Colligative Properties

BY
DR. V.N. GOWARDIPE

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Methods of expressing concentration of solutions

A. Percentage

- Percentage by Mass: Amount of solute in grams present in 100g of the solution is called as percentage by mass.

$$\text{Percentage by mass} = \frac{\text{Mass of solute}}{\text{Mass of solution}} \times 100$$

Methods of expressing concentration of solutions

- Percentage by volume (m/v): For solid solute amount of solute in grams present in 100ml of the solution is called as percentage by mass.

$$\text{Percentage by volume} = \frac{\text{Mass of solute}}{\text{Volume of solution}} \times 100$$

Methods of expressing concentration of solutions

- Percentage by volume (v/v): For liquid solute ,volume of solute in ml present in 100ml of the solution is called as percentage by mass.

$$\text{Percentage by volume} = \frac{\text{Volume of solute}}{\text{Volume of solution}} \times 100$$

Methods of expressing concentration of solutions

- Strength: The number of grams of solute present per liter of the solution is called as strength of solution.

$$\text{Strength of solution} = \frac{\text{Weight of solute in grams}}{\text{Volume of solution in liters}}$$

Methods of expressing concentration of solutions

- Molarity: Molarity of solution is defined as Number of moles of a solute present per liter of a solution. It is denoted by 'M'.

$$\text{Molarity (M)} = \frac{\text{Number of moles of solute}}{\text{Volume of solution in liters}}$$

$$\text{Molarity (M)} = \frac{\text{Weight of solute in grams}}{\text{Molar mass of solute}} \times \frac{1000}{\text{Volume of solution in ml}}$$

Methods of expressing concentration of solutions

- Normality: Number of gram equivalents of a solute present per liter of a solution is called as normality of solution.it is denoted by 'N'.

$$\text{Normality (N)} = \frac{\text{Number of gram equivalent of solute}}{\text{Volume of solution in liters}}$$

$$\text{Normality (N)} = \frac{\text{Weight of solute in grams}}{\text{Equivalent Weight of solute}} \times \frac{1000}{\text{Volume of solution in ml}}$$

Methods of expressing concentration of solutions

- Molality : The number of mole of solute present per 1000g of solvent is called as molality of solution. It is denoted by 'm'.

$$\text{Molality (m)} = \frac{\text{Number of mole of solute}}{\text{Mass of solvent in grams}}$$

$$\text{Molality (m)} = \frac{\text{Weight of solute in grams}}{\text{Molar mass of solute}} \times \frac{1000\text{g}}{\text{Mass of solvent in gram}}$$

Methods of expressing concentration of solutions

- Mole fraction : Mole fraction of a component in a solution is defined as " the ratio of number of moles of that component to the total number of moles of all the component"

Consider a binary mixture contains n_A moles of component A and n_B moles of component B. The mole fractions are given by.

$$\text{Mole fraction of A} = X_A = \frac{n_A}{n_A + n_B}$$

$$\text{Mole fraction of B} = X_B = \frac{n_B}{n_A + n_B}$$

Also, $X_A + X_B = 1$

Methods of expressing concentration of solutions

- Parts per million :Number of parts of the solute present in one million parts of solution is called as parts per million (ppm).
- In case of solution of solid solute in liquid, it is defined as " the number of milligrams of a solid solute present in one liter of solution(mg/L)".

$$\text{Concentration in ppm} = \frac{\text{Weight of solute in mg}}{\text{Volume of solution in liter}}$$

Colligative properties

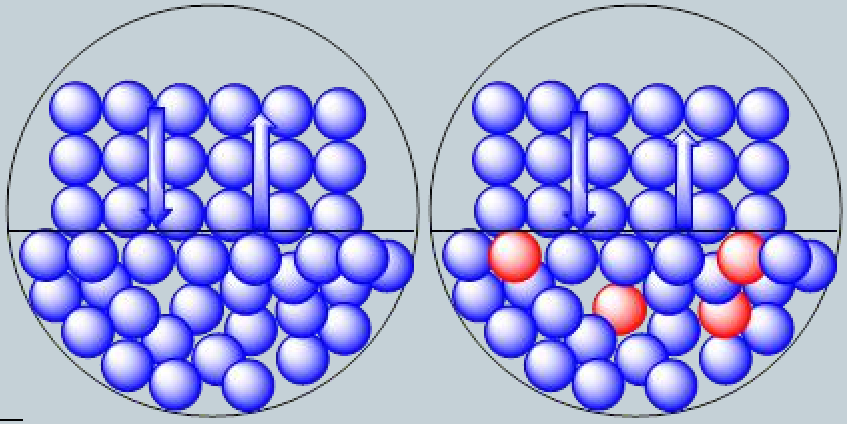
- The properties which depends upon the number of particals of solute present in known volume of given solution and not on the nature of solute are called as **colligative properties**.
- These properties are

1. Lowering of vapour pressure
2. Osmotic pressure
3. Elevation of boiling point
4. Depression in freezing point

Lowering of vapour pressure

- Raoult's Law :This law state that, " The partial vapour of any volatile component of a solution at any temperature is equal to the product of vapour pressure of the pure component and mole fraction of that component in the solution".

Consider a binary mixture of two volatile liquids A and B .Let, n_A and n_B are the number moles of two liquids.



$$\text{Mole fraction of A} = X_A = \frac{n_A}{n_A + n_B}$$

$$\text{Mole fraction of B} = X_B = \frac{n_B}{n_A + n_B}$$

Lowering of vapour pressure

- Consider N moles of a pure solvent with vapour p^o . When n moles of a nonvolatile solute are added to it, the vapour pressure of solution becomes p_s. Then according to Raoult's law,

$$p_s = \frac{N}{N + n} p^o$$

$$\frac{p_s}{p_o} = \frac{N}{N + n}$$

Lowering of vapour pressure

Substracting both sides from 1 we get

$$1 - \frac{p_s}{p_o} = 1 - \frac{N}{N + n}$$

$$\frac{p_o - p_s}{p_o} = \frac{N + n - N}{N + n}$$

Lowering of vapour pressure

$$\frac{p_o - p_s}{p_o} = \frac{n}{N + n} = X_S \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Left hand side of the equation is the relative lowering of vapour pressure of a solution while right hand side is the mole fraction of solute .Hence Raoult's law can be stated as " The relative lowering of vapour of the solution containing a non volatile solute is equal to the mole fraction of the solute in the solution".

Lowering of vapour pressure

For extremely dilute solutions, the number of moles of solute can be neglected as compare to that of solvent. Hence,

$N + n \approx N$

therefore,

$$\frac{p_o - p_s}{p_o} = \frac{n}{N}$$

If w and W be the weights and m and M are molar masses of solute and solvent respectively, then

$n = w/m$ and $N = W/M$

Lowering of vapour pressure

$$\frac{p_o - p_s}{p_o} = \frac{n}{N} = \frac{w/m}{W/M}$$

$$\frac{p_o - p_s}{p_o} = \frac{w \times M}{m \times W} \quad \ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Lowering of vapour pressure

Equation (2) is used for determination of molecular weight of organic substances on the basis of lowering of vapour pressure.

- Experimental determination of lowering of vapour pressure : (Ostwald and Walker's method or Transpiration method)

The method involves following steps-

- Pure dry air is passed through a set of weighed bulbs containing the solution , then through a pure solvent nd then through anhydrous calcium chloride.

Lowering of vapour pressure

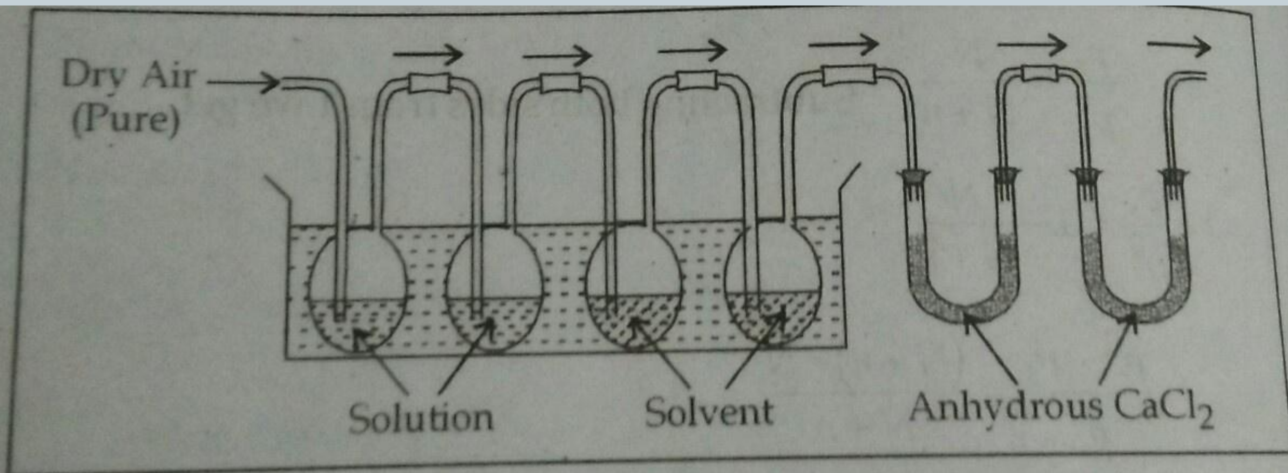


Fig 9.1 : Ostwald and Walker's method

Lowering of vapour pressure

- When air is passes through solution, it gets saturated with vapour. The vapours are carried forward and weight of solution bulb decreases.

loss of weight of solution bulb (w_1) α Vapour pressure of solution (Ps)

- The saturated vapour passes through pure solvent . It takes up a little more vapour, as the vapour pressure of solvent is higher than that of the solution.

loss of weight of solvent α Vapour pressure of solvent (Po) - Vapour pressure of solution (Ps)

Lowering of vapour pressure

$$w_2 \;\alpha\; P_o - P_s$$

Now,

$$\frac{w_2}{w_1+w_2} = \frac{P_o - P_s}{P_s + P_o - P_s} = \frac{P_o - P_s}{P_o} \quad \text{............(1)}$$

This is relative lowering of vapour pressure.

Lowering of vapour pressure

- If water is used as a solvent, the water vapours are absorbed by calcium chloride.

Increase in weight of $CaCl_2$ Tubes (W_3) α Vapour pressure of solvent (P_0)

Therefore,

$$\frac{W_2}{W_3} = \frac{P_0 - P_s}{P_0} \quad \text{..................................(2)}$$

Both equation (1) and (2) can be used for determination of relative