NCERT Solutions for Class-XII Chemistry

CHAPTER -1

NCERT Biology Class 12

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

1. A homogeneous mixture of two or more non-reacting substances whose composition varies within certain fixed limits, known as a solution. Generally, the component that is present in the largest quantity is known as solvent. Solvent determines the physical state in which solution exists. One or more components present in the solution other than solvent are called solutes.

When the solutions contains two, three or four components, it is known as binary, ternary or quaternary solutions respectively. On the basis of physical state of components, the solutions are of the following types:

(1) When both solute and solvent are in solid state. Example: Alloys.

(2) When solute is in solid and solvent is in liquid state. Example: Sugar or salt solutions.

(3) When solute is in solid and solvent is in gaseous state. Example: iodine vapours in air.

(4) When both solute and solvent are in liquid state. Example: alcohol in water.

(5) When solute is in liquid and solvent is in solid state. Example: Zinc amalgam.

(6) When solute is in liquid and solvent is in gaseous state. Example: water vapour in air.

(7) When both solute and solvent are in gaseous state. Example: air.

(8) When solute is in gaseous and solvent is in liquid state. Example: aerated drinks.

(9) When solute is in gaseous and solvent is in solid state. Example: dissolve gas in mineral.

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

2. As the name signifies, a solid solution is one in which solvent is solid.

So considering this aspect absorption of hydrogen over platinum or palladium is an example of such solution. Platinum or palladium is used as a catalyst in hydrogenation processes.

3. Define the following terms:

(i) Mole fraction

(ii) Molality

(iii) Molarity

(iv) Mass percentage.

3. (i) Mole fraction: Commonly used symbol for mole fraction is x and subscript used on the right hand side of x denotes the component. It is defined as:

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

(ii) Molality: Molality (m) is defined as the number of moles of the solute per kilogram (kg) of the solvent and is expressed as:

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

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

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

(iv) Mass percentage: The mass percentage of a component of a solution is defined as:

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

4. Concentrated nitric acid used in 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 the solution is 1.504 g mL^{-1}?

4. Given:

Concentration of Nitric Acid, HNO_3 = 68%

Density of solution, d = 1.504 g/ml

To find: Molarity, M_o

Formula:

$$\text{Density, } d = \frac{\text{Mass}[M]}{\text{Volume}[V]}$$

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

68% of Nitric acid by mass in aqueous solution means that 68g [[68 × 100]/100] of Nitric acid present in 100g of solution.

⇒ Molecular mass of Nitric Acid, HNO_3 = [1 × 1] + [1 × 14] + [16 × 3]

= 63g

⇒ Number of moles of Nitric Acid = [68/63]

= 1.079 moles

⇒ Given Density, d = 1.504 g/ml

⇒ Volume, v = [100/1.504]

= 66.489 ml

⇒ Molarity, Mo = [1.079/66.489] × 1000

= 16.23 M

Therefore the molarity of the sample is 16.24 M.

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 solution is 1.2 g mL^{-1}, then what shall be the molarity of the solution?

5. 10% w/w means 10 g glucose is present in 100 g solution.

Mass of water = 100 – 10 = 90 g = 0.90 kg

10 g glucose = $\frac{10}{180}$ mol = 0.055 moles

Number of moles in 90 g of H_2O = $\frac{90}{18}$ mol = 5 moles

Molality of the solution = $\frac{0.0555}{0.090}$ m = 0.617 m

Mole fraction of glucose = $\frac{0.0555}{5+0.0555} = 0.01$

Mole fraction of H_2O =1 – 0.01 = 0.99

Volume of 100 g solution = $\frac{100}{1.2}$ mL = 83.33 mL = 0.08333 L

Molarity = $\frac{0.0555 \text{ mol}}{0.08333 \text{ L}}$ = 0.67 M

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?

6. Given:

Molarity of HCl, = 0.1 M

Mass of Mixture = 1g

To find: Volume of HCl to react completely with mixture

Formula:

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

Calculation of Amount of each component in mixture:

⇒ Let the amount of Na_2CO_3 be × g

⇒ And Let amount of $NaHCO_3$ be [1 – X] g

⇒ Molecular Weight of Na_2CO_3 = [23 × 2] + [12] + [3 × 16]

= 106 g

⇒ Molecular Weight of $NaHCO_3$ = [23] + [1] + [12] + [3 × 16]

= 84 g

⇒ Number of moles of $NaHCO_3$ = $\frac{1-x}{84}$

$\Rightarrow$ Number of moles of $Na_2CO_3 = \frac{x}{106}$

Now it is given in the question that the mixture is equimolar, so

$\Rightarrow$ Number moles of Na_2CO_3 = Number of moles of $NaHCO_3$

$\Rightarrow \frac{1-x}{84} = \frac{x}{106}$

$106 - 106X = 84X$

$190X = 106$

$X = \frac{106}{190}$

$X = 0.5579$

≈ 0.558

Amount of $Na_2CO_3 = 0.558$ g

$\Rightarrow$ Amount of $NaHCO_3 = 1 - 0.558$ g $= 0.442$ g

$\Rightarrow$ Number moles of $Na_2CO_3 = [0.558/106]$

$= 0.00526$ moles

$\Rightarrow$ Number of moles of NaHCO3 = 0.00526 moles …. [Mixture is equimolar]

Calculation of volume of HCl required:

$\Rightarrow$ In the question it is given that HCl reacts with the mixture.

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

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

From the above chemical equations it can be found that 2 moles of HCl is required to react with one mole of Na_2CO_3 and 1 moles of HCl is required to react with one mole of $NaHCO_3$.

So total number of moles of HCl required to completely react with mixture is as follows:

$\Rightarrow$ Total Number of Moles of HCl = $[2 \times 0.00526] + 0.00526$

$= 0.01578$ moles

From Molarity Formula we have,

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

$\Rightarrow 0.1 = \frac{0.01578}{\text{Volume in litres}\,[V]}$

$\Rightarrow$ Volume in litres, V = [0.01578/0.1]

$= 0.1578$ L

$\Rightarrow$ Volume in ml, V = 0.1578×1000

$= 157.8$ ml

Therefore the volume 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 is 157.8 ml.

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.

7. Total amount of solute present in the mixture is given by, $300 \times \frac{25}{100} + 400 \times \frac{40}{100} = 75 + 160 = 235$ g

Total amount of solution = 300 + 400 = 700 g

Therefore, mass percentage (w/w) of the solute in the resulting solution, = $\frac{235}{700} \times 100\% = 33.57\%$

And, mass percentage (w/w) of the solvent in the resulting solution = (100 − 33.57) % = 66.43%

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?

8. Given:

Mass of ethylene glycol ($C_2H_6O_2$) = 222.6 g

Mass of water = 200 g

Density, d = 1.072 g/ml

To find: Molality and Molarity of solution

Formula:

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

$$\text{Molarity, } M_O = \frac{\text{Number of moles of solute}}{\text{Volume of solution in litres}}$$

$$\text{Density, d} = \frac{\text{Mass [M]}}{\text{Volume [V]}}$$

Solution:

Calculation of Molality:

$\Rightarrow$ Molecular Mass of ethylene glycol ($C_2H_6O_2$) = [12 × 2] + [6 × 1] + [16 × 2]
= 24 + 6 + 32
= 62 g

$\Rightarrow$ Number of moles of ethylene glycol ($C_2H_6O_2$) = [222.6/62]
= 3.59 moles

$\Rightarrow$ Mass of water = 200 g

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

$= \frac{3.59}{200} \times 1000$

$= 17.95$ m

Calculation of Molarity:

$\Rightarrow$ Total mass of solution = [222.6 + 200]

= 422.6 g

From density formula we can find out the volume required.

$\Rightarrow$ Volume of solution, V = [422.6 /1.072]

= 394.216 ml

$\Rightarrow$ Molarity, $M_O = \frac{\text{Number of moles of solute}}{\text{Volume of solution in litres}}$

$\Rightarrow$ Molarity, $M_O = \frac{3.59}{394.216} \times 1000$

$\Rightarrow$ Molarity = 9.1067

$\Rightarrow$ Molarity $\approx$ 9.11 M

Therefore the Molality and Molarity of the solution is as follows:

Molality = 17.95 m

Molarity = 9.11 M

9. A sample of drinking water was found to be severely contaminated with chloroform ($CHCl_3$) supposed to be a carcinogen.

The level of contamination was 15 ppm (by mass):

(i) express this in percent by mass

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

9. 15 ppm means 15 part in one million (10^6) parts by mass in the solution. Therefore,

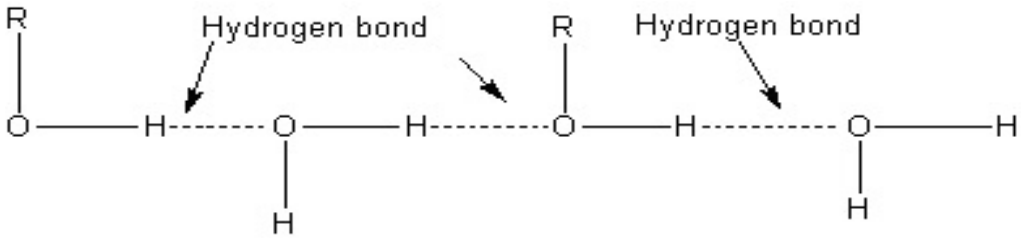
Percentage by mass = $\frac{18}{10^6} \times 100 = 5 \times 10^{-4}$

Taking 15 g chloroform in 106 g of the solution, mass of the solvent = 106 g [$\because$ Neglecting 15 g in comparison with 10^6 g] Molar mass of $CHCl_3 = 12 + 1 + 3 \times 35.5 = 119.5$ g mol^{-1}

Therefore, molality = $\frac{\frac{15}{119.5}}{10^6} \times 100 = 1.25 \times 10^{-4}$m

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

10. The lower members of alcohols are completely miscible [highly soluble] with water but the solubility decreases with increase in the molecular weight. The lower members of the alcohol group have the capability to form intermolecular hydrogen bonding with water molecules as alcohols are polar molecules in nature.



Alkyl groups are hydrophobic [prevents formation of hydrogen bonds with water] in nature. In lower alcohols, the alkyl group is small and the –OH group of alcohol is effective in making hydrogen bonds with water.

But with the increase in the size of alkyl group, the hydrophobic [water hating] nature of alkyl group dominates over the hydrophilic [water liking] nature of –OH group making the molecule less soluble in water. So solubility of alcohols decreases with increase in its molecular mass.

Since molecular interaction is weaker between higher alcohols and water, as a result, when alcohol and water are mixed, the intermolecular interactions become weaker and the molecules can easily get liberated off. This increases the vapour pressure of the solution, which in turn lowers the boiling point of the resulting solution.

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

11. Dissolution of gas in liquid is an exothermic process.

Gas + solvent ⇌ Solution + Heat

As the temperature is increased, equilibrium shifts backward, according to Le Chatelier's Principle.

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

12. The solubility of a gas in water depends on following three parameters:

1. Nature of gas
2. Temperature
3. Pressure

The solubility decreases with increase in temperature. Temperature and pressure follow inverse proportionality. So solubility increases with increase with pressure. A quantitative relation between pressure and solubility of a gas in a solvent was given by W. Henry [1803]. This relationship is known as Henry's law. Statement:

Henry's law can be expressed as follows.

At constant temperature, the solubility of a gas in a liquid is directly proportional to the pressure of the gas. Mathematically,

Solubility $\propto$ Pressure of the gas

Some of the important applications of Henry's law are as follows.

[i] Since the solubility of a gas in water increases with pressure, soft drink bottles are sealed under high pressure to accommodate more CO_2 in the soft drink making the drink fizzier.

[ii] If deep sea divers [scuba divers] use air for respiration, they develop a medical condition known as bends with involves the blocking of capillaries. This is because air is mainly a mixture of oxygen and nitrogen. According to Henry's Law, the solubility of gases increases with increase in pressure. When diver breathes air under high pressure in water, nitrogen dissolves in his blood. When the diver comes towards surface, the pressure gradually decreases. This releases the dissolved gases and leads to the formation of bubbles in the blood. This is quite painful and dangerous to life. In order to avoid bends and toxic effects of dissolved nitrogen in blood, the tanks used by sea divers are filled with air diluted with helium [11.7% He + 56.2% N_2 + 32.1% O_2].

[iii] The pressure of oxygen in air decreases in going up the mountains. At very high altitudes the partial pressure of oxygen in air is much less than that at the ground level. Therefore, people living at high altitude or climbers have low concentrations of oxygen in the blood and tissues. This leads to weakness and loss in the clarity of thinking. These symptoms create a condition known as anoxia.

[iv] Henry's law is also related to biology as it explains the supply of inhaled oxygen to tissues. When air is inhaled, it combines with haemoglobin [oxygen carrier of RBCs] of the blood in lungs to form oxyhaemoglobin because in lungs the partial pressure of oxygen is high. Partial pressure of oxygen is low in tissues. Hence, oxygen is released from oxyhaemoglobin and is utilised by the cells to carry out their tasks.

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?

13. Molar mass of ethane (C_2H_6) = $2 \times 12 + 6 \times 1 = 30$ g mol^{-1}

∴ Number of moles present in 6.56 × 10−2 g of ethane = $\frac{6.56 \times 10 - 2}{30}$ = 2.187×10^{-3} mol

Let the number of moles of the solvent be x. According to Henry's law,

$p = K_H X$

$$\Rightarrow 1\,\text{bar} = K_H . \frac{2.187 \times 10^{-3}}{2.187 \times 10^{-3} + x} \quad \Rightarrow \quad 1\,\text{bar} = K_H . \frac{2.187 \times 10^{-3}}{x}$$

$$\Rightarrow K_H = \frac{x}{2.187 \times 10^{-3}}\,\text{bar}$$

Number of moles present in 5.00×10^{-2} g of ethane

$$= \frac{5.00 \times 10^{-2}}{30} = 1.67 \times 10^{-3}\,\text{mol}$$

According to Henry's law,

$p = K_H x$

$$= \frac{x}{2.187 \times 10^{-3}} \times \frac{1.67 \times 10^{-3}}{1.67 \times 10^{-3} + x}$$

$$= \frac{x}{2.187 \times 10^{-3}} \times \frac{1.67 \times 10^{-3}}{1.67 \times 10^{-3} + x} \qquad \left[\because \; x >> 1.67 \times 10^{-3}\right]$$

= 0.764 bar

Hence, partial pressure of the gas shall be 0.764 bar.

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

14. Raoult's law states that at a given temperature, the vapour pressure of a solution containing non volatile solute is directly proportional the mole fraction of the solvent.

Non ideal solutions show positive and negative deviations from ideal behaviour.

Non ideal solutions showing positive deviations from Raoult's law-

A solution is said to show positive deviation from Raoult's Law when at any composition, its vapour pressure is higher than that given by Raoult's Law.

The positive deviation is shown by those liquid pairs in which the A-B molecular interaction forces are weaker than the corresponding A-A or B-B molecular interaction forces. When the A-B molecular interaction forces are weaker, then molecules of liquid A find it easier to escape as compared to pure solution thereby increasing the vapour pressure of solution.

As a result, each component of solution has a partial vapour pressure greater than expected on the basis of Raoult's law. This is called positive deviations from Raoult's law, that is $P_A > P_A^oXA$ and $P_B > P_B^oX_B$

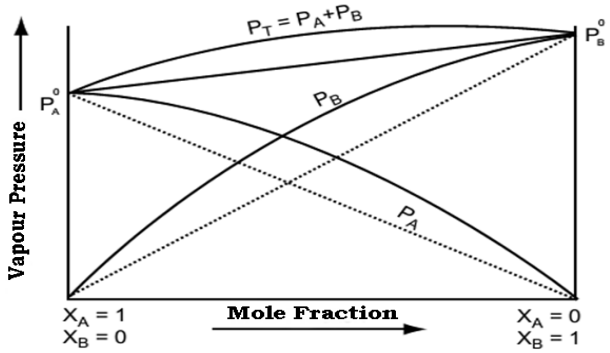
$\Delta_{mix}H$ [Change in Enthalpy] is positive because energy is required to <u>break A-A & B-B attractive forces</u>. Hence it is an endothermic process.

Examples of liquid Pairs:

1. Water + methanol
2. Water + ethanol
3. Acetone + benzene
4. Carbon tetrachloride + benzene

The graph of vapour pressure and mole fraction for liquids showing positive deviation from Raoult's Law is shown below:

From the diagram it is clear that the composition curve of such a solution lies above the composition curve obtained on basis of Raoult's Law.



P-X Diagram for Solutions Showing Positive Deviation from Raoult's Law

Non ideal solutions showing Negative deviations from Raoult's law –

When the vapour pressure of the solution is lower than that calculated on the basis of Raoult's Law, the solution is said to show negative deviation from Raoult's Law. Even the vapour pressure of individual components show negative deviation from Raoult's Law

The negative deviation is shown by those liquid pairs in which the A-B molecular interaction forces are stronger than the corresponding A-A or B-B molecular interaction forces. When the A-B molecular interaction forces are stronger, then molecules of liquid A find it easier to escape from pure solution as compared to the mixture thereby decreasing the vapour pressure of solution.

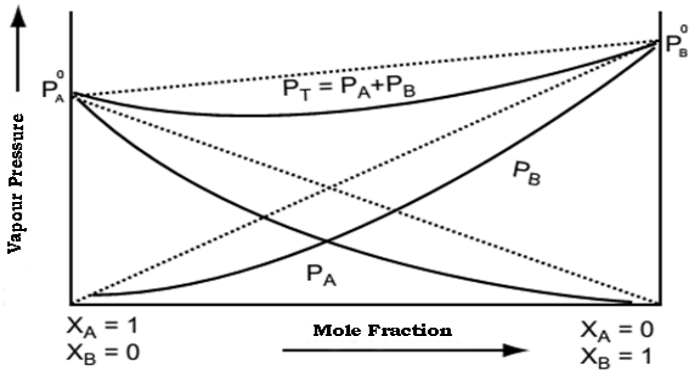
Consequently, each component of solution has a partial vapour pressure less than expected on the basis of Raoult's law. This is called negative deviations from Raoult's law, i.e. $P_A < P_A^oX_A$ & $P_B^oX_B$.

Examples of liquid pairs:

1. Water + hydrochloric acid
2. Water + nitric acid
3. Chloroform + benzene
4. Acetone + aniline

$\Delta_{mix}H$ is negative because energy is released due to increase in attractive forces. Hence it is an exothermic process.

The graph of vapour pressure and mole fraction for liquids showing negative deviation from Raoult's Law is shown below:



P-X Diagram for Solutions Showing Negative Deviation from Raoult's Law

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?

15. Here, Vapour pressure of the solution at normal boiling point (p_1) = 1.004 bar
Vapour pressure of pure water at normal boiling point (p_1^0) = 1.013 bar
Mass of solute, (w_2) = 2 g and Mass of solvent (water), (w_1) = 98 g
Molar mass of solvent (water), (M_1) = 18 g mol^{-1} According to Raoult's law,

$$\frac{p_1^0 - p_1}{p_1^0} = \frac{w_2 \times M_1}{M_2 \times w_1}$$

$$\Rightarrow \frac{1.013 - 1.004}{1.013} = \frac{2 \times 18}{M_2 \times 98}$$

$$\Rightarrow \frac{0.009}{1.013} = \frac{2 \times 18}{M_2 \times 98}$$

$$\Rightarrow M_2 = \frac{1.013 \times 2 \times 18}{0.009 \times 98}$$

= 41.35 g mol^{-1}
Hence, the molar mass of the solute is 41.35 g mol^{-1}.

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?

16. Given: Temperature=373k
Vapour pressure of pure heptane (p_1^0) = 105.2 kpa and that of octane (p_2^0) = 46.8 kpa
Mass of heptane = 26 g
Mass of octane = 35 g
Molecular weight of heptane = C_7H_{16} = 12 × 7 + 1 × 16 = 100 g mol^{-1}
Molecular weight of octane = C_8H_{18} = 114 gmol^{-1}
Moles of heptane, n_1 = given mass /molecular weight =26/100

$\Rightarrow n_1 = 0.26\text{mol}$

Moles of octane, n_2 = given mass /molecular weight =35/114

$\Rightarrow n_2 = 0.307\text{mol}$

$\therefore$ Mole fraction of heptane, $\chi_1 = \frac{\text{No. moles of heptane } (n_1)}{\text{Total moles } (n_1 + n_2)}$

$\Rightarrow \chi_1 = \frac{0.26}{0.26 + .307}$

$\Rightarrow \chi_1 = 0.456$

Now, Mole fraction of octane, $\frac{\text{No. moles of heptane}}{\text{Total moles}}$

$\Rightarrow \chi_2 = \frac{0.307}{0.26 + .307}$

$\Rightarrow \chi_2 = 0.544$

$\therefore$ Partial pressure of heptane, $p_1 = x_1 \times p_1^0$

$\Rightarrow p_1 = 0.456 \times 105.2 = 47.97$ kpa

$\therefore$ Partial pressure of octane, $p_1 = \chi_2 \times p_2^0$

$\Rightarrow p_2 = 0.544 \times 46.8 = 25.46$ kpa

$\therefore$ Total pressure exerted by solution = $p_1 + p_2$

= 47.97 + 25.46

= 73.43kpa

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

17. 1 molal solution means 1 mol of the solute is present in 100 g of the solvent (water).

Molar mass of water = 18 g mol^{-1}

Therefore, number of moles present in 1000 g of water = $\frac{1000}{18} = 55.56$ mol

Therefore, mole fraction of the solute in the solution is $x_2 = \frac{1}{1 + 55.56} = 0.0177$

It is given that,

Vapour pressure of water, $p_1^0 = 12.3$ kPa

Applying the relation,

$\frac{p_1^0 - p_1}{p_1^0} = x_2 \Rightarrow \frac{12.3 - p_1}{12.3} = 0.0177$

$\Rightarrow 12.3 - p_1 = 0.2177 \Rightarrow p_1 = 12.0823 = 12.08$ kPa (approximately)

Hence, the vapour pressure of the solution is 12.08 kPa.

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%.

18. Given:

Molar mass of non-volatile solute=40g

Let no. of moles of solute be n.

Mass of octane = 114g

Molar mass of octane (C_8H_{18}) = 12 × 8 + 1 × 18 = 114g/mol

Moles of octane=given mass/molar mass

$\Rightarrow$ n = 114/114 moles

$\Rightarrow$ n=1 mole

Molar fraction of solute, $\chi_2 = \frac{\text{moles of solute}}{\text{moles of solute + moles of octane}}$

$\Rightarrow x_2 = n/n + 1$

Let the vapour pressure of original solvent(without solute) be p_1^0

Accordingly after addition of solute vapour pressure of solution reduces to 80% i.e. 0.8 $p_1^0 = p_1$

Applying the formula:

$$\frac{p_1^0 - p_1}{p_1^0} = x_2$$

$$\Rightarrow \frac{p_1^0 - 0.8p_1^0}{p_1^0} = \frac{n}{n+1}$$

$\Rightarrow n/n + 1 = 0.2$

$\Rightarrow 0.2n + 0.2 = n$

$\Rightarrow n = 0.25$ moles

Hence, mass of solute is:

moles =given mass/molar mass

$\Rightarrow$ 0.25moles = mass/40g

$\Rightarrow$ mass = 10g.

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.

19. (i) Let, the molar mass of the solute be M g mol^{-1}

Now, the no. of moles of solvent (water), $n_1 = \frac{90\text{ g}}{18\text{ g mol}^{-1}}$ = 5 mol and, the no. of moles of solute, n_2

$$= \frac{30g}{M\ g\ mol^{-1}} = \frac{30}{M}\ mol$$

p_1 = 2.8 kPa, Applying the relation:

$$\frac{p_1^0 - p_1}{p_1^0} = \frac{n}{n_1 + n_2}$$

$$\Rightarrow \frac{p_1^0 - 2.8}{p_1^0} = \frac{\frac{30}{M}}{5 + \frac{30}{M}}$$

$$\Rightarrow 1 - \frac{2.8}{p_1^0} = \frac{\frac{30}{M}}{\frac{5M + 30}{M}}$$

$$\Rightarrow 1 - \frac{2.8}{p_1^0} = \frac{30}{5M + 30}$$

$$\Rightarrow \frac{2.8}{p_1^0} = 1 - \frac{30}{5M + 30}$$

$$\Rightarrow \frac{2.8}{p_1^0} = \frac{5M + 30 - 30}{5M + 30}$$

$$\Rightarrow \frac{2.8}{p_1^0} = \frac{5M}{5M + 30}$$

$$\Rightarrow \frac{p_1^0}{2.8} = \frac{5M + 30}{5M} \quad \text{....(i)}$$

After the addition of 18 g of water: $n_1 = \frac{90g + 18g}{18gmol^{-1}} = 6$ mol

p_1 = 2.9 kPa, Again, applying the relation:

$$\frac{p_1^0 - p_1}{p_1^0} = \frac{n_2}{n_1 + n_2}$$

$$\Rightarrow \frac{p_1^0 - 2.9}{p_1^0} = \frac{\frac{30}{M}}{6 + \frac{30}{M}}$$

$$\Rightarrow 1 - \frac{2.9}{p_1^0} = \frac{\frac{30}{M}}{\frac{6M + 30}{M}}$$

$$\Rightarrow 1 - \frac{2.9}{p_1^0} = \frac{30}{6M + 30}$$

$$\Rightarrow \frac{2.9}{p_1^0} = \frac{6M + 30 - 30}{6M + 30}$$

$$\Rightarrow \frac{2.9}{p_1^0} = \frac{6M}{6M + 30}$$

$$\Rightarrow \frac{p_1^0}{2.9} = \frac{6M + 30}{6M} \qquad \text{.....(ii)}$$

Dividing equation (i) by (ii), we have :

$$\frac{2.9}{2.8} = \frac{\frac{5M + 30}{5M}}{\frac{6M + 30}{6M}}$$

$$\Rightarrow \frac{2.9}{2.8} \times \frac{6M + 30}{6} = \frac{5M + 30}{5}$$

$\Rightarrow 2.9 \times 5 \times (6M + 30) = 2.8 \times 6 \times (5M + 30)$

$\Rightarrow 87M + 435 = 84\ M + 504$

$\Rightarrow 3M = 69$

$\Rightarrow\ M = 23u$

Therefore, the molar mass of the solute is 23 g mol^{-1}.

(ii) Putting the value of 'M' in equation (i), we have:

$$\frac{p_1^0}{2.8} = \frac{5 \times 23 + 30}{5 \times 23}$$

$$\Rightarrow \frac{p_1^0}{2.8} = \frac{145}{115}$$

$$\Rightarrow p_1^0 = 3.53$$

Hence, the vapour pressure of water at 298 K is 3.53 kPa.

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

20. Freezing point of solution = 271k

Freezing point of pure water = 273.15k

Molar mass of cane sugar ($C_{12}H_{22}O_{11}$) = 12 × 12 + 1 × 22 + 16 × 11=342g

Moles of cane sugar= mass/molar mass = 5/342

$\Rightarrow$ n = 0.0146mol

Molality of solution=moles of solute/mass of solvent(in kg)

$\Rightarrow$ M = 0.0146/0.095

$\Rightarrow$ Molality = 0.154M

Depression in freezing point = ΔT_f = 273.15 – 271 = 2.15k

Applying the formula: $\Delta T_f = K_f \times M$

Where
ΔT_f = depression in freezing point
$\Rightarrow$ K_f = molal depression constant
M= molality of solution
$\Rightarrow K_f = 2.15/0.154$
$\Rightarrow K_f = 13.96k$ kg mol^{-1}
Second condition: mass of glucose = 5g
Molar mass of glucose($C_6H_{12}O_6$) = 12 × 6 + 1 × 12 + 16 × 6 = 180g
Moles of glucose = mass/molar mass
$\Rightarrow$ n = 5/180moles
$\Rightarrow$ n = 0.0278mol
Molality of solution=moles of solute/mass of solvent (in kg)
$\Rightarrow$ molality = 0.0278/0.095
$\Rightarrow$ M=0.2926M
Applying the formula: ΔTf = Kf × M
Where
ΔT_f= depression in freezing point
K_f = molal depression constant
M = molality of solution
$\Rightarrow \Delta T_f = 13.96 \times 0.2926$
$\Rightarrow \Delta T_f = 4.08k$
Freezing point of solution = 273.15 + 4.08 = 277.234k

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 Kkg mol^{-1}. Calculate atomic masses of A and B.

21. We know that, $M_2 = \dfrac{1000 \times w_2 \times k_f}{\Delta T_f \times w_1}$

Then,
$$M_{AB_2} = \frac{1000 \times 1 \times 5.1}{2.3 \times 20} = 110.87 \text{ g mol}^{-1}$$
$$M_{AB_4} = \frac{1000 \times 1 \times 5.1}{1.3 \times 20} = 196.15 \text{ g mol}^{-1}$$

Now, we have the molar masses of AB_2 and AB_4 as 110.87 g mol^{-1} and 196.15 g mol^{-1} respectively.
Let the atomic masses of A and B be x and y respectively.
Now, we can write:
$x + 2y = 110.87$ … (i)
$x + 4y = 196.15$ … (ii)

Subtracting equation (i) from (ii), we have

$2y = 85.28 \quad \Rightarrow y = 42.64$

Putting the value of 'y' in equation (1), we have $x + 2 \times 42.64 = 110.87$

$\Rightarrow x = 25.59$

Hence, the atomic masses of A and B are 25.59 u and 42.64 u respectively.

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

22. Here,

T = 300 K

ϖ = 1.52 bar

R = 0.083 bar L

Applying the relation, $\varpi = CRT$

Where

π = osmotic pressure of solution

C = concentration of solution

R = universal gas constant

T = temperature

$$\Rightarrow C = \frac{\varpi}{RT} = \frac{1.52}{0.083 \times 300}$$

$\Rightarrow C = 0.061$ mol/L

Concentration of the solution is 0.061 mol/L

23. Suggest the most important type of intermolecular attractive interaction in the following pairs.

23. (i) Van der Wall's forces of attraction.

(ii) Van der Wall's forces of attraction.

(iii) Ion-diople interaction.

(iv) Dipole-dipole interaction.

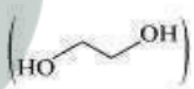
(v) Dipole-dipole interaction.

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.

24. Now n-octane is non-polar solvent due to long chain saturated structure. We know that "like dissolves like" so a non-polar compound will be more soluble in non-polar solvent as compared to polar compound.

So cyclohexane is non-polar due to symmetric structure. KCl is ionic in nature as it will dissociate into K^+ and Cl^- ions. CH_3CN is polar as mentioned above and CH_3OH is also polar in nature.
The order of increasing polarity is:
Cyclohexane < CH_3CN < CH_3OH < KCl (O is more electronegative than N)
Therefore, the order of increasing solubility is:
KCl < CH_3OH < CH_3CN < Cyclohexane

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.

25. (i) Phenol (C_6H_5OH) has the polar group −OH and non-polar group $-C_6H_5$. Thus, phenol is partially soluble in water.
(ii) Toluene ($C_6H_5-CH_3$) has no polar groups. Thus, toluene is insoluble in water.
(iii) Formic acid (HCOOH) has the polar group −OH and can form H-bond with water. Thus, formic acid is highly soluble in water.
(iv) Ethylene glycol  has polar −OH group and can form H−bond. Thus, it is highly soluble in water.
(v) Chloroform is insoluble in water.
(vi) Pentanol ($C_5H_{11}OH$) has polar −OH group, but it also contains a very bulky nonpolar $-C_5H_{11}$ group. Thus, pentanol is partially soluble in water.

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

26. Mass of ions = 92g
Molar mass of ions = Na^+ = 23g(neglect the mass lost due to absence of a electron)
Moles of ions=mass of ions/molar mass
$\Rightarrow$ n=92/23 moles
$\Rightarrow$ n=4moles
Molality of solution= moles of solute/mass of solvent(in kg)
Molality=4/1=4M

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

27. Solubility product of CuS, $K_{sp} = 6 \times 10^{-16}$ Let s be the solubility of CuS in mol L^{-1}.

$$CuS \leftrightarrow Cu^{2+} + S^{2-}$$

$$K_{sp} = \left[\overset{s}{Cu^{2+}}\right]\left[\overset{s}{S^{2-}}\right]$$

Now,

$= s \times s = s^2$

Then, we have, $K_{sp} = s^2 = 6 \times 10^{-16}$

$\Rightarrow s = \sqrt{6 \times 10^{-16}} = 2.45 \times 10^{-8}$ mol L^{-1}

Hence, the maximum molarity of CuS in an aqueous solution is 2.45×10^{-8} mol L^{-1}.

28. Calculate the mass percentage of aspirin ($C_9H_8O_4$) in acetonitrile (CH_3CN) when 6.5 g of C_9H8O_4 is dissolved in 450 g of CH_3CN.

28. Total mass of solution = 6.5g + 450g = 456.5g

Therefore mass percentage of aspirin in solution = (mass of aspirine/total mass of solution) = 6.5/456.5

$\Rightarrow$ mass % of aspirine =1.424%

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.

29. The molar mass of Nalorphene (C19H21NO3) is given as:

$19 \times 12 + 12 \times 1 + 1 \times 14 + 3 \times 16 = 311$ g mol^{-1}

In 1.5×10^{-3}m aqueous solution of nalorphene, 1 kg (1000 g) of water contains 1.5×10^{-3} mol

$= 1.5 \times 10^{-3} \times 311$ g = 0.4665 g

Therefore, total mass of the solution = (1000 + 0.4665) g = 1000.4665 g

This implies that the mass of the solution containing 0.4665 g of nalorphene is 1000.4665 g.

Therefore, mass of the solution containing 1.5 mg of nalorphene is: $\frac{1000.4665 \times 1.5 \times 10^{-3}}{0.4665}$ g = 3.22 g

Hence, the mass of aqueous solution required is 3.22 g.

30. 0.15 M solution of benzoic acid in methanol means,

1000 mL of solution contains 0.15 mol of benzoic acid

Therefore, 250 mL of solution contains = $\frac{0.15 \times 250}{1000}$ mol of benzoic acid = 0.0375 mol of benzoic acid

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

Hence, required benzoic acid = 0.0375 mol × 122 g mol^{-1} = 4.575 g

30. Volume of the solution=250mL=0.25L

Let the no. Of moles of solute be n

Molarity = No. of moles of solute/volume of solution

$\Rightarrow$ 0.15 = n/0.25

$\Rightarrow$ n = 0.0375moles

Molar mass of $C_6H_5OH = 6 \times 12 + 5 \times 1 + 16 + 1 = 94$g

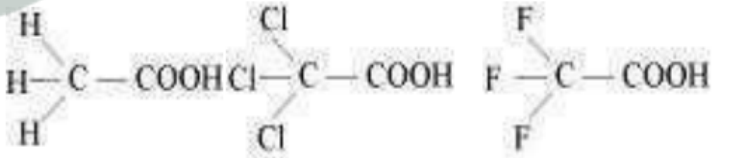
Moles=mass/molar mass

$\Rightarrow$ 0.0375=m/94

Mass of benzoic acid required = 3.525g.

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.

31. Among H, Cl, and F, H is least electronegative while F is most electronegative. Then, F can withdraw electrons towards itself more than Cl and H. Thus, trifluoroacetic acid can easily lose H^+ ions i.e., trifluoroacetic acid ionizes to the largest extent. Now, the more ions produced, the greater is the depression of the freezing point. Hence, the depression in the freezing point increases in the order: Acetic acid < trichloroacetic acid < trifluoroacetic acid



Acetic acid Trichloroacetic acid Trifluoroacetic acid

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}.

32. Mass of $CH_3CH_2CHClCOOH$= 10 g

Mass of water = 250g

$K_a = 1.4 \times 10^{-3}$,

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

Molar mass of $CH_3CH_2CHClCOOH = 12 + 3 + 12 + 2 + 12 + 1 + 35.5 + 2 + 16 + 16 + 1$ = 122.5 g mol–1

Number of moles of solute = $\frac{\text{Mass of solute}}{\text{Molar mass}}$

$\rightarrow$ No. of moles = (10 g)/(122.5 g/mol)

$\therefore$ No. of moles = $\frac{10g}{122.5\,g/mol}$

Now, Molality is given as,

$$M = \frac{\text{Number of moles of solute}}{\text{Kg of solvent}}$$

$$M = \frac{\left(8.16\times10^{-2}\times1000\frac{g}{mol}\right)}{250g}$$

M = 0.3264 kg/mol

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

Initial moles	1	0	0
Equilibrium moles	(1-α)	α	α

Total moles at equilibrium = (1 – α) + 2α

= 1 + α

In order to find out the depression in freezing point, $\Delta T_f = iK_f \times m$, values of i(vant Hoff's factor) and α(degree of dissociation) are to be found out.

To find out degree of dissociation, α

$$\rightarrow K_a = \frac{C\alpha + C\alpha}{C(1-\alpha)}$$

Here, the value of α is negligible as compared to 1, and hence 1 – α = 1, giving,

$$K_a = C\alpha^2$$

$$\alpha = \sqrt{\frac{K_a}{C}}$$

$$\rightarrow \alpha = \sqrt{\frac{1.4\times10^{-3}}{0.3264}}$$

$$\therefore \alpha = 6.54\times10^{-2}$$

To find out Vant Hoff's factor,

$$\rightarrow \alpha = \frac{i-1}{n-1}$$

$$0.0654 = \frac{i-1}{2-1}$$

$$0.0654 = i - 1$$

$\therefore$ i = 1.0654

Now, to find out the depression in freezing point,

$\rightarrow \Delta T_f = iK_f \times m$

$\Delta T_f = 1.0654 \times 1.86 \times 0.3264$

$\Delta T_f = 0.65K$

$\therefore \Delta T_f = 0.65°C$

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

33. It is given that :

$w_1 = 500$ g

$w_2 = 19.5$ g

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

$\Delta T_f = 1K$

We know that:

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

$$= \frac{1.86 K \text{ kg mol}^{-1} \times 19.5 \text{ g} \times 1000 \text{ g kg}^{-1}}{500 \text{ g} \times 1 K}$$

$= 72.54$ g mol^{-1}

Therefore, observed mass of CH_2FCOOH, $(M_2)_{bs} = 72.54$ g mol^{-1}

The calculated mass of CH_2FCOOH, $(M_2)_{al} = 14 + 19 + 12 + 16 + 16 + 1 = 78$ g mol^{-1}

Therefore, the van't Hoff factor, $i = \frac{(M_2)_{cal}}{(M_2)_{obs}}$

$$= \frac{78 \text{ g mol}^{-1}}{72.54 \text{ g mol}^{-1}}$$

$= 1.0753$

Let α be the degree of dissociation of CH_2FCOOH.

$$CH_2FCOOH \leftrightarrow CH_2FCCO^- + H^+$$

Initial conc.	C mol L^{-1}	0	0	
At equilibrium	$C(1 - \alpha)$	$C\alpha$	$C\alpha$	Total = $C(1 + \alpha)$

$\therefore i = \frac{C(1+\alpha)}{C}$

$\Rightarrow i = 1 + \alpha$

$\Rightarrow \alpha = i - 1$

$= 1.0753 - 1$

$= 0.0753$

Now, the value of K_a is given as :

$$K_a = \frac{[CH_2FCOO^-][H^+]}{[CH_2FCOOH]}$$

$$= \frac{C\alpha.C\alpha}{C(1-\alpha)}$$

$$= \frac{C\alpha^2}{1-\alpha}$$

Taking the volume of the solution as 500 mL, we have the concentration:

$$C = \frac{\frac{19.5}{78}}{500} \times 1000M$$

$= 0.5$ M

Therefore, $K_a = \frac{C\alpha^2}{1-\alpha}$

$$= \frac{0.5 \times (0.0753)^2}{1 - 0.0753}$$

$$= \frac{0.5 \times 0.00567}{0.9247}$$

$= 0.00307$ (approximately)

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

34. Vapour pressure of water at 293 Kis 17.535 mm Hg. Calculate the vapour pressure of water at 293 Kwhen 25 g of glucose is dissolved in 450 g of water.

34. Vapour pressure of water, $P_A^0 = 17.535$ mm Hg

$W_B = 25$ g of glucose

$W_A = 450$g of water

Molar mass of water, $H_2O = 1 + 1 + 16 = 18$ g mol^{-1}

Molar mass of glucose, $C_6H_{12}O_6 = (12 \times 6) + (1 \times 12) + (16 \times 6) = 180$ g mol^{-1}

Using Raoult's law for solution of non-volatile solute,

$$\frac{P_A^0 - P_A}{P_A^0} = x_B \rightarrow \underline{\text{Equation 1}}$$

where χ_B is the mole fraction of the solute

$$\rightarrow x_B = \frac{W_B}{M_B} \times \frac{M_A}{W_A} = \frac{25}{180} \times \frac{18}{450}$$

$$\therefore x_B = \frac{1}{1800}$$

Substituting the value of x_B in equation 1, we get,

$$\rightarrow \frac{P_A^0 - P_A}{P_A^0} = x_B$$

$$1 - \frac{P_A}{P_A^0} = \frac{1}{180}$$

$$1 - \frac{P_A}{17.535} = \frac{1}{180}$$

$$\frac{P_A}{17.535} = \frac{179}{180}$$

$$P_A = \frac{179 \times 17.535}{180}$$

$\therefore$ P_A = 17.437 mm Hg

Answer- Thus, the vapour pressure of water at 293 K at the given conditions is 17.437 mm Hg

35. Henry's law constant for the molality of methane in benzene at 298 Kis 4.27×10^5 mm Hg. Calculate the solubility of methane in benzene at 298 Kunder 760 mm Hg.

35. Here, p = 760 mm Hg $k_H = 4.27 \times 10^5$ mm Hg

According to Henry's law, $p = kHx$

$$\Rightarrow x = \frac{p}{k_H} = \frac{760 \text{ mm Hg}}{4.27 \times 10^5 \text{ mm Hg}}$$

$= 177.99 \times 10^{-5}$

$= 178 \times 10^{-5}$ (approximately)

Hence, the mole fraction of methane in benzene is 178×10^{-5}.

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.

36. Given-

Mass of liquid A, W_A = 100g, Molar mass, M_A = 140 g mol^{-1}

Mass of liquid B, W_B = 1000 g, Molar mass, M_B = 180 g mol^{-1}

Using the formula below calculate the no. of moles in liquid A and B.

$$\rightarrow \text{Number of moles} = \frac{\text{Mass}}{\text{Molar mass}}$$

Number of moles of liquid A, M_A = 100/140 = 0.714 mol^{-1}

Number of moles of liquid B, M_B =1000/ 180 = 5.556 mol^{-1}

Using the formula,

mole fraction of a liquid = $\frac{\text{No.of moles of the liquid}}{\text{Total no. of moles}}$

we calculate the mole fraction of liquids A and B.

$\rightarrow$ Mole fraction of A, $x_A = x_A = \frac{0.714}{(0.714 + 5.556)}$

$\therefore x_A = 0.114$

$\rightarrow$ Mole fraction of B, $x_B = 1 - x_A = 1 - 0.114$

$\therefore x_B = 0.886$

Vapour pressure of pure liquid B, $P_B^0 = 500$ torr (given)

According to Henry`s law,

$\rightarrow P_B = P_B^0 \times x_B$

$$P_B = 500 \times 0.886$$

$$\therefore P_B = 443 \text{ torr}$$

Having given the total vapour pressure of the solution, Ptotal = 475 torr,

$\rightarrow P_{total} = P_A + P_B$

$$P_A = P_{total} - P_B$$

$= 475 - 443$

$$\therefore P_A = 32 \text{ torr}$$

Using Henry`s law again to get the vapour pressure of pure liquid A,

$\rightarrow P_A = P_A^0 \times x_A$

$P_A^0 = \frac{32}{0.114}$

$\therefore P_A^0 = 280.7$ torr

Answer-Thus, the vapour pressure of pure liquid A = 280.7 torr and vapour pressure of liquid A in the solution = 32 torr

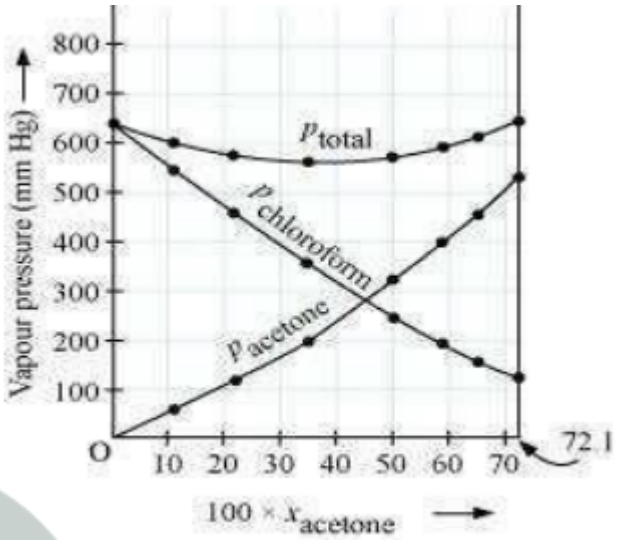
37. Vapour pressure of pure acetone and chloroform at 328 K are 741.8 mm Hg and 632.8 mm Hg respectively. Assuming that they form ideal solution over the entire range of composition, plot ptotal' pchloroform' and pacetone as a function of xacetone. The experimental data observed for different compositions of mixture is.

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

37. From the question, we have the following data

$100 \times X_{acetone}$	0	11.8	23.4	36.0	50.8	58.2	64.5	72.1
$P_{acetone}$/mm Hg	0	54.9	110.1	202.4	322.7	405.9	454.1	521.1

$P_{chloroform}$/mm Hg	632.8	548.1	469.4	359.7	257.7	193.6	161.2	120.7
P_{tota} (mm Hg)	632.8	603.0	579.5	562.1	580.4	599.5	615.3	641.8



It can be observed from the graph that the plot for the p_{total} of the solution curves downwards. Therefore, the solution shows negative deviation from the ideal behaviour.

38. Benzene and toluene form ideal solution over the entire range of composition. The vapour pressure of pure benzene and naphthalene at 300 Kare 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.

38. p_A^0 of benzene = 50.71 mm Hg

p_A^0 of naphthalene = 32.06 mm Hg

Using the formula of lowering vapour pressure to calculate mole fraction of benzene and naphthalene in solution,

$$\rightarrow x_{benzene} = \frac{n_{benzene}}{n_{benzene} + n_{naphthalene}}$$

$$\rightarrow x_{benzene} = \frac{\frac{80}{78}}{\frac{80}{78} + \frac{100}{128}} = \frac{80 \times 128}{12240 + 7800}$$

$$\therefore z_{benzene} = 0.567$$

Thus, $\rightarrow x_{naphthalene} = 1 - 0.567$

$\therefore x_{naphthalene} = 0.433$

Using formula for vapour pressure,

$\rightarrow P_A = P_A^0 \times x_A$

$p_{benzene} = 0.567 \times 50.71$

$\therefore\ p_{benzene} = 28.75$ mm Hg

$\therefore\ p_{napthalene} = 0.433 \times 32.06$

$\therefore\ p_{napthalene} = 13.88$ mm Hg

Mole fraction of benzene in vapour phase is calculated by,

$$\rightarrow x_{benzene} = \frac{n_{benzene}}{n_{benzene} + n_{naphthalene}}$$

$$\rightarrow x_{benzene} = \frac{28.75}{28.75 + 13.88}$$

Answer- Thus, mole fraction of benzene in vapour phase is 0.6744

39. The air is a mixture of a number of gases. The major components are oxygen and nitrogen with approximate proportion of 20% is to 79% by volume at 298
K. The water is in equilibrium with air at a pressure of 10 atm. At 298 Kif 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.

39. Percentage of oxygen (O_2) in air = 20 %

Percentage of nitrogen (N2) in air = 79%

Also, it is given that water is in equilibrium with air at a total pressure of 10 atm, i.e., (10 × 760) mm Hg = 7600 mm Hg

Therefore,

Partial pressure of oxygen, $p_{o_2} = \frac{20}{100} \times 7600$ mm Hg = 1520 mm Hg

Partial pressure of nitrogen, $P_{N_2} = \frac{79}{100} \times 7600$ mm Hg = 6004 mm Hg

Now, according to Henry's law: $p = K_H.x$

lllkaaa

For oxygen: $P_{O_2} = K_H.x_{O_2}$

$$\Rightarrow x_{O_2} = \frac{p_{O_2}}{K_H} = \frac{1520 \text{ mm Hg}}{3.30 \times 10^7 \text{ mm Hg}} = 4.61 \times 10^{-5} \qquad [\because K_H = 3.30 \times 10^7 \text{ mm Hg}]$$

For nitrogen : $P_{N_2} = K_H.x_{N_2}$

$$\Rightarrow x_{N_2} = \frac{p_{N_2}}{K_H} = \frac{6004 \text{ mm Hg}}{6.51 \times 10^7 \text{ mm Hg}} = 9.22 \times 10^{-5}$$

Hence, the mole fractions of oxygen and nitrogen in water are 4.61×10^{-5} and 9.22×10^{-5} respectively.

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

40. Given-

Vant Hoff's factor, I = 2.47

osmotic pressure, π = 0.75 atm

Volume of solution = 2.5L.

To determine the amount of $CaCl_2$, we use vant Hoff's equation for dilute solutions, given as,

$\pi V = inRT$

where, n is the number of moles of solute, R is solution constant which is equal to the gas constant and T is the absolute temperature.

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

$$0.75\ \text{atm} \times 2.5\text{L} = 2.47 \times \frac{W_B}{111} \times 0.082 \times 300\text{K}$$

where, the molecular mass of $CaCl_2$ is 111, t = 300 K (27°C + 273 K) and R=0.082,

$$W_B = \frac{0.75 \times 2.5 \times 111}{2.47 \times 24.6} = \frac{208.125}{60.762}$$

$$\therefore W_B = 3.425\text{g}$$

Answer- Hence, the amount of CaCl2 dissolved is 3.425g

41. Determine the osmotic pressure of a solution prepared by dissolving 25 mg of K_2SO_4 in 2 liter of water at 25° C, assuming that it is completely dissociated.

41. When K_2SO_4 is dissolved in water, K^+ and SO_4^{2-} ions are produced

$$K_2SO_4 \rightarrow 2K^+ + SO_4^{2-}$$

Total number of ions produced = 3, therefore i =3

Given, w = 25 mg = 0.025 g, V = 2 L, T = 25ºC = (25 + 273) K = 298 K

Also, we know that:

R = 0.0821 L atm $K^{-1}mol^{-1}$ and M = (2 × 39) + (1 × 32) + (4 × 16) = 174 g mol^{-1}

Appling the following relation,

$$\pi = i\frac{n}{v}RT$$

$$= i\frac{w}{M}\frac{1}{v}RT$$

$$= 3 \times \frac{0.025}{175} \times \frac{1}{2} \times 0.0821 \times 298$$

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