SOLUTIONS

Topic-1

CLASSIFICATION OF SOLUTIONS, STANDARD SOLUTIONS, CONCENTRATIONS AND THEIR DEFINITIONS

VERY SHORT ANSWER QUESTIONS

1. Define molarity?

Ans: Molarity**:** The number of gram moles of the dissolved solute per litre of solution is known as the molarity of the solution. It is represented by 'M'.

$$= \frac{\text{number of moles of the solute}}{\text{volume of the solution in litres}}$$

$$\mathbf{M} = \frac{w}{M.W} \times \frac{1000}{V_{(ml)}}$$

- Units for molarity are moles/litre.
- The molarity is the most convenient and commonly used method of expressing the concentration of solution.
- The molarity of a solution slightly decreases with increase in temperature of the solution, due to increase in volume

2. State the definition of molality?

Ans: Molality : The number of gram moles of the solute dissolved in one kilogram of the solvent is known as the molality of the solution. It is represented by 'm'.

$$m = \frac{\text{number of gram moles of the solute}}{\text{weight of solvent in kilograms}}$$

- The units for molality are mole / kg.
- Molality is independent of temperature.
- Molality is the most inconvenient method of expressing concentration of a solution because it involves determining the weights of liquids.

3. In a binary solution what is mole fraction?

Ans: The ratio between the number of moles of solute and the total number of moles of solute and solvent in the solution is known as the mole fraction of the solute. It is represented by X_1.

$$X_1 = \frac{n}{n+N}$$ n = No.of moles of solute

N = No.of moles of solvent

The ratio between the number of moles of solvent and the total number of solute and the solvent in the solution is known as the mole fraction of the solvent. It is represented by X_2.

$$X_2 = \frac{N}{n+N}$$

4. What is equivalent weight of a salt?

Ans: Equivalent weight of salt: $= \frac{\text{molecular weight}}{\text{total charge(postive or negative)}}$

$$\text{Ex: } E_{NaCl} = \frac{\text{molecular weight}}{1}$$

$$E_{MgCl_2} = \frac{\text{molecular weight}}{2}$$

$$E_{AlCl_3} = \frac{\text{molecular weight}}{3}$$

$$E_{Al_2(SO_4)_3} = \frac{\text{molecular weight}}{6}$$

5. What is Solubility? Give expression for solubility?

Ans: Solubility: It is the weight of solute dissolved in 100 grams of solvent to form saturated solution.

$$\text{Solubility} = \frac{\text{weight of solute}}{\text{weight of solvent}} \times 100$$

6. Define Normality?

Ans: Normality (N)**:** The number of gram equivalents of the solute dissolved in one litre of solution is known as its normality. Units for normality are gram equivalents/ litre.

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$$N = \frac{\text{No.of gram equivalent of the solute}}{\text{volume of the solution in litres}}$$

$$N = \frac{\text{number of milli equivalents of solute}}{\text{volume of solution (m}\ell)}$$

Number of equivalent weight of solute = $N \times V_{(lit)}$

Number of milli equivalents of solute = $N \times V_{(ml)}$

*** The normality of a solution decreases with increase in temperature of the Solution.**

7. Define is equivalent weight?

Ans: Equivalent weight (E): The weight of the substance which combines with 1 gram of hydrogen or 8 grams of oxygen is called equivalent weight.

Equivalent weight is the weight of the substance which loses or gains 1 mole of electrons

$$\text{No.of equivalents} = \frac{\text{weight of the substance(g)}}{\text{equivalent weight}}$$

$$\text{No.of milli equivalents} = \frac{\text{weight of the substance(mg)}}{\text{equivalent weight}}$$

$$E_{element} = \frac{\text{Atomic weight}}{\text{valency}}$$

$$E_{acid} = \frac{\text{molecular weight}}{\text{number of replaceble hydrogens}}$$

Ex: $$E_{HCl} = \frac{\text{molecular weight}}{1}$$

8. What is the equivalent weight of a Base?

Ans: Equivalent weight of base $= \dfrac{\text{molecular weight}}{\text{number of replaceble } OH^- \text{ ions}}$

Ex : $$E_{NaOH} = \frac{\text{molecular weight}}{1}$$

$$E_{Ca(OH)_2} = \frac{\text{molecular weight}}{2}$$

$$E_{NH_3} = \frac{\text{molecular weight}}{1}$$

9. What is equivalent weight of oxidizing or reducing agent?

Equivalent weight of oxidising or reducing agent $= \dfrac{\text{molecular weight}}{\text{change in oxidation state}}$

Ex: $$E_{KMnO_4} = \frac{\text{molecular weight}}{5}$$

$(MnO_4^- \rightarrow Mn^{2+}$ in acid medium)

$$E_{KMnO_4} = \frac{\text{molecular weight}}{1}$$

$(MnO_4^- \rightarrow MnO_4^{2-}$ in basic medium)

$$E_{KMnO_4} = \frac{\text{molecular weight}}{3}$$

$(MnO_4^- \rightarrow MnO_2$ in neutral medium)

$$E_{K_2Cr_2O_7} = \frac{\text{molecular weight}}{6}$$

$(Cr_2O_7^{2-} \rightarrow Cr^{3+}$ in acid and basic medium)

10. What is formality?

Ans: Formality (F): Fomality is the number of formula weights of solute per litre of solution.

$$\text{Formality} = \frac{\text{weight of solute}}{\text{formula weight}} \times \frac{1000}{\text{volume of solution}(m\ell)}$$

Ionic compounds and polymers do not contain molecules and molecular weights. Instead of molecular weight, the formula weight to be taken and instead of molarity the formality to be considered.

For any given solution, molarity and formality are same.

SHORT ANSWER TYPE QUESTIONS

1. Define Molarity and Molality?

Ans: Molarity**:** The number of gram moles of the dissolved solute per litre of solution is

known as the molarity of the solution. It is represented by 'M'.

$$= \frac{\text{number of moles of the solute}}{\text{volume of the solution in litres}}$$

$$\mathbf{M} = \frac{w}{M.W} \times \frac{1000}{V_{(ml)}}$$

Units for molarity are moles/litre.

The molarity is the most convenient and commonly used method of expressing the concentration of solution. The molarity of a solution slightly decreases with increase in temperature of the solution, due to increase in volume

Molality: The number of gram moles of the solute dissolved in one kilogram of the solvent is known as the molality of the solution. It is represented by 'm'.

$$\mathbf{m} = \frac{\text{number of gram moles of the solute}}{\text{weight of solvent in kilograms}}$$

The units for molality are mole / kg.

Molality is independent of temperature. Molality is the most inconvenient method of expressing concentration of a solution because it involves determining the weights of liquids.

2. What is meant by mole fraction? Explain.

Ans: Mole fraction:

The ratio between the number of moles of solute and the total number of moles of solute and solvent in the solution is known as the mole fraction of the solute. It is represented by X_1.

$$X_1 = \frac{n}{n+N}$$

n = No.of moles of solute

N = No.of moles of solvent

The ratio between the number of moles of solvent and the total number of solute and the solvent in the solution is known as the mole fraction of the solvent. It is represented by X_2.

$$X_2 = \frac{N}{n+N}$$

N = No.of moles of solvent

n = No.of moles of solute

Mole fraction can be expressed with reference to any component of the solution.

If molality of aqueous solutions is known, then

$$X_1 = \frac{m}{m+55.55}$$

Mole fraction of solute has no units. The sum of mole fractions of all components in a solution = 1. Mole fraction is independent of temperature.

3. Define Normality of Solution? What is its relationship with molality?

Ans: The number of gram equivalents of the solute dissolved in one litre of solution is known as its normality.

$$N = \frac{\text{No.of gram equivalent of the solute}}{\text{volume of the solution in litres}}$$

$$N = \frac{\text{number of milli equivalents of solute}}{\text{volume of solution (m}\ell)}$$

Units for normality are gram equivalents/ litre. The normality of a solution decreases with increase in temperature of the solution.

Number of equivalent weight of solute = $N \times V_{(lit)}$

Number of milli equivalents of solute = $N \times V_{(ml)}$

$$N = \frac{\text{weight of solute in grams}}{\text{gram equivalent weight of solute}} \times \frac{1}{V_{(litres)}}$$

$$N = \frac{W}{G.E.W} \times \frac{1000}{V_{(ml)}}$$

$W = N \times G.E.W \times V_{(lit)}$

$$N = \frac{10 \times \%}{G.E.W} \quad \left(\% = \frac{w}{v}\right)$$

$$N = \frac{\text{density of solution} \times 10 \times \%}{G.E.W} \quad \left(\% \frac{W}{W}\right)$$

Normality $\times$ Equivalent weight = molarity $\times$ molecular weight

For any given solute, Mol.weight $\geq$ equivalent weight

For any given solution, $M \leq N$

LONG ANSWER QUESTIONS

1. Explain with suitable examples the terms Molarity, Molality, Normality and Mole fractions. Which method expressing concentration is better than the other? Why?

Ans: Molarity: The number of gram moles of the dissolved solute per litre of solution is known as the molarity of the solution. It is represented by 'M'.

$$M = \frac{\text{number of moles of the solute}}{\text{volume of the solution in litres}}$$

$$M = \frac{n}{v}; \quad M = \frac{\text{no.of milli moles of solute}}{\text{volume of solution in m}\ell}$$

No.of moles of solute = $M \times V$ (lit)

No.of milli moles of solute = $M \times V$ (mℓ)

$$M = \frac{\text{weight of solute in grams}}{\text{G.M.W of solute}} \times \frac{1}{V_{(lit)}}$$

$$M = \frac{w}{M.W} \times \frac{1000}{V_{(ml)}}$$

$w = M \times M.W. \times V_{(lit)}$

$$M = \frac{\% \times 10}{G.M.W} \left(\% \frac{W}{V}\right)$$

$$M = \frac{density \times 10 \times \%}{G.M.W} \left(\% \frac{W}{W}\right)$$

Units for molarity are moles/litre. The molarity is the most convenient and commonly used method of expressing the concentration of solution. The molarity of a solution slightly decreases with increase in temperature of the solution, due to increase in volume.

Molality: The number of gram moles of the solute dissolved in one kilogram of the solvent is known as the molality of the solution. It is represented by 'm'.

$$m = \frac{\text{number of gram moles of the solute}}{\text{weight of solvent in kilograms}}$$

$$m = \frac{\text{weight of solute in grams}}{\text{G.M.W of solute}} \times \frac{1000}{\text{weight of solvent in grams}}$$

The molality of a saturated solution is given by

$$m = \frac{10 \times \text{solubility}}{\text{G.M.W.of solute}}$$

The units for molality are mole / kg. Molality is independent of temperature. Molality is the most inconvenient method of expressing concentration of a solution because it involves determining the weights of liquids.

Normality (N):

The number of gram equivalents of the solute dissolved in one litre of solution is known as its normality.

$$N = \frac{\text{No.of gram equivalent of the solute}}{\text{volume of the solution in litres}}$$

$$N = \frac{\text{number of milli equivalents of solute}}{\text{volume of solution } (m\ell)}$$

Number of equivalent weight of solute = $N \times V_{(lit)}$

Number of milli equivalents of solute = $N \times V_{(ml)}$

$$N = \frac{\text{weight of solute in grams}}{\text{gram equivalent weight of solute}} \times \frac{1}{V_{(litres)}}$$

$$N = \frac{W}{G.E.W} \times \frac{1000}{V_{(ml)}}$$

$W = N \times G.E.W \times V_{(lit)}$

Normality $\times$ Equivalent weight = molarity $\times$ molecular weight

For any given solute, Mol.weight $\geq$ equivalent weight

For any given solution, $M \leq N$

Units for normality are gram equivalents/ litre. The normality of a solution decreases with increase in temperature of the solution.

Mole fraction:

The ratio between the number of moles of solute and the total number of moles of solute and solvent in the solution is known as the mole fraction of the solute. It is represented by X_1.

$$X_1 = \frac{n}{n+N}$$ n = No.of moles of solute

N = No.of moles of solvent

The ratio between the number of moles of solvent and the total number of solute and the solvent in the solution is known as the mole fraction of the solvent. It is represented by X_2.

$$X_2 = \frac{N}{n+N}$$ N = No.of moles of solvent

n = No.of moles of solute

Mole fraction can be expressed with reference to any component of the solution.

If molality of aqueous solutions is known, then

$$X_1 = \frac{m}{m+55.55}$$

Mole fraction of solute has no units. The sum of mole fractions of all components in a solution = 1. Mole fraction is independent of temperature.

Both Mole fraction and Molality are the best methods of expressing concentrations as they are temperature independent and depend only on masses. Whereas Molarity and normality are dependent on temperature as the volumes of the solutions are taken for defining concentrations. As the volume of the solution varies with respect to temperature, Molarity and Normality are not the best way of expressing the concentrations.

2. Explain the classification of solutions on their Physical state and amount of solute Dissolved in solvent?

Ans:

Based on the physical state, solutions are of 3 types.

Gaseous solution : Solvent is Gas
The liquid solutions: Solvent is Liquid
Solid solutions : Solvent is solid

In any type of solution the solute may be gas or liquid or solid.

Solutions are of 7 types based on the physical states of solute and solvent.

1) Gas in gas : Mixture of any two gases
2) Gas in liquid : Soda water
3) Liquid in liquid: Alcohol in water
4) Solid in liquid : Sugar in water
5) Gas in solid : H_2 occluded in Pd
6) Liquid in solid : Amalgams
7) Solid in solid : Alloys

Liquid in gas and solid in gas are not considered as true solutions as they are not homogenous. A solution in which water is used as a solvent is known as aqueous solution. A solution in which alcohol is used as a solvent is known as alcoholic solution. A solution in which an organic liquid is used as a solvent is known as non – aqueous solution.

The commonly used solvents in non – aqueous solutions are CCl_4, CS_2, $CHCl_3$, C_6H_6 liquid SO_2, acetic acid, liquid NH_3 etc.

Based on the amount of dissolved solute, solutions are of 3 types.

Saturated solutions*:* which can not dissolve any more solute. Usually some amount of undissolved solute is present in it. A dynamic equilibrium exists between dissolved solute and undissolved solute.

Unsaturated solutions*:* which can dissolve some more amount of solute. No excess of undissolved solute exists. No dynamic equilibrium exists.

3. Calculate the equivalent weights of H_2SO_4, Na_2SO_4, Na_2CO_3, $KMnO_4$ (in acid medium) and $Ba(OH)_2$.

$$E_{element} = \frac{\text{Atomic weight}}{\text{valency}}$$

$$E_{acid} = \frac{\text{molecular weight}}{\text{number of replaceble hydrogens}}$$

a) Equivalent weight of H_2SO_4

$$E_{H2SO4} = \frac{\text{Molecular Wt.}}{\text{Basicity}}$$

$$E_{H_2SO_4} = \frac{\text{molecular weight}}{2}$$

Molecular weight of H_2SO_4 is = (2 + 32 + 64) = 98

$$E_{H2SO4} = \frac{98}{2} = 49$$

b) Equivalent weight of Na_2CO_3

$$E_{Na2CO3} = \frac{\text{molecular weight}}{\text{total charge(postive or negative)}}$$

Molecular weight of Na_2CO_3 = (23x2 + 12 + 48) = 106

$$E_{Na2CO3} = \frac{106}{2} = 53$$

c) Equivalent weight of $KMnO_4$

$$E_{KMnO4} = \frac{\text{molecular weight}}{\text{change in oxidation state}}$$

$$E_{KMnO_4} = \frac{\text{molecular weight}}{5}$$

$(MnO_4^- \rightarrow Mn^{2+}$ in acid medium)

Molecular weight of $KMnO_4$ = (39 + 55 +64) = 158

$$E_{KMnO4} = \frac{158}{5} = 31.6$$

5

d) Equivalent weight of $Ba(OH)_2$

$$E_{Ba(OH)2} = \frac{\text{molecular weight}}{\text{number of replaceble } OH^- \text{ ions}}$$

Molecular weight of = (137.33 32 + 2) = 171.33

$$E_{Ba(OH)2} = \frac{171.33}{2} = \mathbf{85.67}$$