Question 2.1:
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.

Answer

\[
\text{Mass percentage of } C_6H_6 = \frac{\text{Mass of } C_6H_6}{\text{Mass of } C_6H_6 + \text{Mass of } CCl_4} \times 100\%
\]

\[
= \frac{22}{22 + 122} \times 100\%
\]

\[= 15.28\%
\]

\[
\text{Mass percentage of } CCl_4 = \frac{\text{Mass of } CCl_4}{\text{Mass of } C_6H_6 + \text{Mass of } CCl_4} \times 100\%
\]

\[
= \frac{122}{22 + 122} \times 100\%
\]

\[= 84.72\%
\]

Alternatively,

\[
\text{Mass percentage of } CCl_4 = (100 - 15.28)\%
\]

\[= 84.72\%
\]

Question 2.2:
Calculate the mole fraction of benzene in solution containing 30% by mass in carbon tetrachloride.

Answer

Let the total mass of the solution be 100 g and the mass of benzene be 30 g.

\[
\text{Mass of carbon tetrachloride} = (100 - 30)\text{g}
\]

\[= 70 \text{g}
\]

Molar mass of benzene \((C_6H_6)\) = \((6 \times 12 + 6 \times 1) \text{ g mol}^{-1}\)

\[= 78 \text{ g mol}^{-1}\]
Number of moles of \( \text{C}_6\text{H}_6 \) = \( \frac{30}{78} \) mol

= 0.3846 mol

Molar mass of carbon tetrachloride (\( \text{CCl}_4 \)) = \( 1 \times 12 + 4 \times 355 \)

= 154 g mol\(^{-1}\)

Number of moles of \( \text{CCl}_4 \) = \( \frac{70}{154} \) mol

= 0.4545 mol

Thus, the mole fraction of \( \text{C}_6\text{H}_6 \) is given as:

\[
\text{Mole fraction of } \text{C}_6\text{H}_6 = \frac{0.3846}{0.3846 + 0.4545}
\]

= 0.458

**Question 2.3:**

Calculate the molarity of each of the following solutions:

(a) 30 g of \( \text{Co(NO}_3\text{)}_2.6\text{H}_2\text{O} \) in 4.3 L of solution

(b) 30 mL of 0.5 M \( \text{H}_2\text{SO}_4 \) diluted to 500 mL.

**Answer**

Molarity is given by:

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

(a) Molar mass of \( \text{Co(NO}_3\text{)}_2.6\text{H}_2\text{O} = 59 + 2 (14 + 3 \times 16) + 6 \times 18 \)

= 291 g mol\(^{-1}\)

\[
\text{Moles of Co (NO}_3\text{)}_2.6\text{H}_2\text{O} = \frac{30}{291} \text{ mol}
\]

= 0.103 mol

Therefore, molarity = \( \frac{0.103 \text{ mol}}{4.3 \text{ L}} \)

= 0.023 M

(b) Number of moles present in 1000 mL of 0.5 M \( \text{H}_2\text{SO}_4 \) = 0.5 mol
Number of moles present in 30 mL of 0.5 M H_2SO_4 = \frac{0.5 \times 30}{1000} \text{ mol} = 0.015 \text{ mol}

Therefore, molarity = \frac{0.015}{0.5} \text{ mol L}^{-1} = 0.03 \text{ M}

Question 2.4:
Calculate the mass of urea (NH_2CONH_2) required in making 2.5 kg of 0.25 molal aqueous solution.

Answer
Molar mass of urea (NH_2CONH_2) = 2(1 \times 14 + 2 \times 1) + 1 \times 12 + 1 \times 16 = 60 \text{ g mol}^{-1}

0.25 molar aqueous solution of urea means:
1000 g of water contains 0.25 mol = (0.25 \times 60)g of urea = 15 g of urea

That is,
(1000 + 15) g of solution contains 15 g of urea

\[ \frac{15 \times 2500}{1000 + 15} \text{ g} \]

Therefore, 2.5 kg (2500 g) of solution contains = 36.95 g = 37 g of urea (approximately)

Hence, mass of urea required = 37 g

Note: There is a slight variation in this answer and the one given in the NCERT textbook.

Question 2.5:
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}.

Answer
(a) Molar mass of KI = 39 + 127 = 166 g mol^{-1}

20% (mass/mass) aqueous solution of KI means 20 g of KI is present in 100 g of solution.
That is,

20 g of KI is present in \((100 − 20)\) g of water = 80 g of water

Therefore, molality of the solution

\[
\text{molality} = \frac{\text{Moles of KI}}{\text{Mass of water in kg}}
\]

\[
= \frac{20}{166} \text{ m}
\]

\[
= 0.12 \text{ m}
\]

\[
= 0.12 \text{ m (approximately)}
\]

(b) It is given that the density of the solution = 1.202 g mL\(^{-1}\)

∴ Volume of 100 g solution

\[
\text{Volume} = \frac{100 \text{ g}}{1.202 \text{ g mL}^{-1}}
\]

\[
= 83.19 \text{ mL}
\]

\[
= 83.19 \times 10^{-3} \text{ L}
\]

Therefore, molarity of the solution

\[
\text{molarity} = \frac{20}{166} \text{ mol}
\]

\[
= \frac{20}{166} \times \frac{10^{-3}}{83.19} \text{ L}
\]

\[
= 0.12 \text{ M}
\]

(c) Moles of KI

\[
= \frac{20}{166} = 0.12 \text{ mol}
\]

Moles of water

\[
= \frac{80}{18} = 4.44 \text{ mol}
\]

Therefore, mole fraction of KI

\[
\text{mole fraction of KI} = \frac{\text{Moles of KI}}{\text{Moles of KI} + \text{Moles of water}}
\]

\[
= \frac{0.12}{0.12 + 4.44}
\]

\[
= 0.0263
\]

Question 2.6:
H$_2$S, a toxic gas with rotten egg like smell, is used for the qualitative analysis. If the solubility of H$_2$S in water at STP is 0.195 m, calculate Henry’s law constant.

**Answer**

It is given that the solubility of H$_2$S in water at STP is 0.195 m, i.e., 0.195 mol of H$_2$S is dissolved in 1000 g of water.

\[
\text{Moles of water} = \frac{1000 \text{ g}}{18 \text{ g mol}^{-1}}
\]

\[
= 55.56 \text{ mol}
\]

\[
\therefore \text{Mole fraction of H}_2\text{S, } x = \frac{0.195}{0.195 + 55.56}
\]

\[
= 0.0035
\]

At STP, pressure ($p$) = 0.987 bar

According to Henry’s law:

\[
p = K_H x
\]

\[
\Rightarrow K_H = \frac{p}{x}
\]

\[
= \frac{0.987}{0.0035}\text{ bar}
\]

\[
= 282 \text{ bar}
\]

**Question 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.

**Answer**

Total amount of solute present in the mixture is given by,

\[
300 \times \frac{25}{100} + 400 \times \frac{40}{100}
\]

\[
= 75 + 160
\]

\[
= 235 \text{ g}
\]
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\%

Question 2.8:
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.

Answer
It is given that:

\( p_A^0 = 450 \) mm of Hg
\( p_B^0 = 700 \) mm of Hg
\( p_{\text{total}} = 600 \) mm of Hg

From Raoult’s law, we have:
\( P_A = p_A^0 x_A \)
\( P_B = p_B^0 x_B = p_B^0 (1 - x_A) \) Therefore, total pressure, \( P_{\text{total}} = P_A + P_B \)
\( \Rightarrow P_{\text{total}} = p_A^0 x_A + p_B^0 (1 - x_A) \)
\( \Rightarrow P_{\text{total}} = p_A^0 x_A + p_B^0 - p_B^0 x_A \)
\( \Rightarrow P_{\text{total}} = (p_A^0 - p_B^0) x_A + p_B^0 \)
\( \Rightarrow 600 = (450 - 700) x_A + 700 \)
\( \Rightarrow -100 = -250 x_A \)
\( \Rightarrow x_A = 0.4 \)

Therefore, \( x_B = 1 - x_A \)
= 1 − 0.4
= 0.6
Now, \( p_A = p_A^0 x_A \)
\[ = 450 \times 0.4 \]
= 180 mm of Hg

\( p_B = p_B^0 x_B \)
\[ = 700 \times 0.6 \]
= 420 mm of Hg

Now, in the vapour phase:

Mole fraction of liquid A
\[
= \frac{p_A}{p_A + p_B}
\]
\[ = \frac{180}{180 + 420} \]
\[ = \frac{180}{600} \]
= 0.30

And, mole fraction of liquid B = 1 − 0.30
= 0.70

**Question 2.9:**

Vapour pressure of pure water at 298 K is 23.8 mm Hg. 50 g of urea \((\text{NH}_2\text{CONH}_2)\) is dissolved in 850 g of water. Calculate the vapour pressure of water for this solution and its relative lowering.

**Answer**

It is given that vapour pressure of water, \( p_1^0 = 23.8 \) mm of Hg

Weight of water taken, \( w_1 = 850 \) g

Weight of urea taken, \( w_2 = 50 \) g

Molecular weight of water, \( M_1 = 18 \) g mol\(^{-1}\)

Molecular weight of urea, \( M_2 = 60 \) g mol\(^{-1}\)

Now, we have to calculate vapour pressure of water in the solution. We take vapour pressure as \( p_1 \).

Now, from Raoult’s law, we have:
Hence, the vapour pressure of water in the given solution is 23.4 mm of Hg and its relative lowering is 0.0173.

Question 2.10:
Boiling point of water at 750 mm Hg is 99.63°C. How much sucrose is to be added to 500 g of water such that it boils at 100°C. Molal elevation constant for water is 0.52 K kg mol\(^{-1}\).

Answer
Here, elevation of boiling point \(\Delta T_b = (100 + 273) - (99.63 + 273)\)
\(= 0.37 \text{ K}\)

Mass of water, \(w_1 = 500 \text{ g}\)

Molar mass of sucrose (C\(_{12}\)H\(_{22}\)O\(_{11}\)), \(M_2 = 11 \times 12 + 22 \times 1 + 11 \times 16\)
\(= 342 \text{ g mol}^{-1}\)

Molal elevation constant, \(K_b = 0.52 \text{ K kg mol}^{-1}\)

We know that:
Hence, 121.67 g of sucrose is to be added.

**Note:** There is a slight variation in this answer and the one given in the NCERT textbook.

**Question 2.11:**

Calculate the mass of ascorbic acid (Vitamin C, C₆H₈O₆) to be dissolved in 75 g of acetic acid to lower its melting point by 1.5°C. \( K_f = 3.9 \text{ K kg mol}^{-1} \).

**Answer**

Mass of acetic acid, \( w_1 = 75 \text{ g} \)

Molar mass of ascorbic acid (C₆H₈O₆), \( M_2 = 6 \times 12 + 8 \times 1 + 6 \times 16 \)

\( = 176 \text{ g mol}^{-1} \)

Lowering of melting point, \( \Delta T_f = 1.5 \text{ K} \)

We know that:

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

\[
\Rightarrow w_2 = \frac{\Delta T_f \times M_2 \times w_1}{K_f \times 1000}
\]

\[
= \frac{1.5 \times 176 \times 75}{3.9 \times 1000}
\]

\( = 5.08 \text{ g (approx)} \)

Hence, 5.08 g of ascorbic acid is needed to be dissolved.

**Note:** There is a slight variation in this answer and the one given in the NCERT textbook.
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°C.

**Answer**

It is given that:

Volume of water, \( V = 450 \text{ mL} = 0.45 \text{ L} \)

Temperature, \( T = (37 + 273) \text{ K} = 310 \text{ K} \)

Number of moles of the polymer, \( n = \frac{1}{185000} \text{ mol} \)

We know that:

\[
\pi = \frac{nRT}{V}
\]

\[
= \frac{1}{185000} \text{ mol} \times \frac{1}{0.45 \text{ L}} \times 8.314 \times 10^3 \text{ Pa L K}^{-1} \text{ mol}^{-1} \times 310 \text{ K}
\]

= 30.98 Pa

= 31 Pa (approximately)

**Question 2.13:**

The partial pressure of ethane over a solution containing \( 6.56 \times 10^{-3} \text{ g of ethane} \) is 1 bar. If the solution contains \( 5.00 \times 10^{-2} \text{ g of ethane} \), then what shall be the partial pressure of the gas?

**Answer**

Molar mass of ethane (\( \text{C}_2\text{H}_6 \)) = \( 2 \times 12 + 6 \times 1 \)

= 30 g mol\(^{-1}\)

\[
\Rightarrow \text{Number of moles present in } 6.56 \times 10^{-2} \text{ g of ethane } = \frac{6.56 \times 10^{-2}}{30} \text{ mol}
\]

= 2.187 \times 10^{-3} \text{ mol}

Let the number of moles of the solvent be \( x \).

According to Henry’s law,

\[ p = K_Hx \]

\[
\Rightarrow 1 \text{ bar} = K_H \cdot \frac{2.187 \times 10^{-3}}{2.187 \times 10^{-3} + x}
\]
Number of moles present in $5.00 \times 10^{-2} \text{ g of ethane}$

$= 1.67 \times 10^{-3} \text{ mol}$

According to Henry’s law,

$p = K_H x$

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

$= \frac{x}{2.187 \times 10^{-3}} \times \frac{1.67 \times 10^{-3}}{x}$ (Since, $x \gg 1.67 \times 10^{-3}$)

$= 0.764 \text{ bar}$

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

**Question 2.14:**

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?

**Answer**

According to Raoult’s law, the partial vapour pressure of each volatile component in any solution is directly proportional to its mole fraction. The solutions which obey Raoult’s law over the entire range of concentration are known as ideal solutions. The solutions that do not obey Raoult’s law (non-ideal solutions) have vapour pressures either higher or lower than that predicted by Raoult’s law. If the vapour pressure is higher, then the solution is said to exhibit positive deviation, and if it is lower, then the solution is said to exhibit negative deviation from Raoult’s law.
Vapour pressure of a two-component solution showing positive deviation from Raoult’s law

In the case of an ideal solution, the enthalpy of the mixing of the pure components for forming the solution is zero.

$$\Delta_{\text{sol}} H = 0$$

In the case of solutions showing positive deviations, absorption of heat takes place.

$$\therefore \Delta_{\text{sol}} H = \text{Positive}$$

In the case of solutions showing negative deviations, evolution of heat takes place.

$$\therefore \Delta_{\text{sol}} H = \text{Negative}$$

Question 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?

Answer
Here,
Vapour pressure of the solution at normal boiling point \( (p_2) = 1.004 \) bar

Vapour pressure of pure water at normal boiling point \( (p_1^0) = 1.013 \) bar

Mass of solute, \( (w_2) = 2 \) g

Mass of solvent (water), \( (w_1) = 98 \) g

Molar mass of solvent (water), \( (M_1) = 18 \) g mol\(^{-1}\)

According to Raoult’s law,

\[
\frac{p_1^0 - p_1}{p_1^0} = \frac{w_2 	imes M_1}{M_2 	imes w_1}
\]

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

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

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

\[
= 41.35 \text{ g mol}^{-1}
\]

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

**Question 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?

**Answer**

Vapour pressure of heptane \( (p_1^0) = 105.2 \) kPa

Vapour pressure of octane \( (p_2^0) = 46.8 \) kPa

We know that,

Molar mass of heptane \( (C_7H_{16}) = 7 \times 12 + 16 \times 1 \)

\[
= 100 \text{ g mol}^{-1}
\]

\[
\therefore \text{Number of moles of heptane} = \frac{26}{100} \text{ mol}
\]

\[
= 0.26 \text{ mol}
\]
Molar mass of octane (C\textsubscript{8}H\textsubscript{18}) = 8 \times 12 + 18 \times 1 \\
= 114 \text{ g mol}^{-1} \\
\therefore \text{Number of moles of octane} = \frac{35}{114} \text{ mol} \\
= 0.31 \text{ mol} \\
Mole fraction of heptane, \\
\begin{align*}
x_1 &= \frac{0.26}{0.26 + 0.31} \\
&= 0.456 \\
\end{align*} \\
And, mole fraction of octane, \\
\begin{align*}
x_2 &= 1 - 0.456 \\
&= 0.544 \\
\end{align*} \\
Now, partial pressure of heptane, \\
\begin{align*}
p_1 &= x_1 p_1^0 \\
&= 0.456 \times 105.2 \\
&= 47.97 \text{ kPa} \\
\end{align*} \\
Partial pressure of octane, \\
\begin{align*}
p_2 &= x_2 p_2^0 \\
&= 0.544 \times 46.8 \\
&= 25.46 \text{ kPa} \\
\end{align*} \\
Hence, vapour pressure of solution, \\
\begin{align*}
p_{\text{total}} &= p_1 + p_2 \\
&= 47.97 + 25.46 \\
&= 73.43 \text{ kPa} \\
\end{align*} \\

**Question 2.17:** 

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. 

**Answer** 

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\(^{-1}\) 

\begin{align*}
\therefore \text{Number of moles present in 1000 g of water} &= \frac{1000}{18} \\
&= 55.56 \text{ mol} \\
\end{align*} 

Therefore, mole fraction of the solute in the solution is
It is given that,

Vapour pressure of water, \(p_1^0 = 12.3\) kPa

Applying the relation,

\[
\frac{p_1^0 - p_1}{p_1^0} = x_2
\]

\[
\Rightarrow \frac{12.3 - p_1}{12.3} = 0.0177
\]

\[
\Rightarrow p_1 = 12.0823
\]

\[
= 12.08\text{ kPa (approximately)}
\]

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

**Question 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%.

**Answer**

Let the vapour pressure of pure octane be \(p_1^0\).

Then, the vapour pressure of the octane after dissolving the non-volatile solute is

\[
\frac{80}{100} p_1^0 = 0.8 p_1^0.
\]

Molar mass of solute, \(M_2 = 40\) g mol\(^{-1}\)

Mass of octane, \(w_1 = 114\) g

Molar mass of octane, \((C_8H_{18})\), \(M_1 = 8 \times 12 + 18 \times 1\)

\[
= 114\text{ g mol}^{-1}
\]

Applying the relation,
Hence, the required mass of the solute is 8 g.

Question 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.

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

\[
\frac{P_i^0 - P_i}{P_i^0} = \frac{w_2 \times M_1}{M_2 \times w_i}
\]

\[
\Rightarrow P_i^0 - 0.8 P_i^0 = \frac{w_2 \times 114}{40 \times 114}
\]

\[
\Rightarrow \frac{0.2 P_i^0}{P_i^0} = \frac{w_2}{40}
\]

\[
\Rightarrow 0.2 = \frac{w_2}{40}
\]

\[
\Rightarrow w_2 = 8 \text{ g}
\]

Hence, the required mass of the solute is 8 g.

(ii) 

\[
\frac{n_1}{n_2} = \frac{90 \text{ g}}{18 \text{ g mol}^{-1}} = 5 \text{ mol}
\]

\[
\frac{n_2}{n_3} = \frac{30 \text{ g}}{M \text{ mol}^{-1}} = \frac{30}{M} \text{ mol}
\]

And, the no. of moles of solute,

\[
p_i = 2.8 \text{ kPa}
\]

Applying the relation:
\[ \frac{P_1^0 - P_1}{P_1^0} = \frac{n_2}{n_1 + n_2} \]

\[ \Rightarrow \frac{P_1^0 - 2.8}{P_1^0} = \frac{30}{5 + \frac{30}{M}} \]

\[ \Rightarrow 1 - \frac{2.8}{P_1^0} = \frac{30}{5M + 30} \]

\[ \Rightarrow 1 - \frac{2.8}{P_1^0} = \frac{30}{5M + 30} \]

\[ \Rightarrow \frac{2.8}{P_1^0} = 1 - \frac{30}{5M + 30} \]

\[ \Rightarrow \frac{2.8}{P_1^0} = \frac{5M + 30 - 30}{5M + 30} \]

\[ \Rightarrow \frac{2.8}{P_1^0} = \frac{5M}{5M + 30} \]

\[ \Rightarrow \frac{P_1^0}{2.8} = \frac{5M + 30}{5M} \quad (i) \]

After the addition of 18 g of water:

\[ n_0 = \frac{90 + 18 g}{18} = 6 \text{ mol} \]

\[ P_1 = 2.9 \text{ kPa} \]

Again, applying the relation:
\[
\frac{P_1^0 - P_1}{P_1^0} = \frac{n_2}{n_1 + n_2}
\]

\[
\Rightarrow \frac{P_1^0 - 2.9}{P_1^0} = \frac{\frac{30}{M}}{6 + \frac{30}{M}}
\]

\[
\Rightarrow 1 - \frac{2.9}{P_1^0} = \frac{\frac{30}{M}}{6M + 30}
\]

\[
\Rightarrow 1 - \frac{2.9}{P_1^0} = \frac{30}{6M + 30}
\]

\[
\Rightarrow \frac{2.9}{P_1^0} = 1 - \frac{30}{6M + 30}
\]

\[
\Rightarrow \frac{2.9}{P_1^0} = \frac{6M + 30 - 30}{6M + 30}
\]

\[
\Rightarrow \frac{2.9}{P_1^0} = \frac{6M}{6M + 30}
\]

\[
\Rightarrow \frac{P_1^0}{2.9} = \frac{6M + 30}{6M} \quad (ii)
\]

Dividing equation \((i)\) by \((ii)\), we have:
Therefore, the molar mass of the solute is 23 g mol\(^{-1}\).

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

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

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

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

\[
\Rightarrow 87M + 435 = 84M + 504
\]

\[
\Rightarrow 3M = 69
\]

\[
\Rightarrow M = 23 \text{ u}
\]

Hence, the molar mass of the solute is 23 g mol\(^{-1}\).

Question 2.20:

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.

Answer

Here, \(\Delta T_f = (273.15 - 271) \text{ K}\)

\(= 2.15 \text{ K}\)

Molar mass of sugar (C\(_{12}\)H\(_{22}\)O\(_{11}\)) = 12 \times 12 + 22 \times 1 + 11 \times 16

\(= 342 \text{ g mol}^{-1}\)

5% solution (by mass) of cane sugar in water means 5 g of cane sugar is present in (100 - 5) g = 95 g of water.
Now, number of moles of cane sugar = \( \frac{5}{342} \) mol
= 0.0146 mol

Therefore, molality of the solution, 
= 0.1537 mol kg\(^{-1}\)
Applying the relation,
\[ \Delta T_f = K_f \times m \]
\[ \Rightarrow K_f = \frac{\Delta T_f}{m} \]
\[ = \frac{2.15 K}{0.1537 \text{ mol kg}^{-1}} \]
= 13.99 K kg\(^{-1}\)
Molar of glucose (C\(_6\)H\(_{12}\)O\(_6\)) = 6 \times 12 + 12 \times 1 + 6 \times 16
= 180 g mol\(^{-1}\)
5% glucose in water means 5 g of glucose is present in (100 − 5) g = 95 g of water.

\[ \text{Number of moles of glucose} = \frac{5}{180} \text{ mol} \]
= 0.0278 mol

Therefore, molality of the solution, 
= 0.2926 mol kg\(^{-1}\)
Applying the relation,
\[ \Delta T_f = K_f \times m \]
= 13.99 K kg\(^{-1}\) \times 0.2926 mol kg\(^{-1}\)
= 4.09 K (approximately)
Hence, the freezing point of 5% glucose solution is (273.15 − 4.09) K= 269.06 K.

**Question 2.21:**
Two elements A and B form compounds having formula AB\(_2\) and AB\(_4\). When dissolved in 20 g of benzene (C\(_6\)H\(_6\)), 1 g of AB\(_2\) lowers the freezing point by 2.3 K whereas 1.0 g of
AB₄ 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.

Answer
We know that,
\[ M_2 = \frac{1000 \times w_2 \times k_f}{\Delta T_f \times w_1} \]
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 AB₂ and AB₄ 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:
\[ x + 2y = 110.87 \quad (i) \]
\[ x + 4y = 196.15 \quad (ii) \]

Subtracting equation (i) from (ii), we have
\[ 2y = 85.28 \]
\[ \Rightarrow y = 42.64 \]

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.

Question 2.22:
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?

Answer
Here,
\[ T = 300 \text{ K} \]
\[ n = 1.52 \text{ bar} \]
\[ R = 0.083 \text{ bar L K}^{-1} \text{ mol}^{-1} \]

Applying the relation,
\[ n = CRT \]
\[ \Rightarrow C = \frac{\pi}{RT} \]
\[ = \frac{1.52 \text{ bar}}{0.083 \text{ bar L K}^{-1} \text{ mol}^{-1} \times 300 \text{ K}} \]
\[ = 0.061 \text{ mol} \]

Since the volume of the solution is 1 L, the concentration of the solution would be 0.061 M.

Question 2.23:
Suggest the most important type of intermolecular attractive interaction in the following pairs.

(i) n%hexane and n%octane
(ii) I\textsubscript{2} and CCl\textsubscript{4}
(iii) NaClO\textsubscript{4} and water
(iv) methanol and acetone
(v) acetonitrile (CH\textsubscript{3}CN) and acetone (C\textsubscript{3}H\textsubscript{6}O).

Answer
(i) Van der Wall’s forces of attraction.
(ii) Van der Wall’s forces of attraction.
(iii) Ion-dipole interaction.
(iv) Dipole-dipole interaction.
(v) Dipole-dipole interaction.

Question 2.24:
Based on solute-solvent interactions, arrange the following in order of increasing solubility in n-octane and explain. Cyclohexane, KCl, CH\textsubscript{3}OH, CH\textsubscript{3}CN.

Answer
$n$-octane is a non-polar solvent. Therefore, the solubility of a non-polar solute is more than that of a polar solute in the $n$-octane.

The order of increasing polarity is:
Cyclohexane $<$ CH$_3$CN $<$ CH$_3$OH $<$ KCl
Therefore, the order of increasing solubility is:
KCl $<$ CH$_3$OH $<$ CH$_3$CN $<$ Cyclohexane

**Question 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.

**Answer**

(i) Phenol (C$_6$H$_5$OH) has the polar group $-\text{OH}$ and non-polar group $-\text{C}_6\text{H}_5$. Thus, phenol is partially soluble in water.

(ii) Toluene (C$_6$H$_5$−CH$_3$) has no polar groups. Thus, toluene is insoluble in water.

(iii) Formic acid (HCOOH) has the polar group $-\text{OH}$ and can form H−bond with water. Thus, formic acid is highly soluble in water.

(iv) Ethylene glycol has polar $-\text{OH}$ group and can form H−bond. Thus, it is highly soluble in water.

(v) Chloroform is insoluble in water.

(vi) Pentanol (C$_5$H$_{11}$OH) has polar $-\text{OH}$ group, but it also contains a very bulky non-polar $-\text{C}_5\text{H}_{11}$ group. Thus, pentanol is partially soluble in water.

**Question 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 molality of Na$^+$ ions in the lake.

**Answer**

Number of moles present in 92 g of Na$^+$ ions = $\frac{92 \text{ g}}{23 \text{ g mol}^{-1}} = 4 \text{ mol}$
Therefore, molality of Na\(^+\) ions in the lake = \(4 \text{ m}\)

**Question 2.27:**

If the solubility product of CuS is \(6 \times 10^{-16}\), calculate the maximum molarity of CuS in aqueous solution.

**Answer**

Solubility product of CuS, \(K_{sp} = 6 \times 10^{-16}\)

Let \(s\) be the solubility of CuS in mol L\(^{-1}\).

\[
\text{CuS} \rightleftharpoons \text{Cu}^{2+} + \text{S}^{2-}
\]

\[\begin{align*}
\text{s} & \quad s \\
\end{align*}\]

Now,

\[
K_{sp} = [\text{Cu}^{2+}][\text{S}^{2-}]
\]

\[
= s \times s \\
= s^2
\]

Then, we have,

\[
K_{sp} = s^2 = 6 \times 10^{-16}
\]

\[
\Rightarrow s = \sqrt{6 \times 10^{-16}}
\]

\[
= 2.45 \times 10^{-8} \text{ mol L}^{-1}
\]

Hence, the maximum molarity of CuS in an aqueous solution is \(2.45 \times 10^{-8} \text{ mol L}^{-1}\).

**Question 2.28:**

Calculate the mass percentage of aspirin (C\(_9\)H\(_8\)O\(_4\)) in acetonitrile (CH\(_3\)CN) when 6.5 g of C\(_9\)H\(_8\)O\(_4\) is dissolved in 450 g of CH\(_3\)CN.

**Answer**

6.5 g of C\(_9\)H\(_8\)O\(_4\) is dissolved in 450 g of CH\(_3\)CN.

Then, total mass of the solution = (6.5 + 450) g

= 456.5 g

Therefore, mass percentage of C\(_9\)H\(_8\)O\(_4\)

\[
= \frac{6.5}{456.5} \times 100\%
\]

= 1.424%
Question 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 $1.5 \times 10^{-3}$ m aqueous solution required for the above dose.

Answer

The molar mass of nalorphene $(C_{19}H_{21}NO_{3})$ is given as:

$19 \times 12 + 21 \times 1 + 1 \times 14 + 3 \times 16 = 311 \text{ g mol}^{-1}$

In $1.5 \times 10^{-3}$ m aqueous solution of nalorphene,

$1 \text{ kg (1000 g) of water contains } 1.5 \times 10^{-3} \text{ mol} = 1.5 \times 10^{-3} \times 311 \text{ g}$

$= 0.4665 \text{ g}$

Therefore, total mass of the solution $= (1000 + 0.4665) \text{ g}$

$= 1000.4665 \text{ g}$

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:

$\frac{1000.4665 \times 1.5 \times 10^{-3}}{0.4665} \text{ g}$

$= 3.22 \text{ g}$

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

Note: There is a slight variation in this answer and the one given in the NCERT textbook.

Question 2.30:
Calculate the amount of benzoic acid (C_{6}H_{5}COOH) required for preparing 250 mL of 0.15 M solution in methanol.

Answer

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 (C₆H₅COOH) = 7 × 12 + 6 × 1 + 2 × 16
= 122 g mol⁻¹
Hence, required benzoic acid = 0.0375 mol × 122 g mol⁻¹
= 4.575 g

Question 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.
Answer

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

Question 2.32:
Calculate the depression in the freezing point of water when 10 g of CH₃CH₂CHClCOOH is added to 250 g of water. \( K_a = 1.4 \times 10^{-3} \), \( K_f = 1.86 \) K kg mol⁻¹.
Answer
Molar mass of \( CH₃CH₂CHClCOOH \) = 15 + 14 + 35.5 + 12 + 16 + 16 + 1
= 122.5 g mol⁻¹
\( CH₃CH₂CHClCOOH = \frac{10 \text{ g}}{122.5 \text{ g mol}^{-1}} \)
∴ No. of moles present in 10 g of
= 0.0816 mol
It is given that 10 g of $\text{CH}_3\text{CH}_2\text{CHClCOOH}$ is added to 250 g of water.

\[ \text{Molality of the solution,} \quad m = \frac{0.0186}{250} \times 1000 \]

\[ = 0.3264 \text{ mol kg}^{-1} \]

Let $\alpha$ be the degree of dissociation of $\text{CH}_3\text{CH}_2\text{CHClCOOH}$.

$\text{CH}_3\text{CH}_2\text{CHClCOOH}$ undergoes dissociation according to the following equation:

\[ \text{CH}_3\text{CH}_2\text{CHClCOOH} \leftrightarrow \text{CH}_3\text{CH}_2\text{CHClCOO}^- + \text{H}^+ \]

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

\[ \therefore K_a = \frac{C\alpha \cdot C\alpha}{C(1 - \alpha)} \]

\[ = \frac{C\alpha^2}{1 - \alpha} \]

Since $\alpha$ is very small with respect to 1, $1 - \alpha \approx 1$

\[ K_a = \frac{C\alpha^2}{1} \]

Now,

\[ \Rightarrow K_a = C\alpha^2 \]

\[ \Rightarrow \alpha = \sqrt{\frac{K_a}{C}} \]

\[ = \sqrt{\frac{1.4 \times 10^{-3}}{0.3264}} \quad \left( \therefore K_a = 1.4 \times 10^{-3} \right) \]

\[ = 0.0655 \]

Again,

\[ \text{CH}_3\text{CH}_2\text{CHClCOOH} \leftrightarrow \text{CH}_3\text{CH}_2\text{CHClCOO}^- + \text{H}^+ \]

Initial moles | 1 | 0 | 0
---|---|---|---
At equilibrium | 1$-\alpha$ | $\alpha$ | $\alpha$
Total moles of equilibrium = 1 − α + α + α
= 1 + α

\[ \therefore i = \frac{1 + \alpha}{1} \]

= 1 + α
= 1 + 0.0655
= 1.0655

Hence, the depression in the freezing point of water is given as:

\[ \Delta T_f = iK_f m \]

= 1.0655 \times 1.86 \text{ K kg mol}^{-1} \times 0.3264 \text{ mol kg}^{-1}

= 0.65 \text{ K}

**Question 2.33:**

19.5 g of CH₂FCOOH 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.

**Answer**

It is given that:

\[ w_1 = 500 \text{ g} \]

\[ w_2 = 19.5 \text{ g} \]

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

\[ \Delta T_f = 1 \text{ K} \]

We know that:

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

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

\[ = 72.54 \text{ g mol}^{-1} \]

Therefore, observed molar mass of CH₂FCOOH, \( M_2 \)_{obs} = 72.54 g mol
The calculated molar mass of $\text{CH}_2\text{FCOOH}$ is:

$$(M_2)_{\text{cal}} = 14 + 19 + 12 + 16 + 16 + 1 = 78 \text{ g mol}^{-1}$$

Therefore, van’t Hoff factor,

$$i = \frac{(M_2)_{\text{cal}}}{(M_2)_{\text{obs}}} = \frac{78 \text{ g mol}^{-1}}{72.54 \text{ g mol}^{-1}} = 1.0753$$

Let $\alpha$ be the degree of dissociation of $\text{CH}_2\text{FCOOH}$

$$\text{CH}_2\text{FCOOH} \leftrightarrow \text{CH}_2\text{FCOO}^- + \text{H}^+$$

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:

$$K_a = \frac{[\text{CH}_2\text{FCOO}^-][\text{H}^+]}{[\text{CH}_2\text{FCOOH}]}$$

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

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

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

\[ C = \frac{78}{500} \times 1000 \text{ M} \]

\[ = 0.5 \text{ M} \]

\[ K_v = \frac{C \alpha^2}{1 - \alpha} \]

Therefore,

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

\[ = \frac{0.5 \times 0.00567}{0.9247} \]

\[ = 0.00307 \text{ (approximately)} \]

\[ = 3.07 \times 10^{-3} \]

**Question 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.

**Answer**

Vapour pressure of water, \( P_1^0 = 17.535 \text{ mm Hg} \)

Mass of glucose, \( w_2 = 25 \text{ g} \)

Mass of water, \( w_1 = 450 \text{ g} \)

We know that,

Molar mass of glucose (\( C_6H_{12}O_6 \)), \( M_2 = 6 \times 12 + 12 \times 1 + 6 \times 16 \)

\[ = 180 \text{ g mol}^{-1} \]

Molar mass of water, \( M_1 = 18 \text{ g mol}^{-1} \)

Then, number of moles of glucose,

\[ n_1 = \frac{25}{180 \text{ g mol}^{-1}} \]

\[ = 0.139 \text{ mol} \]
And, number of moles of water,
= 25 mol

We know that,
\[
\frac{p^0_1 - p_1}{p^0_1} = \frac{n_1}{n_2 + n_1}
\]
\[
\Rightarrow \frac{17.535 - p_1}{17.535} = \frac{0.139}{0.139 + 25}
\]
\[
\Rightarrow 17.535 - p_1 = \frac{0.139 \times 17.535}{25.139}
\]
\[
\Rightarrow 17.535 - p_1 = 0.097
\]
\[
p_1 = 17.44 \text{ mm of Hg}
\]

Hence, the vapour pressure of water is 17.44 mm of Hg.

**Question 2.35:**

Henry’s law constant for the molality of methane in benzene at 298 K is $4.27 \times 10^5$ mm Hg. Calculate the solubility of methane in benzene at 298 K under 760 mm Hg.

**Answer**

Here,

\[
p = 760 \text{ mm Hg}
\]

\[
k_H = 4.27 \times 10^5 \text{ mm Hg}
\]

According to Henry’s law,

\[
p = k_H x
\]

\[
\Rightarrow x = \frac{p}{k_H}
\]
\[
= \frac{760 \text{ mm Hg}}{4.27 \times 10^5 \text{ mm Hg}}
\]
\[
= 177.99 \times 10^{-5}
\]
\[
= 178 \times 10^{-5} \text{ (approximately)}
\]

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

**Question 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.

**Answer**

Number of moles of liquid A,
\[ n_A = \frac{100}{140} \text{ mol} \]
\[ = 0.714 \text{ mol} \]

Number of moles of liquid B,
\[ n_B = \frac{1000}{180} \text{ mol} \]
\[ = 5.556 \text{ mol} \]

Then, mole fraction of A,
\[ x_A = \frac{n_A}{n_A + n_B} \]
\[ = \frac{0.714}{0.714 + 5.556} \]
\[ = 0.114 \]

And, mole fraction of B, \( x_B = 1 - 0.114 \)
\[ = 0.886 \]

Vapour pressure of pure liquid B, \( p_B^0 = 500 \text{ torr} \)

Therefore, vapour pressure of liquid B in the solution,
\[ p_B = p_B^0 x_B \]
\[ = 500 \times 0.886 \]
\[ = 443 \text{ torr} \]

Total vapour pressure of the solution, \( p_{\text{total}} = 475 \text{ torr} \)

\[ \therefore \] Vapour pressure of liquid A in the solution,
\[ p_A = p_{\text{total}} - p_B \]
\[ = 475 - 443 \]
\[ = 32 \text{ torr} \]

Now,
\[ p_A = p_A^0 x_A \]
\[ \Rightarrow p_A^0 = \frac{P_A}{x_A} = \frac{32}{0.114} = 280.7 \text{ torr} \]

Hence, the vapour pressure of pure liquid A is 280.7 torr.

**Question 2.37:**

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 \( p_{\text{total}} \), \( p_{\text{chloroform}} \) and \( p_{\text{acetone}} \) as a function of \( x_{\text{acetone}} \). The experimental data observed for different compositions of mixture is.

<table>
<thead>
<tr>
<th>( 100 \times x_{\text{acetone}} )</th>
<th>0</th>
<th>11.8</th>
<th>23.4</th>
<th>36.0</th>
<th>50.8</th>
<th>58.2</th>
<th>64.5</th>
<th>72.1</th>
</tr>
</thead>
<tbody>
<tr>
<td>( p_{\text{acetone}} / \text{mm Hg} )</td>
<td>0</td>
<td>54.9</td>
<td>110.1</td>
<td>202.4</td>
<td>322.7</td>
<td>405.9</td>
<td>454.1</td>
<td>521.1</td>
</tr>
<tr>
<td>( p_{\text{chloroform}} / \text{mm Hg} )</td>
<td>632.8</td>
<td>548.1</td>
<td>469.4</td>
<td>359.7</td>
<td>257.7</td>
<td>193.6</td>
<td>161.2</td>
<td>120.7</td>
</tr>
</tbody>
</table>

**Answer**

From the question, we have the following data

<table>
<thead>
<tr>
<th>( 100 \times x_{\text{acetone}} )</th>
<th>0</th>
<th>11.8</th>
<th>23.4</th>
<th>36.0</th>
<th>50.8</th>
<th>58.2</th>
<th>64.5</th>
<th>72.1</th>
</tr>
</thead>
<tbody>
<tr>
<td>( p_{\text{acetone}} / \text{mm Hg} )</td>
<td>0</td>
<td>54.9</td>
<td>110.1</td>
<td>202.4</td>
<td>322.7</td>
<td>405.9</td>
<td>454.1</td>
<td>521.1</td>
</tr>
<tr>
<td>( p_{\text{chloroform}} / \text{mm Hg} )</td>
<td>632.8</td>
<td>548.1</td>
<td>469.4</td>
<td>359.7</td>
<td>257.7</td>
<td>193.6</td>
<td>161.2</td>
<td>120.7</td>
</tr>
<tr>
<td>( p_{\text{total}}(\text{mm Hg}) )</td>
<td>632.8</td>
<td>603.0</td>
<td>579.5</td>
<td>562.1</td>
<td>580.4</td>
<td>599.5</td>
<td>615.3</td>
<td>641.8</td>
</tr>
</tbody>
</table>
It can be observed from the graph that the plot for the $p_{\text{total}}$ of the solution curves downwards. Therefore, the solution shows negative deviation from the ideal behaviour.

**Question 2.38:**

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

**Answer**

Molar mass of benzene \( (C_6H_6) = 6 \times 12 + 6 \times 1 \)

= 78 g mol\(^{-1}\)

Molar mass of toluene \( (C_6H_5CH_3) = 7 \times 12 + 8 \times 1 \)

= 92 g mol\(^{-1}\)

Now, no. of moles present in 80 g of benzene

\[
\frac{80}{78} \text{ mol} = 1.026 \text{ mol}
\]

And, no. of moles present in 100 g of toluene

\[
\frac{100}{92} \text{ mol} = 1.087 \text{ mol}
\]

\[
\therefore \text{Mole fraction of benzene, } x_b = \frac{1.026}{1.026 + 1.087} = 0.486
\]

And, mole fraction of toluene, \( x_t = 1 - 0.486 = 0.514 \)
It is given that vapour pressure of pure benzene, \( p_b^0 = 50.71 \text{ mmHg} \)

And, vapour pressure of pure toluene, \( p_t^0 = 32.06 \text{ mmHg} \)

Therefore, partial vapour pressure of benzene, \( p_b = x_b \times p_b \)
\[ = 0.486 \times 50.71 \]
\[ = 24.645 \text{ mmHg} \]

And, partial vapour pressure of toluene, \( p_t = x_t \times p_t \)
\[ = 0.514 \times 32.06 \]
\[ = 16.479 \text{ mmHg} \]

Hence, mole fraction of benzene in vapour phase is given by:

\[
\frac{p_b}{p_b + p_t} = \frac{24.645}{24.645 + 16.479}
\]
\[ = \frac{24.645}{41.124} \]
\[ = 0.599 \]
\[ = 0.6 \]

**Question 2.39:**

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 K if the Henry’s law constants for oxygen and nitrogen are \( 3.30 \times 10^7 \text{ mm} \) and \( 6.51 \times 10^7 \text{ mm} \) respectively, calculate the composition of these gases in water.

**Answer**

Percentage of oxygen (O\(_2\)) in air = 20 %
Percentage of nitrogen (N\(_2\)) in air = 79%

Also, it is given that water is in equilibrium with air at a total pressure of 10 atm, that is, 
(10 \times 760) \text{ mm Hg} = 7600 \text{ mm Hg}
Therefore,

Partial pressure of oxygen,
\[ p_{O_2} = \frac{20}{100} \times 7600 \text{ mm Hg} \]
= 1520 mm Hg

Partial pressure of nitrogen,
\[ p_{N_2} = \frac{79}{100} \times 7600 \text{ mm Hg} \]
= 6004 mmHg

Now, according to Henry’s law:
\[ p = K_H \cdot x \]

For oxygen:
\[ p_{O_2} = K_H \cdot x_{O_2} \]
\[ \Rightarrow x_{O_2} = \frac{p_{O_2}}{K_H} \]
\[ = \frac{1520 \text{ mm Hg}}{3.30 \times 10^7 \text{ mm Hg}} \]
\[ = 4.61 \times 10^{-5} \]

For nitrogen:
\[ p_{N_2} = K_H \cdot x_{N_2} \]
\[ \Rightarrow x_{N_2} = \frac{p_{N_2}}{K_H} \]
\[ = \frac{6004 \text{ mm Hg}}{6.51 \times 10^7 \text{ mm Hg}} \]
\[ = 9.22 \times 10^{-5} \]

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

**Question 2.40:**
Determine the amount of CaCl2 (\( i = 2.47 \)) dissolved in 2.5 litre of water such that its osmotic pressure is 0.75 atm at 27°C.

**Answer**
We know that,
Here,
\[ R = 0.0821 \text{ L atm K}^{-1}\text{mol}^{-1} \]
\[ M = 1 \times 40 + 2 \times 35.5 = 111 \text{g mol}^{-1} \]

Therefore,
\[ \pi = \frac{w}{iRT} \]
\[ \pi = 0.75 \text{ atm} \]
\[ V = 2.5 \text{ L} \]
\[ i = 2.47 \]
\[ T = (27 + 273) \text{ K} = 300 \text{ K} \]

Here,
\[ R = 0.0821 \text{ L atm K}^{-1}\text{mol}^{-1} \]
\[ M = 1 \times 40 + 2 \times 35.5 = 111 \text{g mol}^{-1} \]

\[ \pi = \frac{0.75 \times 111 \times 2.5}{2.47 \times 0.0821 \times 300} = 3.42 \text{ g} \]

Hence, the required amount of CaCl$_2$ is 3.42 g.

Question 2.41:
Determine the osmotic pressure of a solution prepared by dissolving 25 mg of K$_2$SO$_4$ in 2 liter of water at 25° C, assuming that it is completely dissociated.

Answer

When K$_2$SO$_4$ is dissolved in water, K$^+$ and SO$_4^{2-}$ ions are produced.

K$_2$SO$_4$ $\rightarrow$ 2K$^+$ + SO$_4^{2-}$

Total number of ions produced = 3

\[ \therefore i = 3 \]

Given,
\[ w = 25 \text{ mg} = 0.025 \text{ g} \]
\[ V = 2 \text{ L} \]
\[ T = 25^0 \text{C} = (25 + 273) \text{ K} = 298 \text{ K} \]

Also, we know that:
R = 0.0821 L atm K⁻¹mol⁻¹

\[ M = (2 \times 39) + (1 \times 32) + (4 \times 16) = 174 \text{ g mol}^{-1} \]

Applying the following relation,

\[ \pi = \frac{i}{v} \frac{RT}{M} \]

\[ = 3 \times \frac{0.025 \times 1}{174} \times \frac{0.0821 \times 298}{2} \]

\[ = 5.27 \times 10^{-3} \text{ atm} \]
Text solution

Question 2.1:
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.

Answer

\[
\text{Mass percentage of } C_6H_6 = \left( \frac{\text{Mass of } C_6H_6}{\text{Total mass of the solution}} \right) \times 100\%
\]

\[
= \left( \frac{\text{Mass of } C_6H_6}{\text{Mass of } C_6H_6 + \text{Mass of } CCl_4} \right) \times 100\%
\]

\[
= \left( \frac{22}{22 + 122} \right) \times 100\%
\]

\[
= 15.28\%
\]
Mass percentage of \( \text{CCl}_4 \)

\[
\text{Mass percentage of } \text{CCl}_4 = \frac{\text{Mass of CCl}_4}{\text{Total mass of the solution}} \times 100\% \\
= \frac{\text{Mass of CCl}_4}{\text{Mass of } C_6H_6 + \text{Mass of CCl}_4} \times 100\% \\
= \frac{122}{22 + 122} \times 100\% \\
= 84.72\% \\
\]
Alternatively,

\[
\text{Mass percentage of } \text{CCl}_4 = (100 - 15.28)\% \\
= 84.72\% \\
\]

**Question 2.2:**

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

**Answer**

Let the total mass of the solution be 100 g and the mass of benzene be 30 g.

\[
\therefore \text{Mass of carbon tetrachloride} = (100 - 30)g \\
= 70 \text{ g} \\
\text{Molar mass of benzene } (C_6H_6) = (6 \times 12 + 6 \times 1) \text{ g mol}^{-1} \\
= 78 \text{ g mol}^{-1} \\
\therefore \text{Number of moles of } C_6H_6 = \frac{30}{78} \text{ mol} \\
= 0.3846 \text{ mol} \\
\text{Molar mass of carbon tetrachloride } (\text{CCl}_4) = 1 \times 12 + 4 \times 355 \\
= 154 \text{ g mol}^{-1} \\
\therefore \text{Number of moles of } \text{CCl}_4 = \frac{70}{154} \text{ mol} \\
= 0.4545 \text{ mol} \\
\]

Thus, the mole fraction of \( C_6H_6 \) is given as:

\[
\frac{\text{Number of moles of } C_6H_6}{\text{Number of moles of } C_6H_6 + \text{Number of moles of CCl}_4}
\]
Question 2.3:
Calculate the molarity of each of the following solutions: (a) 30 g of Co(NO$_3$)$_2$.6H$_2$O in 4.3 L of solution (b) 30 mL of 0.5 M H$_2$SO$_4$ diluted to 500 mL.

Answer

Molarity is given by:

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

(a) Molar mass of Co(NO$_3$)$_2$.6H$_2$O = 59 + 2(14 + 3 × 16) + 6 × 18 = 291 g mol$^{-1}$

\[\therefore \text{Moles of Co(NO$_3$)$_2$.6H$_2$O} = \frac{30}{291} \text{ mol}\]

= 0.103 mol

Therefore, molarity = \[
\frac{0.103 \text{ mol}}{4.3 \text{ L}} = 0.023 \text{ M}
\]

(b) Number of moles present in 1000 mL of 0.5 M H$_2$SO$_4$ = 0.5 mol

\[\therefore \text{Number of moles present in 30 mL of 0.5 M H$_2$SO$_4$} = \frac{0.5 \times 30}{1000} \text{ mol}\]

= 0.015 mol

Therefore, molarity = \[
\frac{0.015 \text{ mol}}{0.5 \text{ L}} = 0.03 \text{ M}
\]

Question 2.4:
Calculate the mass of urea (NH$_2$CONH$_2$) required in making 2.5 kg of 0.25 molal aqueous solution.

Answer

Molar mass of urea (NH$_2$CONH$_2$) = 2(1 × 14 + 2 × 1) + 1 × 12 + 1 × 16

\[
= \frac{0.3846}{0.3846 + 0.4545} = 0.458
\]
0.25 molar aqueous solution of urea means:
1000 g of water contains 0.25 mol = (0.25 \times 60) g of urea
= 15 g of urea
That is,
(1000 + 15) g of solution contains 15 g of urea

Therefore, 2.5 kg (2500 g) of solution contains
= \frac{15 \times 2500}{1000 + 15} g
= 36.95 g
= 37 g of urea (approximately)
Hence, mass of urea required = 37 g

Note: There is a slight variation in this answer and the one given in the NCERT textbook.

Question 2.5:
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\(^{-1}\).

Answer
(a) Molar mass of KI = 39 + 127 = 166 g mol\(^{-1}\)
20% (mass/mass) aqueous solution of KI means 20 g of KI is present in 100 g of solution.
That is,
20 g of KI is present in (100 − 20) g of water = 80 g of water

Therefore, molality of the solution
\[ \text{molality} = \frac{\text{Moles of KI}}{\text{Mass of water in kg}} \]
\[ = \frac{20}{166} \text{ m} \]
\[ = 0.08 \text{ m} \]
\[ = 1.506 \text{ m} \]
\[ = 1.51 \text{ m} \text{ (approximately)} \]
(b) It is given that the density of the solution = 1.202 g mL\(^{-1}\)

\[ \Rightarrow \text{Volume of 100 g solution} = \frac{\text{Mass}}{\text{Density}} \]
Therefore, molarity of the solution = \frac{20}{166} \text{ mol} \approx 0.12 \text{ mol}

\text{(c) Moles of KI} = \frac{80}{18} = 4.44 \text{ mol}

\text{Moles of water} = \frac{83.19 \times 10^{-3}}{1.202 \text{ g mL}^{-1}} = 83.19 \text{ mL} = 83.19 \times 10^{-3} \text{ L}

\text{Therefore, mole fraction of KI} = \frac{0.12}{0.12 + 4.44} = 0.0263

\text{Question 2.6:}

\text{H}_2\text{S}, \text{ a toxic gas with rotten egg like smell, is used for the qualitative analysis. If the solubility of H}_2\text{S in water at STP is 0.195 m, calculate Henry’s law constant.}

\text{Answer}

\text{It is given that the solubility of H}_2\text{S in water at STP is 0.195 m, i.e., 0.195 mol of H}_2\text{S is dissolved in 1000 g of water.}

\text{Moles of water} = \frac{1000 \text{ g}}{18 \text{ g mol}^{-1}} = 55.56 \text{ mol}

\text{∴ Mole fraction of H}_2\text{S, x} = \frac{0.195}{0.195 + 55.56}
At STP, pressure \( p \) = 0.987 bar

According to Henry’s law:

\[ p = K_H x \]

\[ \Rightarrow K_H = \frac{p}{x} \]

\[ = \frac{0.987}{0.0035} \text{ bar} \]

\[ = 282 \text{ bar} \]

**Question 2.7:**

Henry’s law constant for \( \text{CO}_2 \) in water is \( 1.67 \times 10^8 \) Pa at 298 K. Calculate the quantity of \( \text{CO}_2 \) in 500 mL of soda water when packed under 2.5 atm \( \text{CO}_2 \) pressure at 298 K.

**Answer**

It is given that:

\[ K_H = 1.67 \times 10^8 \text{ Pa} \]

\[ p_{\text{CO}_2} = 2.5 \text{ atm} = 2.5 \times 1.01325 \times 10^5 \text{ Pa} \]

\[ = 2.533125 \times 10^5 \text{ Pa} \]

According to Henry’s law:

\[ p_{\text{CO}_2} = K_H x \]

\[ \Rightarrow x = \frac{p_{\text{CO}_2}}{K_H} \]

\[ = \frac{2.533125 \times 10^5}{1.67 \times 10^8} \]

\[ = 0.00152 \]

\[ x = \frac{n_{\text{CO}_2}}{n_{\text{CO}_2} + n_{\text{H}_2\text{O}}} \approx \frac{n_{\text{CO}_2}}{n_{\text{H}_2\text{O}}} \]

We can write,

\[ [\text{Since, } n_{\text{CO}_2} \text{ is negligible as compared to } n_{\text{H}_2\text{O}}] \]
In 500 mL of soda water, the volume of water = 500 mL
[Neglecting the amount of soda present]

We can write:
500 mL of water = 500 g of water
\[\frac{500}{18}\text{ mol of water}\]
= 27.78 mol of water

Now, \(\frac{n_{\text{H}_2\text{O}}}{n_{\text{CO}_2}} = x\)

Hence, quantity of CO\(_2\) in 500 mL of soda water = \((0.042 \times 44)\text{ g}\)
= 1.848 g

**Question 2.8:**

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.

**Answer**

It is given that:

\[p_A^0 = 450 \text{ mm of Hg}\]
\[p_B^0 = 700 \text{ mm of Hg}\]
\[p_{\text{total}} = 600 \text{ mm of Hg}\]

From Raoult’s law, we have:

\[p_A = p_A^0 x_A\]
\[p_B = p_B^0 x_B = p_B^0 (1 - x_A)\]

Therefore, total pressure, \(p_{\text{total}} = p_A + p_B\)
Therefore, 
\[ x_b = 1 - x_A \]
\[ = 1 - 0.4 \]
\[ = 0.6 \]

Now, 
\[ p_A = p_A^0 x_A \]
\[ = 450 \times 0.4 \]
\[ = 180 \text{ mm of Hg} \]
\[ p_B = p_B^0 x_B \]
\[ = 700 \times 0.6 \]
\[ = 420 \text{ mm of Hg} \]

Now, in the vapour phase:

\[ \frac{p_A}{p_A + p_B} \]

Mole fraction of liquid A

\[ \frac{180}{180 + 420} \]
\[ = \frac{180}{600} \]
\[ = 0.30 \]

And, mole fraction of liquid B = 1 - 0.30
\[ = 0.70 \]

Question 2.9:

Vapour pressure of pure water at 298 K is 23.8 mm Hg. 50 g of urea (NH\(_2\)CONH\(_2\)) is dissolved in 850 g of water. Calculate the vapour pressure of water for this solution and its relative lowering.
Answer

It is given that vapour pressure of water, $p_1^0 = 23.8$ mm of Hg

Weight of water taken, $w_1 = 850$ g

Weight of urea taken, $w_2 = 50$ g

Molecular weight of water, $M_1 = 18$ g mol$^{-1}$

Molecular weight of urea, $M_2 = 60$ g mol$^{-1}$

Now, we have to calculate vapour pressure of water in the solution. We take vapour pressure as $p_1$.

Now, from Raoult’s law, we have:

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

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

$$\Rightarrow \frac{23.8 - p_1}{23.8} = \frac{50}{\frac{850}{18} + \frac{50}{60}}$$

$$\Rightarrow \frac{23.8 - p_1}{23.8} = \frac{0.83}{47.22 + 0.83}$$

$$\Rightarrow \frac{23.8 - p_1}{23.8} = 0.0173$$

$$\Rightarrow p_1 = 23.4$$ mm of Hg

Hence, the vapour pressure of water in the given solution is 23.4 mm of Hg and its relative lowering is 0.0173.

Question 2.10:

Boiling point of water at 750 mm Hg is 99.63°C. How much sucrose is to be added to 500 g of water such that it boils at 100°C. Molal elevation constant for water is 0.52 K kg mol$^{-1}$.

Answer

Here, elevation of boiling point $\Delta T_b = (100 + 273) - (99.63 + 273)$
Mass of water, \( w_i = 500 \text{ g} \)

Molar mass of sucrose (\( \text{C}_{12}\text{H}_{22}\text{O}_{11} \)), \( M_2 = 11 \times 12 + 22 \times 1 + 11 \times 16 \)
\[
= 342 \text{ g mol}^{-1}
\]

Molal elevation constant, \( K_b = 0.52 \text{ K kg mol}^{-1} \)

We know that:
\[
\Delta T_b = \frac{K_b \times 1000 \times w_2}{M_2 \times w_i}
\]

\[
\Rightarrow w_2 = \frac{\Delta T_b \times M_2 \times w_i}{K_b \times 1000}
\]

\[
= \frac{0.37 \times 342 \times 500}{0.52 \times 1000}
\]

\[
= 121.67 \text{ g (approximately)}
\]

Hence, 121.67 g of sucrose is to be added.

**Note:** There is a slight variation in this answer and the one given in the NCERT textbook.

**Question 2.11:**
Calculate the mass of ascorbic acid (Vitamin C, \( \text{C}_6\text{H}_8\text{O}_6 \)) to be dissolved in 75 g of acetic acid to lower its melting point by 1.5°C. \( K_f = 3.9 \text{ K kg mol}^{-1} \).

**Answer**

Mass of acetic acid, \( w_1 = 75 \text{ g} \)

Molar mass of ascorbic acid (\( \text{C}_6\text{H}_8\text{O}_6 \)), \( M_2 = 6 \times 12 + 8 \times 1 + 6 \times 16 \)
\[
= 176 \text{ g mol}^{-1}
\]

Lowering of melting point, \( \Delta T_f = 1.5 \text{ K} \)

We know that:
\[
\Delta T_f = \frac{K_f \times w_2 \times 1000}{M_2 \times w_1}
\]
\[ w_2 = \frac{\Delta T_f \times M_2 \times w_1}{K_f \times 1000} \]

\[ = \frac{1.5 \times 176 \times 75}{3.9 \times 1000} \]

\[ = 5.08 \text{ g (approx)} \]

Hence, 5.08 g of ascorbic acid is needed to be dissolved.

Note: There is a slight variation in this answer and the one given in the NCERT textbook.

Question 2.12:
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°C.

Answer
It is given that:
Volume of water, \( V = 450 \text{ mL} = 0.45 \text{ L} \)
Temperature, \( T = (37 + 273) \text{ K} = 310 \text{ K} \)

Number of moles of the polymer, \( n = \frac{1}{185000} \text{ mol} \)

We know that:
Osmotic pressure, \( \pi = \frac{nRT}{V} \)

\[ = \frac{1}{185000} \text{ mol} \times \frac{1}{0.45 \text{ L}} \times 8.314 \times 10^3 \text{ Pa L K}^{-1}\text{mol}^{-1} \times 310 \text{ K} \]

\[ = 30.98 \text{ Pa} \]

\[ = 31 \text{ Pa (approximately)} \]
Ge doped with In
B doped with Si

3. Zinc oxide is white but it turns yellow on heating. Explain.

**Long Answer (5 Marks):**

1. It is face centered cubic lattice. A metal has cubic lattice. Edge length of lattice cell is 2A⁰. The density of metal is 2.4g cm⁻³. How many units cell are present in 200g of metal.
2. A metal crystallizes as face centered cubic lattice with edge length of 450pm. Molar mass of metal is 50g mol⁻¹. The density of mental is?

3. A compound forms hexagonal close packed structure. What is the total number of voids in 0.5 mol of it? How many of these are tetrahedral voids?

4. Copper crystallizes into FCC lattice with edge length 3.61*10⁻⁸ cm. Show that calculated density is in agreement with measured value of 8.92g/cc.

5. Niobium crystallizes in bcc structure with density 8.55g/cc, Calculate atomic radius using atomic mass i.e. 93u.

**HOTS Long Answer:**

1. The compound CuCl has FCC structure like ZnS, its density is 3.4g cm⁻³. What is the length of the edge of unit cell?

   \[ Z = \frac{d \times a^3 \times N_A}{M} \]

   \[ 4 = \frac{3.4 \times a^3 \times 6.022 \times 10^{23}}{99} \]

2. If NaCl is dropped with 10⁻³ mol% SrCl₂. What is the concentration of cation valancies?

4. The edge length of the unit cell of mental having molecular weight 75g/mol is A⁰ which crystallizes into cubic lattice. If the density is 2g/cm³ then find the radius of metal atom (N_A = 6.022*10²³)

5. The density of K Br. is 2.75 gm cm⁻³. the length of edge of the unit cell is 654 pm. Predict the type of cubic lattice to which unit cell of KBr belongs.

   \[ \text{NA}=6.023 \times 10^{23} ; \text{at mass of K}=39 ; \text{Br.} = 80 \]

   Ans. Calculate value of \( z = 4 \) so it has fcc lattice

6. The radius of an Iron atom is 1.42 A⁰. It has rock salt structure. Calculate density of unit cell.

   \[ \text{Ans.} 5.74 \text{ g cm}^{-3} \]

7. Copper crystalline with fcc unit cell. If the radius of copper atom is 127.8 pm. Calculate the density of copper metal. At. Mass of Cu=63.55u \( \text{NA}= 6.02 \times 10^{23} \)

   \[ \text{Ans.} a=2\sqrt{2} \cdot r , a^3=4.723 \times 10^{-23} , d=8.95 \text{ } 5.74 \text{ g cm}^{-3} \]

---

**Chapter- 2 Solutions**

**5 Marks Chapter**

**Solubility** - The amount of solute which can be dissolved in 100grm of solvent at particular temp. to make saturated solution.

**Concentration Terms:**
1. **Mole fraction** it is the ratio of no. of one component to the total no. of moles of all components. It is expressed as ‘x’. For two component system made of A and B, \( X_A = \frac{n_A}{n_A + n_B} \), \( X_B = \frac{n_B}{n_A + n_B} \), Sum of all the components is 1 ; \( X_A + X_B = 1 \)

2. **Molarity (M)** = \( \frac{W_B \times 1000}{M_B \times V_{ml}(Solution)} \)

It decreases with increase in temperature as volume of solution increases with temperature.

3. **Molality (m)** = \( \frac{W_B \times 1000}{M_A \times W_A(Solvent)} \)

No effect of change of temperature on molality as it is mass to mass ratio.

4. **Normality (N)** = \( \frac{W_B \times 1000}{E \times V_{ml}(Solution)} \)

It changes with changes temperature.

5. **Parts per million (ppm)** concentration of very dilute solution is expressed in ppm.

\[ P_{ppm} = \frac{W_B}{W_B + W_A} \times 10^6 \]

**Vapor pressure** – It is defined as the pressure exerted by the vapour of liquid over the liquid over the liquid in equilibrium with liquid at particular temperature vapour pressure of liquid depends upon nature of liquid and temperature.

**Roul’s Law** –

1. For the solution containing non-volatile solute the vapor pressure of the solution is directly proportional to the mole fraction of solvent at particular temperature
   \[ P_A \propto X_A \]
   \[ P_A = P^0_A \cdot X_A \]

2. For the solution consisting of two miscible and volatile liquids the partial vapor pressure of each component is directly proportional to its own mole fraction in the solution at particular temperature.
   \[ P_A = P^0_A \cdot X_A, \quad P_B = P^0_B \cdot X_B \]

And total vapor pressure is equal to sum of partial pressure. \( P_{\text{total}} = P_A + P_B \)

**Ideal solution** – The solution which obeys Roul’s law under all conditions of temperature and concentration and during the preparation of which there is no change in enthalpy and volume on mixing the component.

**Conditions** –

\[ P_A = P^0_A \cdot X_A, \quad P_B = P^0_B \cdot X_B \]

\[ \Delta H_{\text{mix}} = 0, \quad \Delta V_{\text{mix}} = 0 \]

This is only possible if A-B interaction is same as A-A and B-B interaction nearly ideal solution are –
1. Benzene and Toluene
2. Chlorobenzene and Bromobenzene

Very dilute solutions exhibit ideal behavior to greater extent.

Non-ideal solution –

(a) \( P_A \neq P_A^0 \cdot X_A \)
(b) \( P_B \neq P_B^0 \cdot X_B \)
(c) \( \Delta H_{\text{mix}} \neq 0 \)
(d) \( \Delta V_{\text{mix}} \neq 0 \)

For non-ideal solution the A-B interaction is different from A-A and B-B interactions

i. For solution showing positive deviation
\( P_A > P_A^0 \cdot X_A \)
\( P_B > P_B^0 \cdot X_B \)
\( \Delta H_{\text{mix}} = \text{positive}, \quad \Delta V_{\text{mix}} = \text{positive} \) (A-B interaction is weaker than A-A and B-B )
E.g. alcohol and water

ii. For the solution showing negative deviation
\( P_A < P_A^0 \cdot X_A \)
\( P_B < P_B^0 \cdot X_B \)
\( \Delta H_{\text{mix}} = \text{negative}, \quad \Delta V_{\text{mix}} = \text{negative} \')
A-B interaction is stronger than A-A and B-B interactions
E.g. Chloroform, acetone, HCl and water

What is Azeotrope? – The mixture of liquids at particular composition which has constant boiling point which behaves like a pure liquid and cannot be separated by simple distillation. Azeotropes are of two types:

(a) minimum boiling Azeotrope (mixture which shows +ve deviations ) ex. alcohol and water
(b) maximum boiling Azeotrope (which shows –ve deviations) ex. acetone and chloroform

Colligative Properties - Properties of ideal solution which depends upon no. of particles of solute but independent of the nature of particle are called colligative property

Relative lowering in vapour pressure:
\[
\left( \frac{P_A^0 - P_A}{P_A^0} \right) = X_B
\]

Determination of molar mass of solute
\[
M_B = \left( \frac{W_A \times M_A \times P_A^0}{W_A \times (P_A^0 - P_A)} \right)
\]

Elevator in Boiling Point
\[
\Delta T_B = K_b \cdot m
\]
Where \( \Delta T_B = T'_B - T_B^0 \)

\( K_b = \) molal elevator constant

\( M = \) molality

\[
M_B = \frac{(K_b \times 1000 \times W_B)}{\Delta T_B \times W_A}
\]

Depression in Freezing Point:
\[ \Delta T_f = k_f \cdot m \]

Where \( \Delta T_f - T'_f \cdot m \) = molality

\( K_f \) = molal depression constant

unit = k.kg.mol\(^{-1}\)

**Osmotic Pressure**

The hydrostatic pressure which is developed on solution side due movement of solvent particles from lower concentration to higher concentration through semipermeable membrane denoted as \( \pi \) and it is expressed as

\[ \pi = n \frac{RT}{V} \]

\[ \pi = CRT \]

\( n \) = No. of moles; \( V \) = volume of solution (L)

\( R = 0.0821 \text{ Latm/mol}^{-1}; T = \text{temperature in kelvin.} \)

Isotonic solutions have same osmotic pressure and same concentration.

Hypertonic solutions have higher osmotic pressure and hypotonic solutions have lower osmotic pressure.

0.91\% solutions have sodium chloride solution RBC swells up or burst.
Q.1. What is Vant Hoff factor?
Ans. It is the ratio of normal molecular mass to observed molecular mass. H is denoted as ‘i’

\[ i = \frac{\text{normal m.m}}{\text{observed m.m}} \]

= no. of particles after association or dissociation / no. of particles before

Q.2. What is the Vant Hoff factor in \( K_4[Fe(CN)_6] \) and \( BaCl_2 \)?
Ans 5 and 3

Q.3. Why the molecular mass becomes abnormal?
Ans. Due to association or dissociation of solute in given solvent.

Q.4. Define molarity, how it is related with normality?
Ans. \( N = M \times \text{Basicity or acidity} \).

Q.5. How molarity is related with percentage and density of solution?
Ans. \( M = \frac{P \times d \times 10}{M.M} \)

Q.6. What role does the molecular interaction play in the solution of alcohol and water?
Ans. Positive deviation from ideal behavior.

Q.7. What is Vant Hoff factor, how is it related with
   a. degree of dissociation
   b. degree of association

Ans. a. \( \alpha = i - \frac{1}{n-1} \)
   b. \( \alpha = i - \frac{1}{n} \cdot 1 \)

Q.8. Why NaCl is used to clear snow from roads?
Ans. It lowers f.p of water

Q.9. Why the boiling point of solution is higher than our liquid
Ans. Due to lowering in v.p

Q.10. What are isotonic solutions?
Ans. Isotonic solutions have same osmotic pressure.

HOTS

Q.1. Out of 1M and 1m aqueous solution which is more concentrated
Ans. 1M as density of water is 1gm/Ml
Q2. Henry law constant for two gases are 21.5 and 49.5 atm, which gas is more soluble.

Ans. KH is inversely proportional to solubility.

Q3. Define azeotrope, give an example of maximum boiling azeotrope.

Q4. Calculate the volume of 75% of $H_2SO_4$ by weight ($d=1.8 \text{ gm/ml}$) required to prepare 1L of 0.2M solution

Hint: $M_1 = P \times d \times 10 / 98$

$M_1 V_1 = M_2 V_2$

14.5ml

Q5. Why water cannot be completely separated from aqueous solution of ethyl alcohol?

Ans. Due to formation of Azeotrope at (95.4%)
Q.1. How many grams of KCl should be added to 1kg of water to lower its freezing point to -8.0°C (kf = 1.86 K kg /mol)

Ans. Since KCl dissociate in water completely L=2

\[ \Delta T_f = i \ k_f \times m \quad ; \quad m = \Delta T_f / i k_f \]

\[ m = 8 / 2 \times 1.86 = 2.15 \text{mol/kg}. \]

Grams of KCl= 2.15 X 74.5 = 160.2 g/kg.

Q.2. With the help of diagram: show the elevator in boiling point colligative properties?

Q.3. what do you mean by colligative properties, which colligative property is used to determine m.m of polymer and why?

Q.4. Define reverse osmosis, write its one use.

Ans. Desalination of water.

Q.5. Why does an azeotropic mixture distills without any change in composition.

Hint: It has same composition of components in liquid and vapour phase.

Q.6. Under what condition Vant Hoff’s factor is

a. equal to 1           b. less than 1         c. more than 1

Q.7. If the density of some lake water is 1.25 gm /ml and contains 92gm of Na⁺ ions per kg of water. Calculate the molality of Na⁺ ion in the lake.

Ans. n = 92/23 = 4

m= 4/1 = 4m

Q.8. An aqueous solution of 2% non-volatile exerts a pressure of 1.004 Bar at the normal boiling point of the solvent. What is the molar mass of the solute.

Hint: \[ P^0_A - P_A / P^0_A = w_B \times m_A / m_B \times w_A \]

\[ 1.013 - 1.004 / 1.013 = 2 \times 18 / m_B \times 98 \]

\[ m_B = 41.35 \text{gm/mol} \]

Q.9. Why is it advised to add ethylene glycol to water in a car radiator in hill station?

Hint: Anti- freeze.

Q.10. what do you mean by hypertonic solution, what happens when RBC is kept in 0.91% solution of sodium chloride?

Q.11. (a). define the following terms.
2. Mole fraction

3. Ideal solutions

(b) 15 g of an unknown molecular material is dissolved in 450 g of water. The resulting solution freezes at -0.34 °C. What is the molar mass of material? Kf for water = 1.86 K Kg mol⁻¹.

Ans. 182.35 glmol

Q 12. (a) Explain the following:

1. Henry’s law about dissolution of a gas in a liquid.

2. Boiling point elevation constant for a solvent.

(b) A solution of glycerol (C₃H₈O₃) in water was prepared by dissolving some glycerol in 500 g of water. The solution has a boiling point of 100.42 °C. What mass of glycerol was dissolved to make this solution?

Kb for water = 0.512 k Kg mol⁻¹

(hint: \[ \text{atb} = \frac{b \times w_b \times 1000}{M_b \times W_a} \])

Ans. 37.73 gm

Q 13. 2 g of benzoic acid (C₆H₅CooH) dissolved in 25 g of benzene shows a depression in freezing point equal to 1.62 K. Kf for benzene is 4.9 K Kg mol⁻¹. What is the percentage association of acid if it forms dimer in solution?

Ans. 99.2%

Q 14. Osmotic pressure of a 0.0103 molar solution of an electrolite is found to be 0.70 atm at 27°C. Calculate Vant Hoff factor. (R = 0.082 L atom mol⁻¹ K⁻¹) Ans. 2.76

Q 15. What do you mean by Henry’s Law? The Henry’s Law constant for oxygen dissolved in water is 4.34×10⁴ atm at 25°C. If the partial pressure of oxygen in air is 0.2 atm, under atmospheric pressure conditions. Calculate the concentration in moles per litre of dissolved oxygen in water in equilibrium with water air at 25°C.

Ans: Partial pressure of the gas is directly proportional to its mole fraction in solution at particular temperature.

\[ P_A \alpha X_A \ ; \ K_H = \text{Henry’s Law of constant} \]

\[ P_A = K_H \times A \]

\[ K_H = 4.34 \times 10^4 \text{ atm} \]

\[ P_{O_2} = 0.2 \text{ atm} \]

\[ X_{O_2} = \frac{P_{O_2}}{K_H} = \frac{0.2}{4.34 \times 10^4} = 4.6 \times 10^{-6} \]

If we assume 1L solution = 1L water

\[ n \text{ water} = 1000/18 = 55.5 \]
\[ X \text{O}_2 = \frac{\text{nO}_2}{(\text{nO}_2 + \text{n H}_2\text{O})} \sim \frac{\text{nO}_2}{\text{n H}_2\text{O}} \]

\[ \text{nO}_2 = 4.6 \times 10^{-6} \times 55.5 = 2.55 \times 10^{-4} \text{ mol} \]

\[ M = 2.55 \times 10^{-4} \text{ M} \]

16. Calculate the mass of compound (molar mass = 256 g/mol) to be dissolved in 75g of benzene to lower its freezing point by 0.48K (\(K_f = 5.12 \text{K g/mol}\))

\[ \text{Ans: } \Delta T_f = K_f \times W_2 \times 1000/W_1 \times M_2 \]

\[ 0.48 = 5.12 \times W_2 \times 1000/75 \times 256 \]

\[ W_2 = 1.8 \text{g} \]

17. Define an ideal solution and write one of its characteristics

\[ \text{Ans. Ideal solution – The solution which obeys Roul't's law under all conditions of temperature and concentration and during the preparation of which there is no change in enthalpy and volume on mixing the component.} \]

\[ \text{Conditions} – \]

\[ P_A = P_A^0 X_A, \quad P_B = P_B^0 X_B \]

\[ \Delta H_{\text{mix}} = 0, \quad \Delta V_{\text{mix}} = 0 \]

This is only possible if A-B interaction is same as A-A and B-B interaction nearly ideal solution are –

**CHAPTER-3 ELECTROCHEMISTRY**