

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

Solubility - Maximum amount of solute that can be dissolved in 100g 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 100gm solution.

$$\text{Mass Percentage} = \frac{\text{mass of solute } W_B}{\text{mass of solution } (W_A + W_B)} \times 100$$

$$\text{Percentage by volume is expressed as} = \frac{\text{Volume of solute } (V_B)}{\text{volume of solution } (V_A + V_B)} \times 100 \text{ (Liquid- liquid solution)}$$

2. **Mole fraction** it is the ratio of no. of moles of one of the components to the total no. of moles of all components. It is expressed as 'x'. For two component system made of A and B ,

$$X_A = n_A / (n_A + n_B), X_B = n_B / (n_A + n_B), \text{ Sum of all the components is } 1 ; X_A + X_B = 1$$

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

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

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

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

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

$$\text{Ppm} = \frac{W_B}{W_B + W_A} \times 10^6$$

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

Raoult's Law –

1. For the solution containing non-volatile solute the vapour pressure of the solution is directly proportional to the mole fraction of solvent at particular temperature

$$P_A \propto X_A$$

$$P_A = P_A^0 \cdot X_A$$

2. For the solution consisting of two miscible and volatile liquids the partial vapour pressure of each component is directly proportional to its own mole fraction in the solution at particular temperature.

$$P_A = P_A^0 \cdot X_A,$$

$$P_B = P_B^0 \cdot X_B$$

And total vapour pressure is equal to sum of partial pressure. $P_{\text{total}} = P_A + P_B$

Ideal solution – The solution which obeys Raoult'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 –

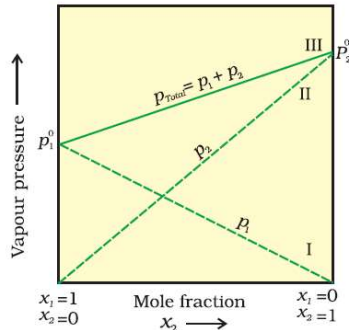
$$P_A = P_A^0 X_A, \quad P_B = P_B^0 X_B$$

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

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

1. Benzene and Toluene
2. Chlorobenzene and Bromobenzene

Very dilute solutions exhibit ideal behavior to greater extent.



The plot of vapour pressure and mole fraction of an ideal solution at constant temperature.

Non-ideal solution –

- (a) $P_A \neq P_A^0 X_A$ (b) $P_B \neq P_B^0 X_B$
 (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

$$P_A > P_A^0 X_A, \quad P_B > P_B^0 X_B$$

$$\Delta H_{\text{Mix}} = \text{positive}, \quad \Delta V_{\text{mix}} = \text{positive (A-B interaction is weaker than A-A and B-B)}$$

E.g. alcohol and water

- ii. For the solution showing negative deviation

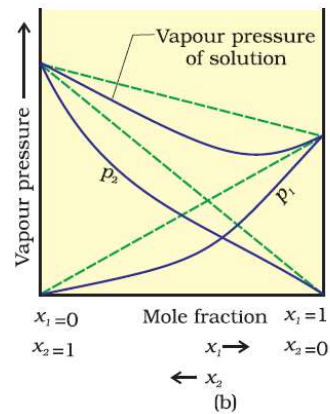
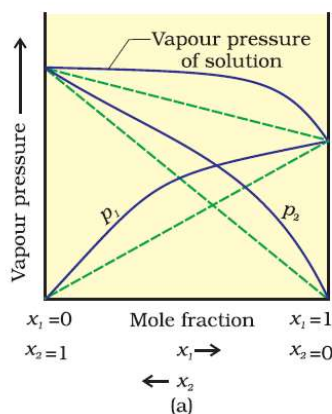
$$P_A < P_A^0 X_A, \quad P_B < P_B^0 X_B$$

$$\Delta H_{\text{Mix}} = \text{negative}, \quad \Delta V_{\text{mix}} = \text{negative}$$

A-B interaction is stronger than A-A and B-B interactions

E.g. Chloroform and acetone, HCl and water

The vapour pressures of two component systems as a function of composition (a) a solution that shows positive deviation from Raoult's law and (b) a solution that shows negative deviation from Raoult's law.



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 - All those properties which depend on the number of solute particles irrespective of their nature relative to the total number of particles present in the solution. Such properties are called *colligative properties* (colligative: from Latin: co means together, ligare means to bind).

These are: (1) relative lowering of vapour pressure of the solvent (2) depression of freezing point of the solvent (3) elevation of boiling point of the solvent and (4) osmotic pressure of the solution.

Relative lowering in vapour pressure:

$$\frac{(P_A^0 - P_A)}{P_A^0} = \chi_B ; \text{ where } \chi_B = \text{mole fraction of solute}$$

Determination of molar mass of solute

$$M_B = \frac{W_A \times M_A \times P_A^0}{W_A \times (P_A^0 - P_A)}$$

Elevation in Boiling Point

$$\Delta T_B = K_b \cdot m$$

$$\text{Where } \Delta T_B = T'_B - T_B^0$$

K_b = molal elevation constant

M = molality

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

Depression in Freezing Point:

$$\Delta T_f = K_f \cdot m$$

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

K_f = molal depression constant

$$\text{unit} = K \cdot \text{kg mol}^{-1}$$

Osmotic Pressure

When two solutions of different concentrations are separated by semipermeable membrane, there is spontaneous flow of solvent from dilute solution to concentrated solution. This phenomenon is Osmosis. The minimum external pressure applied on concentrated solution to stop the flow of solvent is known as Osmotic pressure. It is denoted by π and is expressed as

$$\pi V = nRT$$

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

$$\pi = CRT$$

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

$R = 0.0821 \text{ L atm K}^{-1} \text{ mol}^{-1}$; T = temperature in kelvin.

→ **Isotonic solutions** have same osmotic pressure.

→ Solutions having comparatively higher osmotic pressure are **Hypertonic Solutions** and those having comparatively lower osmotic pressure are called **hypotonic solutions**.

→ Blood fluid possesses osmotic pressure equal to that of 0.91% solutions of sodium chloride.

→ **Abnormal molecular mass**: Molar mass of solute in solution either less or more than the normal molar mass is called abnormal molar mass. Abnormality in the molar mass arises either due to association or dissociation of the solute particles in the solution. Such abnormality in the calculation of molecular mass is overcome by Van't Hoff factor.

→ **Van't Hoff factor(i)** = $\frac{\text{Observed Colligative property}}{\text{Normal Colligative properties}} = \frac{\text{Normal molecular mass}}{\text{Observed molecular mass}}$

→ **Degree of association(α)** = $\frac{i-1}{1/n - 1}$

→ **Degree of dissociation(α)** = $(i-1) / (n-1)$

Important Questions

Q1- What do you mean by Henry's Law? The Henry's Law constant for oxygen dissolved in water is $4.34 \times 10^4 \text{ atm}$ 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.

$P_A \propto X_A$; K_H = Henry's Law constant

$$P_A = K_H \times X_A$$

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

$$p_{O_2} = 0.2 \text{ atm}$$

$$X_{O_2} = p_{O_2} / K_H = 0.2 / 4.34 \times 10^4 = 4.6 \times 10^{-6}$$

If we assume 1L solution = 1L water

$$n_{\text{water}} = 1000/18 = 55.5$$

$$X_{O_2} = \frac{n_{O_2}}{(n_{O_2} + n_{H_2O})} \cong \frac{n_{O_2}}{n_{H_2O}}$$

$$n_{O_2} = 4.6 \times 10^{-6} \times 55.5 = 2.55 \times 10^{-4} \text{ mol}$$

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

Q.2. What is Vant Hoff factor?

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

$i = \text{Theoretical Molar mass} / \text{observed molar mass}$

= Observed no. of particles / Actual no. of particles

= Observed colligative property/Theoretical colligative property

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?

Q.6. How molarity is related with percentage and density of solution ?

Ans. $M = P \times \text{Percentage of density} \times 10 / \text{molar mass}$

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

Ans. A – A and B – B type interactions are more than A – B type interactions. Positive deviation from ideal behaviour is observed.

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

a. degree of dissociation b. degree of association

Ans.a. $\alpha = i - 1/n - 1$ b. $\alpha = i - 1 / 1/n - 1$

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

Ans. It lowers f.p of water

Q10. Why is the boiling point of solution higher than pure liquid?

Ans. Due to lowering in V.P.

Some special Questions

Q1. Out of 1M and 1m aqueous solution which is more concentrated?

Ans. 1M as density of water is 1gm/ml

Q2. Henry's law constant for two gases are 21.5 and 49.5 atm, which gas is more soluble?

Ans. K_H is inversely proportional to solubility. Hence gas with $K_H = 21.5$ atm is more soluble.

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

$$M_1 V_1 = M_2 V_2$$

14.5ml

Self Assessment

1. We have many types of water purifiers. Zero-B is based on disinfecting properties of iodine. UV purifier is based on killing of bacteria by UV light. There are R.O. Purifiers, which are being used in common households.
 - (a) What is the full form of R.O. Purifier?
 - (b) What is the function of Porous membrane?
 - (c) Which method of purification is more economical for countries using sea water, flash distillation or reverse osmosis for getting potable water. Why?
2. Water is used as coolant in vehicles. In cars, ethylene glycol is used as coolant. In cold countries, water gets frozen so it cannot act as coolant. Ethylene glycol is added to water so that its freezing point is lower and it does not freeze. At hill station snow fall takes place. Clearing the snow from the road is essential for smooth running of traffic-
 - (a) What is the role of ethylene glycol when added to water?
 - (b) Why does sprinkling of salt help in clearing snow covered roads in hilly areas? Explain the phenomenon involved in the process.
 - (c) How is life of people affected by snow fall?

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°C ($k_f = 1.86 \text{ K kg /mol}$)

Ans. Since KCl dissociate in water completely $L=2$

$$\Delta T_f = i k_f \times m \quad ; m = \Delta T_f / i k_f$$

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

$$\text{Grams of KCl} = 2.15 \times 74.5 = 160.2 \text{ g.}$$

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 molar mass 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.8. Why is it advised to add ethylene glycol to water in a car radiator in hill station?

Hint: Anti- freeze.

Q 9. (a). Define the following terms.

3. Mole fraction

4. Ideal solution

(b) 15 g of an unknown molecular material is dissolved in 450 g of water. The resulting solution freeze at -0.34°C . What is the molar mass of material? K_f for water = $1.86 \text{ K Kg mol}^{-1}$.

Ans. 182.35 g/mol

Q 10.(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 ($\text{C}_3\text{H}_8\text{O}_3$) 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?

K_b for water = $0.512 \text{ K Kg mol}^{-1}$

$$\text{(hint: } \Delta T_b = \frac{K_B \times W_B \times 1000}{M_B \times W_A})$$

Ans. 37.73 g

Q 11. 2 g of benzoic acid ($\text{C}_6\text{H}_5\text{COOH}$) dissolved in 25 g of benzene shows a depression in freezing point equal to 1.62 K . K_f for benzene is $4.9 \text{ K Kg mol}^{-1}$. What is the percentage association of acid if it forms dimer in solution. Ans. 99.2%

Q12. Osmotic pressure of a 0.0103 molar solution of an electrolyte is found to be 0.70 atm at 27°C . Calculate Vant Hoff factor. ($R = 0.082 \text{ L atm mol}^{-1} \text{ K}^{-1}$) Ans. 2.76

