

Chapter 1: Solutions

NCERT · Class 12 · Chemistry

Textbook exercises

Question 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.

Solution

Ans: Mass percentage is the ratio of the mass of the solute divided by the total mass of the solution multiplied by 100.

$$\text{Mass}\% = \frac{\text{mass}_{\text{solute}}}{\text{mass}_{\text{solution}}} \times 100$$

Here,

The mass percentage of both compounds is given as;

$$\begin{aligned}\text{Mass percentage of } C_6H_6 &= \frac{\text{mass}_{C_6H_6}}{\text{mass}_{C_6H_6} + \text{mass}_{CCl_4}} \times 100 \\ &= \frac{22}{22 + 122} \times 100 \\ &= 15.28 \%\end{aligned}$$

Now, as the solution consists of only two components i.e., C_6H_6 and CCl_4 .

Thus,

$$\begin{aligned}\text{Mass percentage of } CCl_4 &= 100 - 15.28 \\ &= 84.72\%\end{aligned}$$

Therefore, the mass percentages of C_6H_6 and CCl_4 are 15.28% and 84.72% respectively.

Question 2

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

Solution

Ans: Mole fraction is the ratio of moles of solute to the total moles of solution.

$$\text{Mole fraction} = \frac{n_{\text{solute}}}{n_{\text{solution}}}$$

Here,

We have given a solution containing 30% by mass of benzene in carbon tetrachloride; which clearly states that 30 g of benzene is present in 100 g of solution.

Thus, carbon tetrachloride is 70 g in 100 g of solution.

We know that,

Molar mass of benzene = 78 g/mol

Molar mass of carbon tetrachloride = 154 g/mol

Thus,

$$\text{Number of moles of benzene} = \frac{30}{78} = 0.385 \text{ mol}$$

$$\text{Number of moles of carbon tetrachloride} = \frac{70}{154} = 0.455 \text{ mol}$$

Now,

$$\begin{aligned} \text{Mole fraction of benzene} &= \frac{n_{C_6H_6}}{n_{C_6H_6} + n_{CCl_4}} \\ &= \frac{0.385}{0.385 + 0.455} \\ &= \frac{0.385}{0.84} = 0.458 \end{aligned}$$

Therefore, the mole fraction of benzene is 0.458 in the solution.

Question 3

Calculate the molarity of each of the following solutions:

1. 30 g of $Co(NO_3)_2 \cdot 6H_2O$ in 4.3 L of solution.

Solution

Ans: Molarity is the number of moles of solute per liter of solution.

$$\text{Molarity} = \frac{n_{\text{solute}}}{V_{\text{solution}}} \text{ M}$$

Here,

Molarity of 30 g of $Co(NO_3)_2 \cdot 6H_2O$ in 4.3 L of

the solution is given as;

Molar mass of $Co(NO_3)_2 \cdot 6H_2O = 310.7 \text{ g/mol}$.

$$\text{Number of moles} = \frac{30}{310.7} = 0.0966$$

$$\text{Thus, molarity} = \frac{0.0966}{4.3} = 0.022M$$

1. 30 mL of 0.5 M H_2SO_4 diluted to 500 ml.

Ans: Molarity of 30 mL of 0.5 M H_2SO_4 diluted to 500 ml.

1000 ml of 0.5 M H_2SO_4 contains 0.5 moles of H_2SO_4 .

Thus,

30 ml of 0.5 M H_2SO_4 contains;

$$= \frac{0.5}{1000} \times 30 = 0.015 \text{ moles } H_2SO_4.$$

Also, the volume of solution = 500 ml = 0.5 L.

Now,

$$\text{Therefore the molarity} = \frac{0.015}{0.5} = 0.03M$$

Question 4

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

Solution

Ans: Molality is given as ratio of moles of solute per gm of mass of solvent.

$$\text{Molality} = \frac{n_{\text{solute}}}{m_{\text{solvent}}} \text{ m}$$

Here,

0.25 molal solution of urea states that 0.25 moles of urea is present in 1000 gm of solvent.

The molar mass of solute i.e., urea = 60 g/mol

Thus,

$$\text{Mass of urea in the solution} = 0.25 \times 60 = 15g$$

$$\text{Total mass of solution} = 1000 \text{ gm solvent} + 15 \text{ gm of solute}$$

$$= 1015 \text{ gm} = 1.015 \text{ Kg}$$

This states that,

1.015 Kg solution has 15 gm urea.

Thus,

2.5 Kg solution will have;

$$\frac{15}{1.015} \times 2.5 = 37g \text{ urea.}$$

Therefore, the mass of urea required will be 37 g.

Question 5

Calculate the

1. The molality of KI if the density of 20% (mass/mass) aqueous KI is 1.202 g/ml.

Solution

Ans: Given that,

20% of aqueous KI solution has 20 gm of KI in 100 gm of solution.

Mass of water (solvent) = $100 - 20 = 80$ gm.

The volume of solution is given as,

$$\text{Volume} = \frac{\text{mass}}{\text{density}} = \frac{100}{1.202} = 83.194 \text{ ml}$$

Molar mass of KI = 166.0028 g/mol

Thus,

$$\text{Number of moles of KI} = \frac{20}{166.0028} = 0.120 \text{ mol}$$

Molar mass of water = 18 g/mol

Thus,

$$\text{Number of moles of water} = \frac{80}{18} = 4.44 \text{ mol}$$

The molality of KI if the density of 20% (mass/mass) aqueous KI is 1.202 g/ml;

$$\text{Molality} = \frac{0.120}{0.08} = 1.50 \text{ m}$$

1. The molarity of KI if the density of 20% (mass/mass) aqueous KI is 1.202 g/ml.

Ans: Molarity of KI if the density of 20% (mass/mass) aqueous KI is 1.202 g/ml.

$$\text{Molarity} = \frac{0.120}{0.083194} = 1.44 \text{ M}$$

1. Mole fraction of KI if the density of 20% (mass/mass) aqueous KI is 1.202 g/ml.

Ans: Mole fraction of KI if the density of 20% (mass/mass) aqueous KI is 1.202 g/ml.

$$\text{Mole fraction} = \frac{0.120}{0.120 + 4.44} = 0.0263$$

Question 6

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

Solution

Ans: Molality (solubility) of H_2S in water = 0.195 m which states that,

0.195 moles of H_2S in 1Kg of water (1000 g).

Now,

Molar mass of water = 18 g/mol.

Number of moles of water = $\frac{1000}{18} = 55.55 \text{ mol}$

Mole fraction of H_2S is

$$X_{H_2S} = \frac{0.195}{0.195 + 55.55} = 0.00349$$

Pressure at STP is given as 0.987 bar. Thus, applying Henry's law we get;

$$P_{H_2S} = K_H \times X_{H_2S}$$

$$K_H = \frac{P_{H_2S}}{X_{H_2S}} = \frac{0.987}{0.00349} = 282.80 \text{ bar}$$

Therefore, Henry's constant will be 282.80 bar.

Question 7

Henry's law constant for CO_2 in water is 1.67×10^8 Pa at 298 K. Calculate the quantity of CO_2 in 500 ml of soda water when packed under 2.5 atm CO_2 pressure at 298 K.

Solution

Ans: Given that,

Henry's law constant, $K_H = 1.67 \times 10^8 Pa$

Pressure, $P_{CO_2} = 2.5 atm = 2.5 \times 101325 = 253312.5 Pa$

Now, by Henry's law;

$$P_{CO_2} = K_H \times X_{CO_2}$$

$$X_{CO_2} = \frac{253312.5}{1.67 \times 10^8} = 1.5168 \times 10^{-3}$$

Now,

500 ml soda water is equivalent to 500 ml water which indirectly signifies 500 gm of the same.

Thus,

We know that, the molar mass of water = 18 g/mol

$$\text{Number of moles of water} = \frac{500}{18} = 27.78 mol$$

Number of moles of CO_2 is given as,

$$X_{CO_2} = \frac{n_{CO_2}}{n_{CO_2} + n_{water}}$$

$$n_{CO_2} = X_{CO_2} (n_{CO_2} + n_{water})$$

$$n_{CO_2} = 42.20 \times 10^{-3} mol$$

Mass of CO_2 is given as,

Molar mass of CO_2 = 44 g/mol.

Thus,

$$\text{Mass} = n_{CO_2} \times 44 = 1.857 gm$$

Question 8

The vapor 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 the total vapor pressure is 600 mm Hg. Also find the composition of the vapor phase.

Solution

Ans: Vapor pressures of the given pure liquids are;

$$P_A^0 = 450 \text{ mm Hg},$$

$$P_B^0 = 700 \text{ mm Hg and}$$

$$P_{Total} = 600 \text{ mm Hg}$$

By Raoult's law;

$$P_{Total} = P_A + P_B$$

$$P_{Total} = X_A P_A^0 + X_B P_B^0 = X_A P_A^0 + (1 - X_A) P_B^0$$

$$P_{Total} = P_B^0 + (P_A^0 - P_B^0) X_A$$

$$600 = 700 + (450 - 700) X_A$$

$$\therefore X_A = 0.4$$

Thus,

$$X_B = 1 - 0.4 = 0.6$$

$$P_A = X_A P_A^0 = 0.4 \times 450 = 180 \text{ mm Hg}$$

$$P_B = X_B P_B^0 = 0.6 \times 700 = 420 \text{ mm Hg}$$

Thus,

$$\text{Mole fraction of A in vapor phase} = \frac{180}{180 + 420} = 0.3$$

$$\text{Mole fraction of B in vapor phase} = 1 - 0.3 = 0.7$$

Question 9

The vapor pressure of pure water at 298 K is 23.8 mm Hg. 50 g of urea (NH_2CONH_2) is dissolved in 850 g of water. Calculate the vapor pressure of water for this solution and its relative lowering.

Solution

Ans: Given that,

Vapor pressure of pure water, $P^0 = 23.8$ mm Hg

Mass of urea, $W_2 = 50$ g

Molar mass of urea, $M_2 = 60$ g/mol

Mass of water, $W_1 = 850$ g

Molar mass of water, $M_1 = 18$ g/mol

By Raoult's law;

$$\Delta P = P^0 - P_s = X_2 \times P^0$$

$$\frac{P^0 - P_s}{P^0} = X_2 = \frac{n_2}{n_1 + n_2} = \frac{W_2/M_2}{W_1/M_1 + W_2/M_2}$$
$$X_2 = 0.017$$

Now,

We have given that $P^0 = 23.8$ mm Hg;

$$\frac{23.8 - P_s}{23.8} = 0.017$$

Thus, V. P. of solution, $P_s = 23.4$ mmHg.

Question 10

The 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 .

Solution

Ans: Given that,

Boiling point of water = 100°C

Boiling point of water at 750 mm Hg = 99.63°C

Elevation in boiling point, $\Delta T_b = 100 - 99.63 = 0.37$

Ebullioscopic constant, $K_b = 0.52$

Mass of water, $W_1 = 500\text{ g}$

Molar mass of water, $M_1 = 18\text{ g/mol}$

Molar mass of sucrose, $M_2 = 342\text{ g/mol}$

Mass of sucrose, $W_2 = ?$

The elevation in boiling pint is given as;

$$\Delta T_b = K_b \times m$$

$$\Delta T_b = K_b \times \frac{n_2}{W_1} = K_b \times \frac{W_2}{M_2} \times \frac{1000}{W_1}$$

$$W_2 = \frac{\Delta T_b \times M_2 \times W_1}{K_b \times 1000} = 121.67\text{g}$$

$\therefore$ 121.67 g sucrose to be added in water such that it boils at 100°C .

Question 11

Calculate the mass of ascorbic acid (Vitamin C, $C_6H_8O_6$) to be dissolved in 75 g of acetic acid to lower its melting point by 1.5°C . $K_f = 3.9 \text{K g/mol}$.

Solution

Ans: Given that,

Lowering in freezing point, $\Delta T_f = 1.5^\circ \text{C}$

Cryoscopic constant, $K_f = 3.9 \text{K g/mol}$

Mass of acetic acid, $W_1 = 75 \text{ g}$

Molar mass of acetic acid, $M_1 = 60 \text{ g/mol}$

Molar mass of ascorbic acid, $M_2 = 176 \text{ g/mol}$

Mass of ascorbic acid, $W_2 = ?$

The lowering in freezing point is given as;

$$\Delta T_f = K_f \times m$$

$$\Delta T_f = K_f \times \frac{n_2}{W_1} = K_f \times \frac{W_2}{M_2} \times \frac{1000}{W_1}$$

$$W_2 = \frac{\Delta T_f \times M_2 \times W_1}{K_f \times 1000} = 5.077 \text{ g}$$

$\therefore$ Mass of ascorbic acid is 5.077 g.

Question 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 .

Solution

Ans: Given that,

Mass of polymer, $W = 1 \text{ g}$

Molar mass of polymer, $M = 185000 \text{ g/mol}$

Volume of water, $V = 450 \text{ ml} = 0.45 \text{ L}$

Temperature, $T = 37^\circ \text{ C} = 310 \text{ K}$

Gas constant, $R = 8.314 \text{ kPa} \cdot \text{L} \cdot \text{K}^{-1} \text{mol}^{-1} = 8.314 \times 10^3 \text{ Pa} \cdot \text{L} \cdot \text{K}^{-1} \text{mol}^{-1}$

Now, using the formula for osmotic pressure;

$$\pi = CRT = \frac{n}{V} RT = \frac{W}{M} \times \frac{1}{V} \times RT$$

$$\pi = 30.96 \text{ Pa}$$

therefore, Osmotic pressure is 30.96 Pa.