Solution

KEY CONCEPTS

Solution is the homogeneous mixture of two or more substances in which the components are uniformly distributed into each other. The substances which make the solution are called components. Most of the solutions are binary i.e., consists of two components out of which one is solute and other is solvent. Ternary solution consists of three components

Solute - The component of solution which is present in smaller quantity.

Solvent – The component of solution present in larger quantity or whose physical state is same as the physical state of resulting solution.

Types of solutions: Based on physical state of components solutions can be divided into 9 types.

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

Solid solutions are of 2 types -

1. Substitutional solid solution e.g. Brass (Components have almost similar size)

2. Interstitial solid solution e.g. steel (smaller component occupies the interstitial voids)

Expression of concentration of solution

1. **Mass percentage**= amount of solute present in 100grm solution.
   Percentage = $\frac{mass\ of\ solute W_B}{mass\ of\ solution(W_A+W_B)} \times 100$

For liquid solutions percentage by volume is expressed as = $\frac{Volume\ of\ solute(V_B)}{volume\ of\ solution(V_A+W_B)} \times 100$

2**. 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= n_A +n_B , X_B= n_A+n_B , Sum of all the components is 1 ; $X_A+X_B=1$

3. **Molarity (M)** = $\frac{no.of\ moles\ of\ solute}{volume\ of\ solution(L)}$

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

4. **Molality (m)** = $\frac{No.of\ moles\ of\ solute}{Mass\ of\ solvent(in\ kg)}$

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

5**. Normality (N)** = $\frac{no.of\ gram\ equivalent\ of\ solute}{volume\ of\ solution(L)}$

It changes with changes temperature.

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

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.

Roult'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
   $P_A \propto X_A$
   $P_A = P^0_A.X_A$
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.
   $P_A=P^0_{A}.X_{A},$ $P_B=P^0_B.X_B$
   And total vapor pressure is equal to sum of partial pressure. $P_{total} = P_A + P_B$

Ideal solution – The solution which obeys Roult'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 –

$P_A = P^0_A X_{A},$ $P_B = P^0_B.X_B$

$\Delta H_{Mix} = 0,$ $\Delta V_{mix} = 0$

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) $P_A \neq P^0_A.X_A$ (b) $P_B \neq P^0_B.X_B$
(b) $\Delta H_{mix} \neq 0$ (d) $\Delta V_{mix} \neq 0$

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

i. For solution showing positive deviation
   $P_A > P^0_A$, $P_B > P^0_B.X_B$
   ΔH_{Mix} = positive, ΔV_{mix}=positive (A-B interaction is weaker than A-A and B-B)
   E.g. alcohol and water

ii. For the solution showing negative deviation

$P_A < P^0_{A.}X_A$, $P_B < P^0_B.X_B$

ΔH_{Mix}= negative, ΔV_{mix} = 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:

$$(P^o_A - P_A)/P^o_A = X_B$$

Determination of molar mass of solute

$$M_B = (W_A \times M_A \times P^o_A)/W_A \times (P^o_A - P_A)$$

Elevator in Boiling Point

$$\Delta T_B = Kb.\ m$$

Where $\Delta T_B = T'_B - T^o_B$

Kb = molal elevator constant

M = molality

$$M_B = (Kb \times 1000 \times W_B)/\Delta T_B \times W_A$$

Depression in Freezing Point:

$$\Delta T_f = k_f.\ m$$

Where $\Delta T_f - T'_f$; m = molality

K_f = molal depression constant

unit = $k.kgmol^{-1}$

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 **π** and it is expressed as

$$\Pi = \frac{n}{V} RT$$

$$\Pi = CRT$$

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

R = 0.0821 $Latmmol^{-1}$; T = 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.

Q1- What do you mean by Henry's Law? The Henry's Law constant for oxygen dissolved in water is 4.34×10^4 atm at 25^o 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^o C.

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

$$P_A \alpha X_A \ ; K_{H =} \text{ Henry's Law of constant}$$

$$P_A = K_H \times A$$

$$K_H = 4.34\times10^4 \text{ atm}$$

$$PO_2 = 0.2 \text{ atm}$$

$$Xo_2 = PO_2 / K_H \quad =0.2 / 4.34\times10^4 = 4.6\times10^{-6}$$

If we assume 1L solution = 1L water

n water = 1000/18 = 55.5

$$XO_2 = \quad nO_2 \ /(nO_2 + n\, H_2O) \ \sim = \quad nO_2 / nH_2O$$

$nO_2 = 4.6 \text{ X } 10^{-6} \text{ X } 55.5 = 2.55 \text{ X } 10^{-4}$ mol

$M = 2.55 \text{ X } 10^{-4}$ M

Q.2. What is Vant Hoff factor?

Ans. It is the ratio of normal molecular mass to observed molecular mass . H is denoted as 'i'

i = normal m.m / observed m.m

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

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

Ans 5 and 3

Q.4. Why the molecular mass becomes abnormal?

Ans. Due to association or dissociation of solute in given solvent .

Q.5. Define molarity, how it is related with normality ?

Ans. N = M x Basicity or acidity.

Q.6. How molarity is related with percentage and density of solution ?
Ans. M = P x d x10/M.M

Q.7. What role does the molecular interaction play in the solution of alcohol and water?

Ans. Positive deviation from ideal behavior .

Q.8. What is Vant Hoff factor , how is it related with

a. degree of dissociation   b. degree of association

Ans. a. α=i – 1/n-1   b. α = i -1 / 1/n -**1**

Q.9. Why NaCl is used to clear snow from roads ?

Ans. It lowers f.p of water

Q10. why the boiling point of solution is higher than oure liquid

Ans. Due to lowering in v.p

HOTS

Q1. 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 .

Q.3. Define azeotrope , give an example of maximum boiling azeotrope.

Q.4. Calculate the volume of 75% of H_2SO_4 by weight (d=1.8 gm/ml) required to prepare 1L of 0.2M solution

Hint: M_1 = P x d x 10 /98

$M_1 V_1 = M_2V_2$

14.5ml

Q.5. Why water cannot be completely separated from aqueous solution of ethyl alcohol?

Ans. Due to formation of Azeotrope at (95.4%)

SHORT ANSWERS (2 MARKS)

Q.1. How many grams of KCl should be added to 1kg of water to lower its freezing point to -8.0^{0}C (kf = 1.86 K kg /mol)

Ans. Since KCl dissociate in water completely L=2

$\Delta Tf = i\,kf \times m$; m =$\Delta Tf/ikf$

m= 8 / 2X1.86 = 2.15mol/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 = 2X 18 /m_B X 98

$m_{B\,=}$ 41.35gm/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.

1. Mole fraction
2. Ideal solutions

(b)15 g of an unknown molecular material is dissolved in 450 g of water. The resulting solution frrezez at -0.34 ^{0}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. Boling point elevation constant for a solvent

(b)a solution of glycerol ($C_3h_80_3$) in water was prepared by dissolving some glycerol in in 500 g of water. The solution has a boiling point of 100.42 ^{0}c . what mass of glycerol was dissolved to make this solution?

Kb for water = 0.512 k Kg mol^{-1}

(hint: atb = $\frac{b*wb*1000}{Mb*Wa}$

Ans. 37.73 gm

Q 13. 2 g of benzoic acid (c_6h_5cooh) 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%

Q14. Osmotic pressure of a 0.0103 molar solution of an electrolite is found to be 0.70 atm at 27^{0}c . calculate Vant Hoff factor.(R=0.082 L atom mol^{-1} K^{-1}) Ans. 2.76