Exercise Questions:

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

Ans.

Solutions are homogeneous mixtures of two or more than two components. Homogenous mixture we means that its composition and properties are uniform throughout the mixture.

There are nine types of solutions:

Gaseous solutions:

i.)   Gas in gas : mixture of oxygen and nitrogen gases

ii.)   Liquids in gases : Chloroform mixed with nitrogen gas

iii.)   Solid in gas : Camphor in nitrogen gas

 Liquid solutions:

i.)   Gas in liquid : oxygen dissolved in water

ii.)   Liquid in liquid : Ethanol dissolved in water

iii.)   Solid in liquid : Glucose dissolved in water

Solid solutions:

i.)   Gas in solid : solutions of hydrogen in plladium

ii.)   Liquid in solid : Amalgam of mercury with sodium

iii.)   Solid in solid : Copper dissolved in gold

Question:2 Suppose a solid solution is formed between two substances, one whose particles are very large and the other whose particles are very small. What kind of

solid solution is this likely to be?

Ans –

Solution of hydrogen in palladium and dissolved gases in minerals.

Question:3 Define the following terms:
i.)Mole fraction
ii.)Molality
iii.)Molarity
iv.) Mass percentage
Ans –
Mole fraction: It is defined as:
Mole fraction of a component = Number of moles of the component /Total number of moles of all the components
For example, in a binary mixture, if the number of moles of A and B are nA and nB respectively, the mole fraction of A will be
Xa = nA/nA+nB
For a solution containing I number of components, we have
X =ni/n1+n2+------ni
It can be shown that in a given solution sum of all the mole fractions is unity, 1.e.
x1 + x2 + -------+ xi= 1

Molality: Molality (m) is defined as the number of moles of the solute per kilogram (kg) of the solvent and is expressed as:
Molality (m): Moles of solute/ Mass of solvent in kg

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

Mass percentage (w/w): The mass percentage of a component of a solution is defined as:
Mass % of a component =
Mass of the component in the solution × 100 /Total mass of the solution.

Question: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}?

Solution:

68 % nitric acid by mass means that 68g mass of nitric acid is dissolved in 100g mass the solution.

Molar mass of HNO_3 = 6 mol^{-1}

∴. 68g of HNO_3 = 68/63 = 1.079mole

Density of solution =1.504 g mL^{-1} given

∴ Volume of solution = mass/density =100/1.504=66.5 mL

∴ Molarity of solution:

Moles of slolute x 1000/Volume of solution in mL

1.79 x 1000/ 65 =16.23M

Question: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 ton is 1.2 g mol^{-1}, then what shall be the molarity of the solution?

Solution 5.

10 percent w/w solution of glucose in water means 10g glucose and 90g of   water.

∴ 10g of glucose=10/180- 0.0555 moles
And 90g of H20-90/18-5 moles

∴ Molality of solution
= Moles of solutex1000/Mass of solution in grams
0.0555/90 x 1000=0.617 m

Moles fraction of glucose
= X g = no of moles of glucose/No.of moles of glucose + No.of moles of water
=0.0555/5+0.0555=-0.01

Mole fraction of water:
=X g = No. of males of water/No of modes of glucose + No of moles of water
=5/5+0.0555 = 0.99

Volume of 100g solution
Mass of solution/density= 100/1.2= 83.33mL

: Molarity of solution =0.0555/83.33 x 1000

= 0.67M

Question:6 How many mL of 0.1 M HCI are required to react completely with 1 g mixture of Na_2CO_3 and $NaHCO_3$ containing equimolar amounts of both?

Solution:

Calculation of no. of moles of components in the mixture.

Let x g of Na_2CO_3 is present in the mixture.

: (1-x)g of $NaHCO_3$ is present in the mixture.

Molar mass of Na_2CO_3

=2 x 23 + 12 +3 x 16= 84g $mol_{.1}$

And molar mass of $NaHCO_3$

= 23 x 1+1+12+3 x 16 = 84g $mol_{.1}$

No. of moles of Na_2CO_3 in x g = x/106

No. of moles of $NaHCO_3$ in (1-x) g-(1-x)/84

As given that the mixture contains equimolar amounts of Na_2CO_3 and $NaHCO_3$, therefore

x/106 = 1-x /84
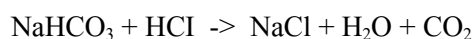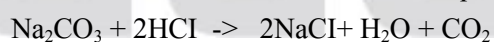
106-106x = 84x

106-190 x

: x = 106/190= 0.558g

No of moles of Na_2CO_3 present

0.558/106 = 0.00526

And no. Of moles of $NaHCO_3$ present

= 1 – 0.558/84 = 0.00526

Calculation of no. of moles of HCL required

$Na_2CO_3 + 2HCI \rightarrow 2NaCI+ H_2O + CO_2$

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

As can be seen, each mole of Na_2CO_3 needs 2 moles of HCl,

: 0.00526 mole of $NaCO_3$ needs = 0.00526 x 2 = 0.01052mole

Each mole of $NaHCO_3$ needs 1 mole of HCI

: 0.00526 mole of $NaCHO_3$ needs =1× 0.00526 = 0.00526 mole

Total amount of HCI needed will be

= 0.01052 + 0.00526 = 0.01578 mole.

0.1 mole of 0.1 M HCl are present in 1000 mL of HCl

∴ 0.01578 mole of 0.1 M HCl will be present in

1000/0.1 × 0.01578 = 157.8 mL

Question: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.

Solution:

300 g of 25% solution will contain = 25 × 300 / 100 = 75 g of solute

400g of 40% solution will contain = 40 × 400 / 100 = 160g of solute

∴ Total mass of solute=160+ 75= 235g

Total mass of solution =300 + 400 = 700g

Now, the percentage of solute in solution= 235/700 x 100 = 33.5 %

And the percentage of water in solution =100-33.5 = 66.5%

Question:8 An antifreeze solution is prepared from 222.6 g of ethylene glycol (C₂H₆O₂) 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?

Solution:

Mass of solute = 222.6g

Molar mass of solute $C_2H_6O_2$ = 12 x 2 + 4 + 2 (12+1) = 62 g mol⁻¹

Moles of solute = 222.6/62= 3.59

Mass of solvent = 200 g

Molality= 3.59/200 x 1000= 17.95 mol kg⁻¹

Total mass of solution = 422.6g

Volume of solution = 422.6/1.072 = 394.21 mL

Molarity= 3.59 / 394.2 x1000 = 9.1 mol L⁻¹

Question:9 A sample of drinking water was found to be severely contaminated with chloroform (CHCl₃) supposed to be a carcinogen. The level of contamination was 15 ppm (by mass) :

i.) Express this in percent by mass

ii.) Determine the modality of chloroform in the water sample.

Solution:

15 ppm means 15 parts in million (10*6) by mass in the solution

: percentage by mass = $15/10^6 \times 100 = 15 \times 10^{-4}$ %

As only 15g of chloroform is present in 10^6g of the solution, mass of the solvent = 106g

Molar mass of $CHCl_3$ -12+1+3 ×35.5 = 119.5 mol^{-1}

Moles of $CHCl_3$ = 15 /119.5

: Molality = $15/119.5 \times 1000 / 10^6 = 1.25 \times 10^{-4}$ m

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

Solution:

Alcohol and water both have strong tendency to form intermolecular hydrogen bonding. On mixing the two, a solution is formed as a result of formation of H-bonds between alcohol and H_2O molecules but these interactions are weaker and less extensive than those in pure H2p. Thus they show a positive deviation from ideal behaviour. As a result of this, the solution of alcohol and water will have higher vapour pressure and lower boiling point than that of water and alcohol.

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

Solution:

When gases are dissolved in water, it is accompanied by a release of heat energy, i.e., process is exothermic. When the temperature is increased, according to Lechatlier's Principle, the equilibrium shifts in backward direction, and thus gases becomes less soluble in liquids.

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

Solution:

The effect of pressure on the solubility of a gas in a liquid is governed by Henry's Law. It states that the solubility of a gas in a liquid at a given temperature is directly proportional to the partial pressure of the gas. Mathematically. P-KHX where P is the partial pressure of the gas and X is the mole fraction of the gas in the solution and KH is Henry's Law constant.

Applications of Henry's law:

(1) In the production of carbonated beverages (as solubility of CO_2 increases at high pressure)

(ii) In the deep sea diving.

(iii) For climbers or people living at high altitudes, where low blood O_2 causes climbers to become weak and make them unable to think clearly.

Question:13 The partial pressure of ethane over a solution containing 6.56 x 10^{-3} g of ethane is 1 bar. If the solution contains 5.00 x 10^{-2} g of ethane, then what shall be the partial pressure of the gas?

Solution:

We know that, m = KH × P

6.56 x 10^2 g = KH x 1 bar…. (i)

5.00 10^2 g=KH × P……(ii)

KH = 6.56 × 10^2/1 bar (from i)

KH = 5.00 x 10^2/P bar (from ii)

∴ 6.56x10^{-2}/1 = 5.00 x10^{-2}/P

P = 5.00/6.56 = 0.762 bar

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

Solution:

Solutions having vapour pressures more than that expected from Raoult's law and to exhibit positive deviation. In these solutions solvent-solute interactions are weaker and $\Delta_{mix}H$ is positive because stronger A-A or B-B interactions are replaced by weaker A-B interactions. Breaking of the stronger interactions requires more energy & less energy is released o formation of weaker interactions. So overall & ΔmixH is positive. Similarly. $\Delta_{mix}V$ is positive I.e. the volume of solution is somewhat more than sum of volumes of solvent and white. So there is expansion in volume on solution formation. Similarly in case of solutions exhibiting negative deviations. A-B interaction are stronger than A-A and B-B. So weaker interactions are replaced by stronger interactions, so there is release of energy I. e. $\Delta_{mix}H$ is negative.

Question: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:

Vapour pressure of the solution at normal boiling point = 1.004 bar

Vapour pressure of pure water at normal boiling point = 1.013 bar

Mass of solute = 2 g

Mass of solvent (water) = 98 g

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

According to Raoulte's law,

$$\frac{p^0_1 - p_1}{p^0_1} = \frac{w_2 \times M_1}{M_2 \times w_1}$$

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

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

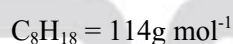$$= M_2 = \frac{1.013 \times 2 \times 18}{0.009 \times 98}$$

$$= 41.35g\ mol^{-1}$$

Question:16 Heptane and octane form an ideal solution. At 373 K, the vapour pressures of the two liquid components are 105.2 k Pa 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:

We have given molar mass of heptane,

C_7H_{16} = 100g mol_{-1}

Molar mass of octane,

C_8H_{18} = 114g mol^{-1}
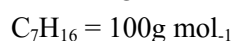
Moles of heptane = $\dfrac{\text{Wt. of heptane}}{\text{Mol. Mass of heptane}}$

= 26/100 = 0.26

Similarly moles of octane,

= 35/114 = 0.31

Mole fraction of heptane,

$$= \frac{n_A}{n_A + n_B}$$

$$= \frac{0.26}{0.26 + 0.31} = 0.456$$

Mole fraction of octane,

$= \underline{0.31}$ $= 0.543$
$0.31 + 0.26$

Partial vapour pressure = mol. Fraction x vapour pressure of pure component

Partial vapour pressure of heptane

= 0.456 x 105.2 = 47.97 kPa

Partial vapour pressure of octane

= 0.543 x 46.8 = 25.4 kPa

Total vapour pressure of solution = 73.08 kPa.

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

Answer:

1 molal solution means 1 mole of solute is present in 1000g of solvent (water)

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

No. of moles present in 1000g of water = 1000/18

= 55.56 mol

Therefore mole fraction of the solute in solution is

x_2 = 1/(1 + 55.56) = 0.0177

It is given that,

Vapour pressure of water p_1^0 = 12.3 kPa

Applying the relation = $p_1^0 - p_1 / p_1^0 = X_2$

= 12.3 – p_1 / 12.3 = 0.0177

12.3 – p_1 = 0.2177

p_1 = 12.0823

Hence the vapour pressure of solution is 12.083 kPa

Question: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:

Vapour pressure of pure octane be p_1^0

Vapour pressure of octane after dissolving the non – volatile solute is 80/100 p_1^0 = 0.8 p_1^0

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

Mass of octane w_1 = 114 g

Molar mass of octane (C_8H_{18}) = 12 x 8 + 1 x 18 = 114g mol^{-1}

Applying the relation,

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

$$\frac{p_1^0 - 0.8p_1^0}{p_1^0} = w_2 \times 114 / (40 \times 114)$$

$$0.2p_1^0 / p_1^0 = w_2/40$$

$$w_2 = 8g$$

Hence, required mass of the solute is 8g.

Question:19 A 5% solution (by mass) of cane sugar in water has freezing point of 271K Calculate the freezing point of 5% glucose in water if freezing point of pure water is 273.15 K.

Answer:

Here, ΔT_f = (273.15 – 271) K

= 2.15 K

Molar mass of sugar ($C_{12}H_{22}O_{11}$) = 12 x 12 + 1 x 22 + 16 x 11 = 342g mol^{-1}

5% of cane sugar in water means 5g of cane sugar is present in (100 – 5)g = 95g of water

Now no. of moles of cane sugar = 5/342 mol

= 0.0146 mol

Molality of the solution, m = 0.0146 mol / 0.095kg

0.1537 mol kg^{-1}

Applying the relation,

$\Delta T_f = K_f \times m$

K_f = 2.15K /0.1537 mol kg^{-1}

13.99K mol kg^{-1}

Molar mass of glucose = 180g mol^{-1}

5% of glucose in water means 5g of glucose is present in (100 – 5)g = 95g of water

Number of moles of glucose = 5/180

= 0.0278 mol

Molality of the solution, m = 0.0278 mol / 0.095kg

= 0.2926 mol kg^{-1}

Applying the relation,

$\Delta T_f = K_f \times m$

= 13.99K mol kg^{-1} x 0.2926 mol kg^{-1}

= 4.09 K

Hence, freezing point of 5% of glucose is (273.15 – 4.09)K = 269.06 K

Question:20 Two elements A and B form compounds having formula AB_2, and AB_4. When dissolved in 20 g of benzene (C_6H_6). 1 g of AB_2, lowers the freezing point by 2.3 K whereas 1.0 g of AB_4, lowers it by 1.3 K. The molar depression constant for benzene is 5.1 K kg mol^{-1}. Calculate atomic masses of A and B.

Answer:

$M_B = (K_f \times w_B \times 1000) / (w_A \times \Delta T_F)$

Now $\Delta T_f = 2.3$, $w_B = 1.0$, $w_A = 20$, $K_f = 5.1$ (given)

Putting the values in the equation:

$M_B = (5.1 \times 1 \times 1000) / (20 \times 2.3) = 110.87$ g/mol

Therefore $M_{AB2} = 110.9$

For AB_4 compound

$\Delta T_f = 1.3$, $w_b = 1$, $w_a = 20$

$M_B = (5.1 \times 1 \times 1000) / (20 \times 1.3) = 196$ g/mol

Therefore $M_{AB} = 196$

Let x be the atomic mass of A & y be the atomic mass of B,

Then $M_{AB2} = x + 2y = 110.9$ ---------- (1)

And $M_{AB} = x + 4y = 196$ ---------- (2)

Subtracting 2 from 1 ,we get

2y = 196 - 110.9

y   = 85.1 / 2

y = 42.6

Putting the value of y in 1 we get

x = 110.9 - 2 x 42.6

x = 25.59

Therefore atomic mass of A = 25.59 u Atomic mass of B = 42.6 u

Question:21 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 K

π = 1.52 bar

R = 0.083 bar L K^{-1} mol^{-1}

Applying the relation,

π = CRT

C = π/RT

C = 1.52 bar / 0.083 bar L K^{-1} x 300K

= 0.061 mol

Since volume of the solution is 1 litre and concentration of the solution would be 0.061 mol.

Question:22 Suggest the most important type of intermolecular attractive interaction in the following pairs.

1.) **N-hexane and n-octane**

2.) **I2 and CCI4**

3.) **NaCIO4 and water**

4.) **methanol and acetone**

5.) **acetonitrile (CH3CN) and acetone (C3H6O).**

Answer:

1.) Both n – hexane and n – octane are non – polar. Thus, the intermolecular interaction will be London dispersion forces.

2.) Both I$_2$ and CCl$_4$ are non – polar. Thus, the intermolecular forces will be London dispersion forces.

3.) NaClO$_4$ is an ionic compound and gives Na$^+$ and ClO$_4^-$ ions in the solution. Water is a polar molecule. Thus, the intermolecular interaction will be ion – dipole interaction.

4.) Both methanol and acetone are polar molecules. Thus, the intermolecular interaction will be dipole – dipole interaction.

5.) Both CH$_3$CN and C$_3$H$_6$O are polar molecules. Thus, intermolecular interaction will be dipole – dipole interaction.

Question:23 Based on solute-solvent interactions, arrange the following in order of increasing solubility in n-octane and explain. Cyclohexane, KCI, CH3OH, CH3CN.

Answer:

(a) Cyclohexane and n – octane both are non – polar. They mix completely in all proportion.

(b) KCl is an ionic compound, KCl will not dissolve in n – octane.

(c) CH$_3$OH is polar, will dissolve in n – octane.

(d) CH_3CN is polar but less than CH_3OH. Therefore, it will dissolve in n – octane but to a greater extent as compared to CH_3OH. Hence, the order is KCL < CH_3OH < CH_3CN < Cyclohexane.

Question:24 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 (having polar – OH) - Partially soluble.
- ii.) Toluene (non – polar) – insoluble.
- iii.) Formic acid (forms hydrogen bond with water molecules) – Highly soluble.
- iv.) Ethylene glycol (form hydrogen bond with water molecules) – Highly soluble.
- v.) Chloroform (non – polar) – insoluble.
- vi.) Pentanol (having polar – OH) – partially soluble.

Question:25 If the density of some lake water is 1.25g ml^{-1} and contains 92 g of Na*+ Ions per kg of water, calculate the molality of Na*+ ions in the lake.

Answer:

Molar mass of Na = 23g mol^{-1}

: No. of moles of Na^+ ions present = 92/23 = 4 moles

: Molality = 4 x 1000/1000 = 4 m.

Question:26 If the solubility product of CuS is 6 x 10^{-16} calculate the maximum molarity of CuS in aqueous solution.

Answer:

CuS $\rightarrow$ Cu^{2+} + S^{2-}, K_s = 6 x 10^{-16}

Maximum molarity of CuS in aqueous solution means solubility of CuS

Let the solubility of CuS be S mol L^{-1}

: $K_S = [Cu^{2+}][S^{2-}]$ 6 x 10^{-16} = S x S = S^2

: S = $\sqrt{6}$ x 10^{-8} = 2.45 x 10^{-8} mol L^{-1}

Question:27 Calculate the mass percentage of aspirin (C9H8O4) in acetonitrile (CH₃CN) when 6.5 g of $C_9H_8O_4$ is dissolved in 450 g of CH_3CN.

Answer:

6.5 g of $C_9H_8O_4$ is dissolved in 450 g of CH_3CN.

Then, total mass of the solution = (6.5 + 450)g = 456.5 g

Therefore, mass percentage of $C_9H_8O_4$

= 6.5/456.5 x 100%

= 1.424%

Question:28 Nalorphene ($C_{19}H_{23}NO_3$). 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.

Answer:

The molar mass of nalorphene ($C_{19}H_{23}NO_3$) is given as:

12 x 19 +1 x 23 + 14 + 16 x 3 = 311g mol^{-1}

In 1.5 x 10^{-3} m aqueous solution of nalorphene

1 kg of water contains 1.5 x 10^{-3} mol = 1.5 x 10^{-3} x 311 g

= 0.4665g

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

= 1000.4665g

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

Therefore, mass of the solution containing 1.5mg 0f nalorphene is :

= 1000.4665 x 1.5 x 10^{-3}g
    0.4665

= 3.22g

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

Question:29 Calculate the amount of benzoic acid (C_6H_5COOH) required for preparing 250 ml of 0.15 M solution in methanol.

Answer:

0.15 M solution of benzoic acid in methanol means, 1000ml of solution contains 0.15 mol of benzoic acid.

0.15 x 250/1000

Therefore, 250 ml of solution contains = mol of benzoic acid = 0.0375 mol of benzoic acid.

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

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

= 4.575g

Question;30 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:

When strongly electron withdrawing groups are present on alpha C atom of acetic acid, the acid strength and the degree of dissociation increases. This increases the vant Hoff factor i and the depression in the freezing point. Trifluoroacetic is most acidic because fluorine is most electron withdrawing in nature. Hence, trifluoroacetic acid has maximum depression in the freezing point.

Question:31 Calculate the depression in the freezing point of water when 10 g of $CH_3CH_2CHClCOOH$ is added to 250 g of water. Ka = 1.4 x 10^{-3}, Kf = 1.86 K kg mol^{-1}.

Answer: Molar mass of $CH_3CH_2CHClCOOH$ = 122.5g mol^{-1}

Moles of CH3CH2CHClCOOH = 10g / 122.5 g/mol

= 0.0816 mol

Therefore molality of the solution

= (0.0816 x 1000) / 250

= 0.3265 mol kg^{-1}

Now if a is the degree of dissociation of $CH_3CH_2CHClCOOH$,

So, Ka = (Cα x Cα) / (C (1-α))

Ka = $Cα^2$ / (1-α)

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

$Ka = C\alpha^2$

$\alpha = \sqrt{K\alpha} / C$

Putting the values ,We get

$\alpha = \sqrt{1.4 \times 10^{-3}} / 0.3265$

$= 0.0655$

Now at equilibrium, the van't hoff factor $i = 1-\alpha +\alpha +\alpha/1$

$= 1 + 0.0655$

$= 1.0655$

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

Therefore $\Delta T_f = i\, K_f\, m\, v$

$= 1.065\, v \times 1.86 \times 0.3265$

$= 0.647°$

Question:32 19.5 g of CH$_2$FCOOH 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:

Fluoroacetic acid has a molecular mass of 78 g/mol.

Number of moles of fluoroacetic acid is $= 19.5/78 = 0.25$.

Molality is the number of moles of solute in 1 kg of solvent.

Molality $= 0.25 \times 1000 / 500 = 0.50$ m

Calculated depression in the freezing point.

$\Delta T_f = K_f \times m = 1.86 \times 0.50 = 0.93$ K

Van't Hoff factor is the ratio of observed freezing point depression to calculated freezing point depression. $i = 1.0 / 0.93 = 1.0753$

Let c be the initial concentration of fluoro acetic acid and α be its degree of dissociation.

$CH_2FCOOH \rightarrow CH_2FCOO^- + H^+$
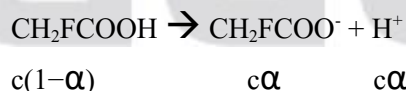
$c(1-\alpha)$ $c\alpha$ $c\alpha$

Total number of moles $= c(1-\alpha)+c\alpha+c\alpha = c(1+\alpha)$

$i = c(1+\alpha) / c = 1+\alpha = 1.0753$

$\alpha = 0.0753$

$[CH_2FCOO^-] = [H^+] = c\alpha = 0.50 \times 0.0753 = 0.03765$

$[CH_2FCOOH] = c(1-\alpha) = 0.50(1-0.0753) = 0.462$

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

Ka = $\frac{0.462}{0.03765 \times 0.03765}$

Ka = 3.07×10^{-3}

Hence, the van't Hoff factor is 1.0753 and dissociation constant is 3.07×10^{-3} for fluoroacetic acid

Question:33 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° = 17.535 mm of Hg

Mass of glucose, w2 = 25 g

Mass of water, w1 = 450 g

We know that,

Molar mass of glucose ($C_6H_{12}O_6$),

M_2 = 6 × 12 + 12 × 1 + 6 × 16 = 180 g mol^{-1}

Molar mass of water, M_1 = 18 g mol^{-1}

Then, number of moles of glucose, n_1 = 25/180 = 0.139 mol

And, number of moles of water, n_2 = 450/18 = 25 mol

Now, we know that,

$(p_1^\circ - p^\circ) / p_1^\circ = n_1 / n_2 + n_1$

$\Rightarrow$ 17.535 - p$^\circ$ / 17.535 = 0.139 / (0.139+25)

$\Rightarrow$ 17.535 – p_1 = 0.097

$\Rightarrow p_1$ = 17.44 mm of Hg

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

Question:34 Henry's law constant for the molality of methane in benzene at 298 K is 4.27 x 10^5 mm Hg. Calculate the solubility of methane in benzene at 298 K under 760 mm Hg.

Answer:

As we know that,

P = k x c

We have given that,

P = 760 mm and k = 4.27 x 10⁵ mm Hg

Putting the given values in equation:

760 = 4.27 x 10⁵ x c or,

c = 760 / 4.27 x 10⁵

c = 178 x 10⁻⁵

Question:35 100 g of liquid A (molar mass 140 g mol) 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 = 100 / 140 = 0.714

Number of Moles of Liquid B, n_B = 1000 / 180 = 5.556

Then Mole fraction of A = n_A / n_A + n_B = 0.714 / 0.714 + 5.556

= 0.114

Now Mole of fraction of B = 1 - 0.114 = 0.886

Now p total = p_A + p_B

Or ptotal = $p°_A X_A$ + $p°_B X_B$

475 = $p°_A$ X 0.114 + 500 X 0.886

$p°_A$ = 280.7 torr

Therefore vapour pressure of pure A = 280.7 torr

Vapour pressure of A in solution = 280.7 x 0.114

= 32 torr

Now

p_A = $p°_A X_A$

Or

$p°_A$ = p_A / X_A

⇒ 32 / 0.114

= 280.7 torr

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

Question:36 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 naphthalene.

Answer:

Number of moles is the ratio of mass to molar mass.

The molar masses of benzene and toluene are 78 g/mol and 92 g/mol respectively.

Number of moles of benzene = 80/78 = 1.026

Number of moles of toluene = 100/92 = 1.087

Mole fraction of benzene, X_B = $\dfrac{1.026}{1.026+1.087}$

=0.486

Mole fraction of toluene, X_T

=1 − 0.486 = 0.514

$P_B = P_B^0 \times X_B$ = 50.71 × 0.486 = 24.65 mm Hg

$P_T = P_T^0 X_T$

=32.06×0.514=16.48 mm of Hg

Total vapour pressure =24.65+16.48=41.13 mm Hg

Mole fraction of benzene in vapour phase is as follows:

Y_B = $\dfrac{41.13}{24.65}$

=0.60

Question:37 The air is a mixture of 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 at 298 K are 3.30 x 10^7 mm and 6.51 x 10^7 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 × 760) mm Hg = 7600 mm Hg

Therefore, Partial pressure of oxygen, p_{O2} = 20/100 *7600

=1520 mm Hg

Partial pressure of nitrogen,p_{N2} = 79/100 *7600

= 6004 mmHg

Now, according to Henry's law:

p = K_H.x

For oxygen:

$P_{O2} = K_H. x_{O2}$

$\Rightarrow x_{O2} = p_{O2} / K_H$

= 1520 / 3.30 X 107

= 4.61 10-5

For nitrogen:

$P_{N2} = K_H.x_{N2}$

$\Rightarrow x_{N2} = p_{N2} / K_H$

= 6004 / 6.51 x 107

= 9.22 x 10-5

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

Question;38 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.

Answer:

π = i n/V RT

$\Rightarrow \pi$ = i w/MV iRT

$\Rightarrow$ w = πMV / iRT   ....(1)

Now we have given below values:

π = 0.75 atm

V = 2.5L

i = 2.47

T = (27+273) K = 300K

Here,

R = 0.0821L atm k^{-1} mol^{-1}

M = 1 x 40 + 2 x 35.5

= 111 g/mol

Now putting the value in equation 1:

w = 0.75 x 111 x 2.5 / 2.47 x 0.0821 x 300
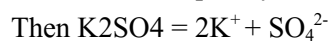
=3.42g

Hence, the required amount of CaCl2 is 3.42 g.

Question:39 Determine the osmotic pressure of a solution prepared by dissolving 25 mg of K_2SO_4 in 2 litre of water at 25° C, assuming that it is completely dissociated.

Answer:

If K_2SO_4 is completely dissociated than these ions are produced

Then $K2SO4 = 2K^+ + SO_4^{2-}$

So total no of ions produced = 3

Therefore I = 3

Now molecule mass of K_2SO_4 = 2 x 39 + 1 x 32 + 4 x 16 = 174 g/mol

Now n = I Crt

= I W_B x RT/ M_B x V

= 3 x 25 x 10^{-3} x 0.082 x 298/ 174 x 2 = 5.27 x 10^{-3}atm.