. of moles after dissociation	$1-\alpha$	α/n

Total number of moles present in solution = $(1-\alpha)+\alpha/n$

$$i = \left[1-\alpha\left(1-\frac{1}{n}\right)\right] \qquad \text{Hence } \alpha = \frac{i-1}{\frac{1}{n}-1} = (i-1)\times\frac{n}{1-n}.$$

CBSE Exam Pattern Exercise
Subjective Questions (1)

(Q 1 to 2) One Mark

1. What role does the molecular interaction play in solution of alcohol and water?

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

(Q 3 to 4) Two Marks

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

4. State Henry's law and mention some of its important applications.

(Q 5 to 6) Three Marks

5.
   (a) Determine the amount of $CaCl_2$ ($i = 2.47$) dissolved in 2.5 litre of water such that its osmotic pressure is 0.75 atm at 27°C.
   (b) 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

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

(Q 7 to 8) Four Marks

7. 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.

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

(Q 9 to 10) Five Marks

9. 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}.

10. 19.5g of CH_2FCOOH is dissolved in 500g of water. The depression in the freezing point observed is 1.0°C. Calculate the van't hoff factor and dissociation constant of fluoroacetic acid. K_f for water is 1.86 K kg mol^{-1}.

Answer & Solution

Q1

There is strong is hydrogen bonding in alcohol molecules as well as water molecules. On mixing, the molecular interactions are weakened. Hence, their solution will show positive deviations from ideal behaviour. As a result, the solution will have higher vapour pressure and lower boiling point that of water and alcohol.

Q2

Dissolution of gas in liquid is an exothermic process $(\text{Gas} + \text{Solvent} \rightleftharpoons \text{Solvent} + \text{Heat})$. As the temperature is increased, equilibrium shifts backward.

Q3

Maximum molarity of CuS in aqueous solution = Solubility of CuS in mol $L–^{1}$

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

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

$$\therefore \qquad S^2 = 6\times10^{-6} \text{ or } S=\sqrt{6\times10^{-16}}=\mathbf{2.45\times10^{-8}\ mol\ L^{-1}.}$$

Q4

The mass of a gas dissolved in a given volume of the liquid at constant temperature is directly proportional to the pressure of the gas present in equilibrium with the liquid.

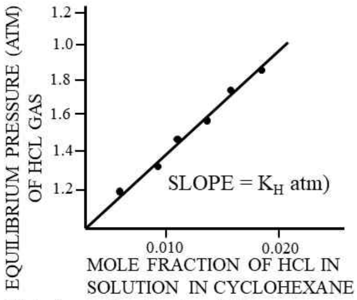
Mathematically, $m \propto P$ or $m = Kp$

Or

The solubility of a gas in a liquid at a particular temperature is directly proportional to the pressure of the gas in equilibrium with the liquid at that temperature.

From eqn (ii), $p_A = \frac{1}{K'}x_A$ or $\boldsymbol{P_A = K_H x_A}$

The partial pressure of a gas in vapour phase (*p*) is directly proportional to the mole fraction (*x*) of the gas in the solution.



Plot of mole fraction in solution versus equilibrium pressure

Application of Henry's law:

(i) **In the production of carbonated beverages**.

(ii) **In the deep sea diving.**
bend or decompression sickness

(iii) **In the function of lungs.**

(iv) **For climbers or people living at high altitudes.**

Q5

$\pi = i \quad CRT = i\frac{n}{V}RT$ or $n = n = \frac{\pi \times V}{i \times R \times T} = \frac{0.75\,\text{atm} \times 2.5\,\text{L}}{2.47 \times 0.0821\ \text{L atm K}^{-1}\text{mol}^{-1} \times 300\,\text{K}}$ **=0.0308 mole**

Molar mass of $CaCl_2$ = 40 + 2×35.5 = 111 g mol^{-1} $\therefore$ Amount dissolved = 0.0308 × 111 g = **3.42g**

Q6

Reduction of vapour pressure to 80% means that if $p° = 100$ mm, then $p_s = 80$ mm. Applying complete formula

$$\frac{p° - p_s}{p°} = \frac{n_2}{n_1 + n_2} = \frac{w_2 M_2}{w_1/M_1 + w_2/M_2}$$

$$\frac{100-80}{100} = \frac{w_2/40}{114/114 + w_2/40}$$ (Mol. mass of octane C_8H_{18} =114 g mol^{-1})

or $\frac{20}{100} = \frac{w_2/40}{1 + w_2/40}$ or $\frac{1}{5}\left(1 + \frac{w_2}{40}\right) = \frac{w_2}{40}$ or $w_2 =$ **10g**

Note that complete formula is required because concentration of solution I greater than 5%
Complete formula can also be applied in the form

$\frac{p° - p_s}{p°_s} = \frac{w_2/M_2}{w_1/M_1}$ or $\frac{100-80}{80} = \frac{w_2/40}{114/114}$ or $\frac{1}{4} = \frac{w_2}{40}$ or $w_2 =$ **10g**

Alternatively, suppose mass of solute dissolved = w g

Moles of solute $= \frac{w}{40} g$

Moles of solvent (octane) $= \frac{114}{114} = 1\,\text{mole}$ (Mol. mass of C_8H_{18}=114g mol^{-1})

$\therefore$ Mole fraction of solvent $= \frac{1}{1 + w/40}$

For a non-volatile solute,
Vapour pressure of solution =Mole fraction of solvent in the solution ×Vapour pressure of pure

solvent

$P_s = x_1 \times p°$

$$\therefore\ 80 = \frac{1}{1+w/40} \times 100 \text{ or } 1 + \frac{w}{40} = \frac{100}{80} \text{ or } \frac{w}{40} = \frac{10}{8} - 1 = \frac{2}{8} = \frac{1}{4} \text{ or } w = \mathbf{10g}$$

Q7

No of moles of liquid A (solute) $= \dfrac{100\,\text{g}}{140\,\text{g mol}^{-1}} = \dfrac{5}{7}$ mole

No. of moles of liquid B (solvent) $= \dfrac{1000\,\text{g}}{180\,\text{g mol}^{-1}} = \dfrac{50}{9}$ mole

$\therefore$ Mole fraction of A in the solution (x_A) $= \dfrac{5/7}{5/7+50/9} = \dfrac{5/7}{395/63} = \dfrac{5}{7} \times \dfrac{63}{395} = \dfrac{45}{395} = 0.114$

$\therefore$ Mole fraction of B in the solution $(x_B) = 1 - 0.114 = 0.886$

Also, given $P_B° = 500$ torr

Applying Raoult's law, $P_A = x_A\ P_A° = 0.114 \times P_A°$

$P_B = x_B\ P_B° = 0.886 \times 500 = 443$ torr

$P_{Total} = p_A + p_B$

$475 = 0.114\ P_B° + 443$ or $p_A° = \dfrac{475-443}{0.114} = \mathbf{280.7\ torr}$

Substituting this value in eqn. (*i*), we get $P_A = 0.114 \times 280.7$ torr $=$ **32 torr.**

Q8

Total pressure of air in equilibrium with water =10 atm

As sir contains 20% oxygen and 79% nitrogen by volume,

$\therefore$ Partial pressure of oxygen $(p_{O_2}) = \dfrac{20}{100} \times 10$ atm $= 2$ atm $= 2 \times 760$ mm $= 1520$ mm

Partial pressure of oxygen $(p_{N2}) = \dfrac{79}{100} \times 10\,\text{atm} = 7.9$ atm 7.9×760 mm $= 6004$ mm

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

Applying Henry's law, $Po_2 = K_H \times xo_2$ or $x_{O_2} = \dfrac{p_{O_2}}{K_H} = \dfrac{1520\text{ mm}}{3.30 \times 10^7\text{ mm}} = 4.61 \times 10^{-5}$

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

Q9

Molar mass of $CH_3CH_2CHClCOOH = 15+14+13+35.5+45 = 122.5$ g mol^{-1}

10 g of $CH_3CH_2CHClCOOH = \dfrac{10}{122.5}$ mole $= 8.16 \times 10^{-2}$ mole

$\therefore$ Molality of the solution (m) $\dfrac{8.16 \times 10^{-2}\text{mole}}{250\,\text{g}} \times 1000\,\text{g kg}^{-1} = 0.3264$

Of *a* is the degree of dissociation of $CH_3CH_2CHClCOOH$, then

$$CH_3CH_2CHClCOOH \rightleftharpoons CH_3CH_2CHClCOO^- + H^+$$

Initial conc. C mol L^{-1} 0 0

At eqm. $C\ (1-\alpha)$ $C\ \alpha$ $C\ \alpha$

$$\therefore \qquad Ka=\frac{C\alpha.C\alpha}{C(1-\alpha)}\simeq C\ \alpha^2 \quad \text{or} \quad \alpha=\sqrt{\frac{K_a}{C}}=\sqrt{\frac{1.4\times10^{-3}}{0.3264}}=0.065$$

To calculate van't Hoff factor:

$$CH_3CH_2CHClCOOH \rightleftharpoons CH_3CH_2CHClCOO^- + H^+$$

Initial moles 1

Moles at eqm. $1-\alpha$ α α Total = $1+\alpha$

$i=\frac{1+\alpha}{1}=1+\alpha=1+0.065=1.065$; $\Delta T_f = i\ K_f m$ = (1.065)(1.86)(0.3264)=**0.65°.**

Q10

Hence, W_2=19.5g, w_1=500 g, Kf =1.86 K kg mol^{-1}, $(\Delta T_f)_{obs}$ = 1.0°

$$\therefore M2\ (\text{observed}) = \frac{100K_f w^2}{w_1 \triangle T_f}=\frac{(1000\,g\ kg^{-1})(1.86\,K\ kg\ mol^{-1})(19.5g)}{(500\,g)\,(1.0\,K)}=72.54\ g$$

M_2 (calculated) for CH_2FCOOH =14+19+45=78 g mol^{-1}

$$\text{van't Hoff factor } (i) = \frac{(M_2)_{cal}}{(M_2)_{obs}}=\frac{78}{72.54}=\mathbf{1.0753.}$$

Calculation of dissociation constant. Suppose degree of dissociation at the given concentration is α.

Then $CH_2FCOOH \rightleftharpoons CH_2FCOO^- + H^+$

Initial C mol L^{-1} 0 0

At eqm. $C(1-\alpha)$ $C\alpha$ $C\alpha$, Total = $C\ (1+\alpha)$

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

$$K_\alpha=\frac{[CH_2FCOO^-][H^+]}{[CH_2FCOOH]}=\frac{C\,\alpha.C\,\alpha}{C(1-\alpha)}=\frac{C\alpha^2}{1-\alpha}$$

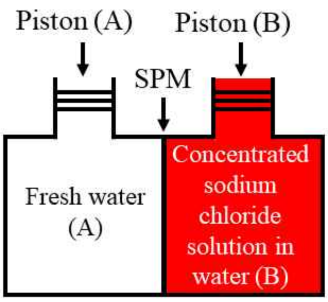
Taking volume of the solution as 500 mL,

$$C=\frac{19.5}{78}\times\frac{1}{500}\times1000=0.5M \qquad \therefore \qquad K_a=\frac{C\ \alpha^2}{1-\alpha}=\frac{(0.5)(0.0753)^2}{1-0.0753}=3.07\times10^{-3}.$$

CBSE Exam Pattern Exercise
Objective Questions (2)

1. Considering the formation, braking and strength of hydrogen bond, predict which of the following mixtures will show a positive deviation from Raoult's law ?
   (a) Methanol and acetone
   (b) Chloroform and acetone
   (c) Nitric acid and water
   (d) Phenol and aniline

2. Consider the figure and mark the correct option.
   (a) water will move form side (A) to side (B) if a pressure lower than osmotic pressure is applied on piston (B)



   (b) water will move from side (B) to side (A) if a pressure greater than osmotic pressure is applied on piston (B)
   (c) water will move from side (B) to side (A) if a pressure equal to osmotic pressure is applied on piston (B)
   (d) water will move from side (A) to side (B) if pressure equal to osmotic pressure is applied on piston (A)

3. If two liquids A and B form minimum boiling azeotrope at some specific composition, then ....
   (a) A–B interactions are stronger than those between A–A or B–B
   (b) vapour pressure of solution increases because more number of molecules of liquids A abd B can escape from the solution
   (c) vapour pressure of solution decreases because less number of molecules of only one of the liquids escape from the solution
   (d) A–B interactions are weaker than those between A–A or B–B

4. 4L of 0.02 M aqueous solution of NaCl was diluted by adding one litre of water. The molality of the resultant solution is ....
   (a) 000.4
   (b) 0.008
   (c) 0.012
   (d) 0.016

5. K_H value for Ar(g), CO_2(g), HCHO (g) and CH_4(g) are 40.39, 1.67, 1.83×10^{-5} and 0.413 respectively.
   Arrange these gases in the order of their increasing solubility.
   (a) $HCHO < CH_4 < CO_2 < Ar$
   (b) $HCHO < CO_2 < CH_4 < Ar$
   (c) $Ar < CO_2 < CH_4 < HCHO$
   (d) $Ar < CH_4 < CO_2 < HCHO$

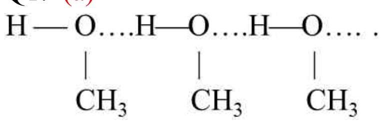
The questions given below consists of an Assertion and the Reason. Use the following key to choose the appropriate answer.

(a) If both assertion and reason are CORRECT and reason is the CORRECT explanation of the assertion.
(b) If both assertion and reason are CORRECT, but reason is NOT THE CORRECT explanation of the Assertion.
(c) If assertion is CORRECT, but the reason is INCORRECT.
(d) If both assertion and reason are INCORRECT.

6. **Assertion :** When NaCl is added to water, a depression in freezing point is observed.
   Reason : The lowering of vapour pressure of a solution causes depression in the freezing point.

Answer & Solution

Q1. (a)



$$\underset{\substack{|\\CH_3}}{H—O}\ldots\underset{\substack{|\\CH_3}}{H—O}\ldots\underset{\substack{|\\CH_3}}{H—O}\ldots.$$

On adding acetone, its molecules get in between the molecules of methanol braking hydrogen bonds and reducing methanol-methanol attractions.

Q2. (b)

The process represented in the image is the reverse osmosis (R.O) which takes place when pressure more than osmotic pressure is applied to the solution.

Due to this, the solvent will flow from the solution into the pure solvent through semi permeable membrane.

Q3. (d)

Minimum boiling azeotrope is formed when actual vapour pressure in higher than expected, i.e. solution shows +ve deviation from Raoult's law which is so when A–B interactions are weaker than A–A or B–B interactions.

Q4. (d)

$M_1V_1 = M_2V_2$, $0.02 \times 4 = M_2 \times 5$ or $M_2 = 0.016$

Q5. (c)

acceleration to the henry's law

$$P_A = K_H\ x_A$$

If x_A has a lower value, then K_H will increase, $\therefore$ solubility decrease.

Q6. (a)

Reason is the correct explanation of the assertion.