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Some Basic Concepts of Chemistry

Mole Concept

- **One Mole** Avogadro's Number $(N_A) = 6.023 \times 10^{23}$. It is the number of atoms present in exactly 12 g of (C^{12}) isotope.
- **Atomic Weight** (A) Atomic weight is the relative weight of one atom of an element with respect to a standard weight.

$$A = \frac{\text{Weight of one atom of an element}}{\frac{1}{12}\text{th part by weight of an atom of } (C^{12}) \text{ isotope}}$$

- **amu** (atomic mass unit) **Weight**

$$1 \text{ amu} = \frac{1}{12}\text{th part by weight of an atom of } (C^{12}) \text{ isotope}$$
$$= \frac{1}{N_A} \text{ g} = 1.66 \times 10^{-24} \text{ g}$$

$$\boxed{\text{Atomic weight } (A) \times \text{amu} = \text{Absolute atomic weight.}}$$

NOTE
- Atomic weight is a relative weight that indicates the relative heaviness of one atom of an element with respect to amu weight.
- Atomic weight has no unit because it is the ratio of weights.
- One mole of an amu = 1.00 g.

- **Change of Scale for Atomic Weight** If an amu is defined differently as $(1/x)$th part by weight of an atom of (C^{12}) isotope rather $(1/12)$th part then the atomic weight (A') can be derived as :

$$\boxed{A' = A\left(\frac{x}{12}\right)}$$

Where, A = conventional atomic weight

Molecular Weight (MW) Like atomic weight, it is the relative weight of a molecule or a compound with respect to amu weight.

$$\boxed{\text{Molecular weight} = \frac{\text{Weight of one molecule of a compound}}{\frac{1}{12}\text{th part by weight of an atom of } C^{12} \text{ isotope}}}$$

Gram Atomic, Gram Molecular Weight (M) It is the weight of 1.0 mole (Avogadro's numbers) of atoms, molecules or ions in gram unit.

$$M = A \text{ amu} \times \text{Avogadro number} = A \text{ gram}$$

Hence, gram molecular weight (M) is numerically equal to the atomic weight or (molecular weight) in gram unit because

$$\boxed{\text{1.0 mole of amu is 1.0 g.}}$$

Empirical and Molecular Formula Empirical formula is the simplest formula of a compound with the elements in the simple whole number ratio, and a **molecular formula** is same or a multiple of the empirical formula.

e.g.

Molecular formula	Empirical formula
C_6H_6 (benzene)	CH
$C_6H_{12}O_6$ (glucose)	CH_2O
H_2O_2	HO
$H_2S_2O_8$ (persulphuric acid)	HSO_4

- **Laws of Chemical Combination** Elements combine in a fixed mass ratio, irrespective of their supplied mass ratio, e.g.

$$\underset{2\text{ g}}{H_2} + \underset{16\text{ g}}{\frac{1}{2}O_2} \longrightarrow \underset{18\text{ g}}{H_2O}$$

Here, H_2 and O_2 combines in a fixed mass ratio of 1 : 8.

No matter in what ratio we mixed hydrogen and oxygen, they will always combine in 1:8 mass ratio (stoichiometric mass ratio).

- **Limiting Reactant** It is the reactant that is consumed completely during a chemical reaction. If the supplied mass ratio of reactants are not stoichiometric ratio, one of the reactant is consumed completely leaving parts of others unreacted. One that is consumed completely is known as limiting reactant.

'Limiting reactant determine the amount of product in a given chemical reaction'

Concentration Units

- **Normality** (N) It is the number of gram equivalent of solute present in one litre of solution :

$$N = \frac{\text{Eq}}{V \text{ (in litres)}}$$

(i) **Molarity** (M) It is the moles of solute dissolve in one litre of solution.

$M = \frac{n}{V}$: n = Number of moles of solute

($\therefore V$ = Volume of solution in litre)

$\Rightarrow$ Molarity (M) $\times$ Volume (V) = n (moles of solute)

If volume is in mL; MV = millimoles

If d (g/cc) is density of a solution and it contains x % of solute of molar mass M, its molarity can be worked out as

$$\boxed{\text{Molarity} = \frac{1000\, dx}{100\, M} = \frac{10dx}{M}}$$

(ii) **Molality** (m) It is the number of moles of solute present in 1.0 kg of solvent.

$$\boxed{m = \frac{\text{Moles of solute } (n)}{\text{Weight of solvent in gram}} \times 1000}$$

NOTE

Molality is a true concentration unit, independent of temperature while molarity depends on temperature.

(iii) **Normality** (N) It is the number of gram equivalents of solute in one litre of solution.

$$\boxed{N = \frac{\text{Gram equivalents of solute (Eq)}}{\text{Volume of solution in litre}}}$$

(iv) **Mole Fraction** (χ_i) It is the fraction of moles of a particular component in a mixture as

$$\boxed{\chi_i = \frac{n_i}{\sum_{i=1}^{n} n_i}}$$

(v) **ppm** (parts per million) **Strength** It is defined as parts of solute present in (10^6 part) of solution.

- **Dilution Formula** If a concentrated solution is diluted, following formula work

$$\boxed{M_1 V_1 = M_2 V_2}$$

(M_1 and V_1 are the molarity and volumes before dilution and M_2 and V_2 are molarity and volumes after dilution)

- **Mixing of two or more solutions of different molarities** If two or more solutions of molarities ($M_1, M_2, M_3, \ldots$) are mixed together, molarity of the resulting solution can be worked out as :

$$\boxed{M = \frac{M_1 V_1 + M_2 V_2 + M_3 V_3 \ldots}{V_1 + V_2 + V_3 \ldots}}$$

Equivalent Concept, Neutralisation and Redox Titration

- **Equivalent Weight** Equivalent weight of an element is that part by weight which combines with 1.0 g of hydrogen or 8.0 g of oxygen or 35.5 g of chlorine.

(i) Equivalent weight of a salt (EW)

$$= \frac{\text{Molar mass}}{\text{Net positive (or negative) valency}}$$

e.g. Equivalent weight

$$CaCl_2 = \frac{M}{2},\ AlCl_3 = \frac{M}{3},\ Al_2(SO_4)_3 = \frac{M}{6}$$

(ii) Equivalent weight of acids $= \frac{\text{Molar mass}}{\text{Basicity}}$

e.g. Equivalent weight

$$HCl = M \text{ (basicity = 1)};\ H_2SO_4 = \frac{M}{2} \text{ (basicity = 2)}$$

$$H_3PO_4 = \frac{M}{3} \text{ (basicity = 3)}$$

(iii) Equivalent weight of bases $= \frac{\text{Molar mass}}{\text{Acidity}}$

e.g. Equivalent weight

$$NaOH = M,\ Ca(OH)_2 = \frac{M}{2},\ Al(OH)_3 = \frac{M}{3}$$

- **The number of gram-equivalents** (Eq)

$$\text{Equivalent} = \frac{\text{Weight of compound}}{\text{Equivalent weight}} = \frac{w}{\text{Equivalent weight}}$$

- **Mole Equivalent Relationship** In a given weight (w) of sample, number of moles (n) and number of equivalents (eq) are related as

$$n = \frac{w}{M} \text{ and } \text{Eq} = \frac{w}{\text{Equivalent weight}}$$

$$\because \quad \boxed{\frac{\text{Eq}}{n} = \frac{M}{\text{Equivalent weight}} = n\text{-factor}}$$

- ***n*-factor** For salt, it is valency, for acid it is basicity, for base it is acidity.

- **Normality/Molarity Relationship**

$$N = \frac{\text{Eq}}{V} \text{ and } M = \frac{n}{V} \Rightarrow \frac{N}{M} = \frac{\text{Eq}}{n} = \frac{\text{MW}}{\text{EW}} = n\text{-factor}$$

- **Acid-Base Titration** In acid-base titration, at the 'End Point'.

$$\boxed{\text{Gram equivalent of acid} = \text{Gram equivalent of base}}$$

- **Titration of a Mixture of $NaOH/Na_2CO_3$** The mixture is analysed by titrating against a standard acid in presence of phenolphthalein and methyl orange indicators.

Phenolphthalein end point occur when the following neutralisation is complete :

$$\left.\begin{array}{l} NaOH + HCl \longrightarrow NaCl + H_2O \\ Na_2CO_3 + 2HCl \longrightarrow NaHCO_3 + NaCl \end{array}\right\}$$

1 millimol of (HCl) = 1 millimol of ($NaOH + Na_2CO_3$)

Methyl orange end point occur when the following neutralisation is complete :

$$\left.\begin{array}{l} NaOH + HCl \longrightarrow NaCl + H_2O \\ Na_2CO_3 + 2HCl \longrightarrow 2NaCl + H_2O + CO_2 \end{array}\right\}$$

methylorange end point millimol (HCl)

$$= \text{millimol (NaOH)} + 2 \text{ millimol of } (Na_2CO_3)$$

- **Titration of a mixture of $NaHCO_3/Na_2CO_3$** The mixture is analysed by titrating against a standard acid in presence of phenolphthalein and methyl orange indicators.

  Phenolphthalein end point occur when the following neutralisation is complete :

$$Na_2CO_3 + HCl \longrightarrow NaHCO_3 + NaCl$$

$$\text{millimol (HCl)} = \text{millimol } (Na_2CO_3)$$

  Methyl orange end point occur when the following neutralisation is complete :

$$\left.\begin{array}{l} Na_2CO_3 + 2HCl \longrightarrow 2NaCl + H_2O + CO_2 \\ NaHCO_3 + HCl \longrightarrow NaCl + H_2O + CO_2 \end{array}\right\}$$

  Methyl orange end point millimol (HCl)

$$= \text{millimol } (NaHCO_3) + 2 \text{ millimol of } (Na_2CO_3)$$

- **Percentage Strength of Oleum** It is the mass of H_2SO_4 obtained on hydrolysis of 100 g of oleum as :

$$H_2S_2O_7 + H_2O \longrightarrow 2H_2SO_4$$

  The net reaction is :

$$\underset{80}{SO_3} + \underset{18}{H_2O} \longrightarrow \underset{98}{H_2SO_4}$$

$$\Rightarrow \quad \boxed{\% \text{ of free } SO_3 \text{ in oleum} = \frac{80}{18}(\% \text{ Strength-}100)}$$

- **Redox Reaction and Redox Titration**
  (i) **Oxidation** Loss of electrons or increase in oxidation number is called oxidation.
  (ii) **Reduction** Gain of electron or decrease in oxidation number is called reduction.

$$K_2\overset{+6}{Cr_2}O_7 + \overset{+2}{Fe}SO_4 + H_2SO_4 \longrightarrow \overset{+3}{Fe_2}(SO_4)_3 + \overset{+3}{Cr_2}(SO_4)_3$$

  In the above redox reaction, chromium is reduced from (+ 6 to +3) and iron is oxidised from (+ 2 to + 3). Hence, $K_2Cr_2O_7$ is known as oxidising agent (itself reduced) and $FeSO_4$ reducing agent (itself oxidised).

Quick Balancing of a Redox Reaction Cross-multiplication by net change in oxidation number per unit formula of oxidising agent and reducing agent will balance the redox reaction in term of OA and RA as:

$\Delta ON = 1$

$$K_2Cr_2O_7 + Fe^{2+} \longrightarrow 2Cr^{3+} + Fe^{3+}$$

$\Delta ON = 12 - 6 = 6$

Hence, multiplying Fe^{2+} by 6 and $K_2Cr_2O_7$ by 1 will balance the reaction in terms of OA and RA.

Disproportionation Reaction It is a special type of redox reaction in which similar species is oxidised as well reduced, e.g. $Br_2 + NaOH \longrightarrow NaBr + NaBrO_3$. In this reaction, bromine is reduced to bromide ion and the same is oxidised to bromate ion, hence bromine is undergoing disproportionation reaction.

Equivalent Weight of OA / RA

$$\boxed{\text{Equivalent weight of OA/RA} = \frac{\text{Molar mass}}{\text{Change in ON per formula unit}}}$$

e.g. $KMnO_4 + H^+ \longrightarrow Mn^{2+} : \left(E = \frac{M}{5}\right)$

$$K_2Cr_2O_7 + H^+ \longrightarrow 2Cr^{3+} : \left(E = \frac{M}{6}\right)$$

$$2KI \longrightarrow I_2 + 2K^+ :$$

$$[E = M \ (\Delta ON \text{ per } I^- = 1)]$$

$$2Na_2S_2O_3 \longrightarrow Na_2S_4O_6 + 2Na^+ :$$

$$[E = M \ (\Delta ON \text{ per } Na_2S_2O_3 = 1)]$$

- ***n*-Factor and Normality/Molarity Relationship**

$$N = \frac{Eq}{V}$$

and

$$M = \frac{n}{V}$$

$$\Rightarrow \quad \frac{N}{M} = \frac{Eq}{n}$$

$$= \frac{MW}{EW} = n\text{-factor}$$

  (*n*-factor = Change in oxidation number per formula unit).

- **Redox Titration** At the end point:
  Gram equivalents of OA = Gram equivalent of RA.