

Volumetric Analysis

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Concept of Equivalent Mass

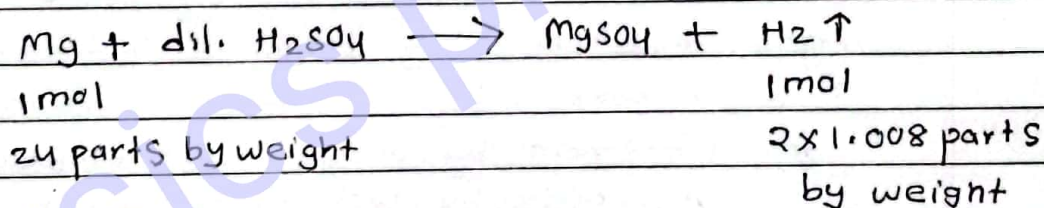
Element :-

~ 6 marks

Equivalent mass is the combining capacity of a substance by its weight.

Actually it is defined as the no. of parts by weight of an element that combines or displaces 1.008 parts by weight of hydrogen or 8 parts by weight of oxygen or 35.5 parts by weight of chlorine.

Let us take an example of Mg reacted with dil. H_2SO_4 .



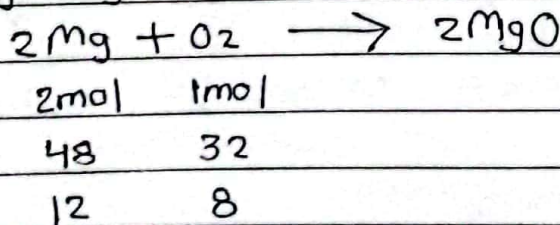
12 parts by weight

1.008 parts by weight

\therefore Equivalent mass of Mg is 12.

Here, 24 parts by weight of Mg displaces 1.008 parts by weight of hydrogen.

Similarly, if Mg burns in air



In this example 12 parts by weight of Mg combines with 8 parts by weight of oxygen. Hence the equivalent mass of Mg is 12.



Relationship between E, A and V

Let E = Equivalent mass of element

A = Atomic mass of that element

V = valency

According to definition of Valency,

If an atom combines with 'V' atoms of hydrogen then valency of atom is V.

Now, the mass of V atom of hydrogen = $1.008 V$

Again, $1.008 V$ parts by weight of hydrogen combines with A parts by weight of atom.

or, 1.008 parts by weight of hydrogen combines with A/V parts by weight of atom.

∴ Accor Equivalent mass (E) = $\frac{A}{V}$ #

Eq.:

Eq. weight of Na = $\frac{A}{V} = \frac{23}{1} = 23 \text{ u}$

Eq. mass of Mg = $\frac{A}{V} = \frac{24}{2} = 12 \text{ u}$

Eq. mass of Ca = $\frac{40}{2} = 20 \text{ u}$

But, if an atom has variable valency, then its equivalent mass can only be determined when its compound is known. For eg:-

NOTE:- O/S → lower valency
I.C → higher valency



$$\text{Eq. mass of Fe in Fe}_2\text{O}_3 = \frac{56}{3} = 18.67 \text{ g}$$

$$\text{Eq. mass of Fe in FeO} = \frac{56}{2} = 28 \text{ g}$$

$$\text{Eq. mass of Cu in CuCl}_2 = \frac{63.5}{2} = 31.75 \text{ g}$$

$$\text{Eq. mass of Cu in Cu}_2\text{Cl}_2 = \frac{63.5 \times 2}{2} = 63.5 \text{ g}$$

Q) 4.8g of divalent metal combine with oxygen to form 8g of oxide. Find the molecular mass of metal chloride.

Solⁿ:- The molecular formula of metal chloride be MCl_2

$$\text{Here, wt. of metal} = 4.8 \text{ g}$$

$$\text{wt. of oxide} = 8 \text{ g}$$

$$\text{wt. of oxygen} = 8 - 4.8 = 3.2 \text{ gm}$$

Now, 3.2 parts by wt. of Oxygen combines with 4.8 parts by wt. of metal.

or 8 parts by wt. of oxygen combines with $\frac{4.8}{3.2} \times 8$ parts by wt. of metal

$$\text{Now, } \text{M} = 12 \times 2 \text{ (VXE)} = 24$$

$$\text{M.w of } \text{MCl}_2 = 24 + 2 \times 36.5 = \text{--- ans} = 12 \text{ parts by wt. of metal.}$$

Equivalent mass of Acid.

It is defined as the no. of parts by weight of it that contains 1.008 parts by weight of replaceable hydrogen.

Alternatively, it is defined as the ratio of molecular weight to its basicity.

$$\text{i.e. Eq. mass} = \frac{\text{Molecular mass}}{\text{Basicity}}$$

where, Basicity is no. of replaceable hydrogen.

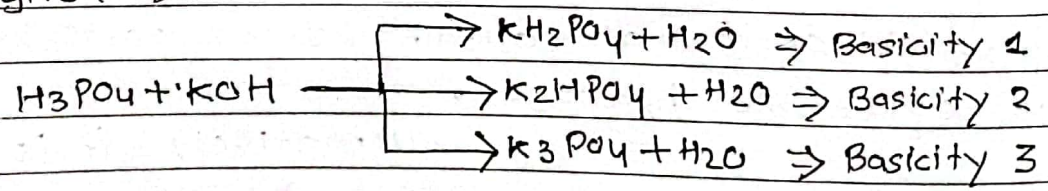


For eg :-

Acid	Basicity	Eq. mass
HCl	1 (monobasic)	$M/1$
H ₂ SO ₄	2 (di-basic)	$M/2$
H ₃ PO ₄	3 (tri-basic)	$M/3$
H ₄ P ₂ O ₇	4	$M/4$
H ₃ PO ₃	2	$M/2$
CH ₃ COOH	1	$M/1$
(COOH) ₂	2	$M/2$
HNO ₃	1	$M/1$

Note :- Not all the hydrogens present in an acid are replaceable hydrogen, only those hydrogens are replaceable hydrogen which are bonded to highly electronegative elements like halogens or oxygen.

The basicity of a polybasic acid may differ from reaction to reaction. For eg: Phosphoric acid (H₃PO₄) reacts with KOH and may form three different products as given below.



Sometime, the molecular mass of a substance changes due to its existence in hydrated and anhydrous form. And hence equivalent mass does.



For eg:- Equivalent mass of Crystalline Oxalic acid
 $(\text{COOH})_2 \cdot 2\text{H}_2\text{O} = \frac{126}{2} = 63 \neq$ whereas.

Eq. mass of anhydrous oxalic acid $(\text{COOH})_2 = \frac{90}{2} = 45 \neq$

Equivalent Mass of Base.

It is defined as the number of parts by weight of a base that would neutralize 1gm equivalent of an acid.

Alternatively, it is defined as the ratio of molecular mass to the acidity.

$$\text{i.e. Eq. mass} = \frac{\text{Molecular mass}}{\text{Acidity}}$$

where, Acidity is no. of ionizable OH^- ion.

Foreg: Eq. mass of NaOH is $\frac{40}{1} = 40$ [$\text{Na}^+ \cdot \text{OH}^-$]

Eq. mass of $(\text{CaOH})_2$ is $\frac{74}{2} = 37$ [$\text{Ca}^{2+} 2\text{OH}^-$]

Eq. mass of Al(OH)_3 is $\frac{78}{3} = 26$ [$\text{Al}^{3+} 3\text{OH}^-$]

In case of metallic oxide, the eq. mass is calculated as :-

$$\text{Eq. mass} = \frac{\text{Molecular mass}}{\text{no. of metal} \times \text{its valency}}$$

For eg:-

Eq. mass of $\text{Na}_2\text{O} = \frac{62}{2 \times 1} = 31 \checkmark$

Eq. mass of $\text{CaO} = \frac{56}{1 \times 2} = 28 \checkmark$

Eq. mass of $\text{Al}_2\text{O}_3 = \frac{102}{2 \times 3} = 17 \checkmark$



→ If a base has acidity two or more than two, then its acidity also differs from reaction to reaction.

In the reaction, $Al(OH)_3 + HCl \rightarrow Na(OH)_{eq2} + H_2O$
two OH group are replaced hence its acidity is two and its Eq mass is $M/2$.

Equivalent mass of salt.

It is defined as the no. of parts by weight of salt that is formed by the neutralization of 1gm equivalent of acid by 1gm equivalent of base.

Alternatively it is defined as the ratio of molecular mass or formula mass of a salt to the total no. of positive charge on cation or anion.

$$\text{i.e. Eq. mass} = \frac{\text{Molecular mass / Formula mass}}{\text{total no. of charge on cation or anion.}}$$

$$\text{or Eq. mass} = \frac{\text{Molecular mass or formula mass}}{\text{no. of metal} \times \text{its valency.}}$$

For eg: Eq. mass of NaCl = $\frac{58.5}{1}$ [$NaCl \rightarrow Na^+ + Cl^-$]

Eq. mass of $Na_2SO_4 = \frac{142}{2} = 71$ [$Na_2SO_4 \rightarrow 2Na^+ + SO_4^{--}$]

Eq. mass of $CaCO_3 = \frac{100}{2} = 50$ [$CaCO_3 \rightarrow Ca^{++} + CO_3^{--}$]

Eq. mass of $Na_2CO_3 = \frac{106}{2} = 53$ [$Na_2CO_3 \rightarrow 2Na^+ + CO_3^{--}$]



Qn) Find the eq. mass of following salts.

1) $KClO_3$ Eq. mass = $122.5/1 = 122.5 \text{ g}$

2) K_2FeF_4 Eq. mass = $255/4 = 63.75 \text{ g}$

3) $CaCl_2$ Eq. mass = $111/2 = 55.5 \text{ g}$

4) $NaHSO_4$ Eq. mass = $120/1 = 120 \text{ g}$

5) $CuSO_4$ Eq. mass = $159.5/2 = 79.75 \text{ g}$

6) NH_4Cl Eq. mass = $175/2 = 87.5 \text{ g}$

7) Na_2KSO_4 Eq. mass = $158/2 = 79 \text{ g}$

8) $NaNO_3$ Eq. mass = $85/1 = 85 \text{ g}$

9) $MgSO_4$ Eq. mass = $120/2 = 60 \text{ g}$

10) $K_2SO_4 \cdot Al_2(SO_4)_3$ Eq. mass = $474/5 = 94.8 \text{ g}$

11) $NaHCO_3$ Eq. mass = $84/1 = 84 \text{ g}$

12) Na_2SO_4 Eq. mass = $142/2 \times 1 = 71 \text{ g}$

13) KCl Eq. mass = $74.5/1 = 74.5 \text{ g}$

14) $NaCl$ Eq. mass = $58.5/1 = 58.5 \text{ g}$

15) $CaCO_3$ Eq. mass = $100/2 = 50 \text{ g}$



* **Equivalent Mass of Radicals / Ions** :

$$\text{Eq. mass} = \frac{\text{Ionic mass}}{\text{charge}}$$

$$\text{Eq. mass of } \text{Fe}^{++} = \frac{56}{2} = 28$$

* **Equivalent mass of Oxidizing agent / Reducing agent** :-

→ It is defined as the no. of parts by weight of an oxidizing agent or reducing agent which gives or accepts 8 parts by weight of nascent oxygen.

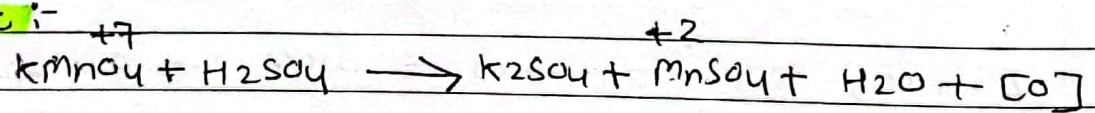
Alternatively, It is defined as the ratio of molecular mass to the change in oxidation number per molecule.

$$\text{i.e. Eq. mass} = \frac{\text{Molecular mass}}{\text{change in oxidation number per molecule}}$$

For eg :-

KMnO_4 :- It acts as oxidizing agent in all 3 medium.

In Acidic :-



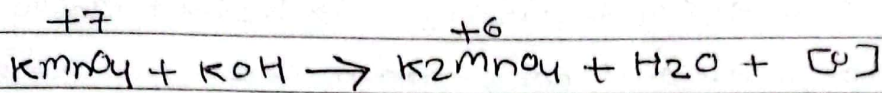
Change in O.N. per Mn atom = 5

Since a molecule of KMnO_4 has an atom of Mn

∴ change in O.N per KMnO_4 molecule = $1 \times 5 = 5$

$$\therefore \text{Eq. mass} = \frac{158}{5} = 31.6 \#$$

In Basic medium:-



change in ON per Mn atom = 1

∴ change in ON per KMnO_4 molecule = $1 \times 1 = 1$

$$\therefore \text{Eq. mass} = \frac{158}{1} = 158 \text{ wt}$$

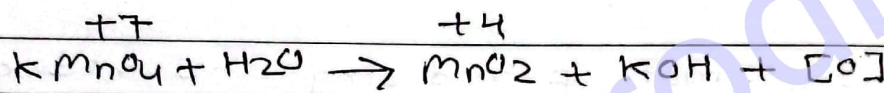
NOTE: change in ON

A → 5

B → 1

N → 3

In Neutral medium:-



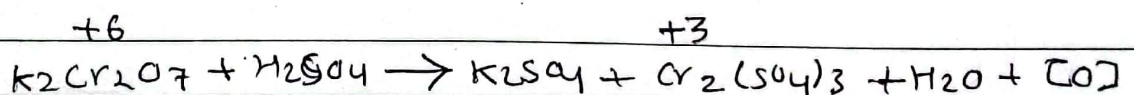
change in ON per Mn-atom = 3

∴ change in ON per KMnO_4 molecule = $1 \times 3 = 3$

$$\therefore \text{Eq. mass} = \frac{158}{3} = 52.6 \#$$

$\text{K}_2\text{Cr}_2\text{O}_7$

Unlike KMnO_4 , It acts as oxidizing agent only in acidic medium.



change in O.N. per Cr atom = 3

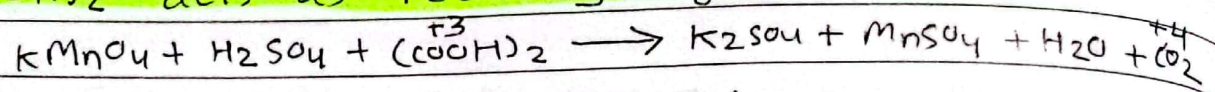
Since a molecule of $\text{K}_2\text{Cr}_2\text{O}_7$ has 2 atoms of Cr

∴ change in O.N. per molecule = $2 \times 3 = 6$

$$\therefore \text{Eq. mass} = \frac{294}{6} = 49.$$



⇒ $(\text{COOH})_2$ acts as reducing agent.



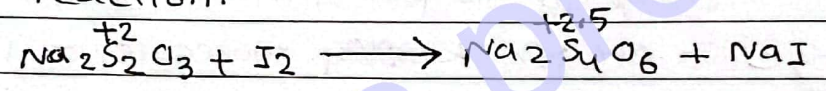
change in o.n. per C-atom = 1

Since a molecule of $(\text{COOH})_2$ contains 2 atoms of carbon.

∴ change in o.n. per molecule = $2 \times 1 = 2$

∴ Eq. mass of $(\text{COOH})_2 = \frac{90}{2} = 45$

Qn) Find the eq. mass of oxidizing and reducing agent in the reaction.



[I = 131]

Here, Oxidizing agent = I_2 And,
 Reducing agent = $\text{Na}_2\text{S}_2\text{O}_3$



Gram equivalent:

If equivalent mass is expressed in gram. Then it is called gram equivalent. For eg:-

Eq. mass of H_2SO_4 is 49, If we say 49 gm of H_2SO_4 . Then, it is equivalent to 1gm equivalent.

The no. of gram equivalent can be calculated as.

$$\text{no. of gm equivalent} = \frac{\text{Given wt. (w)}}{\text{Eq. mass (E)}}$$

Qn) Find the no. of gm equivalent in each case.

- a) 4 gm of NaOH \Rightarrow no. of gm eqv = $4/40 = 0.1$
 b) 50 gm $CaCO_3$ \Rightarrow no. of gm eqv = $50/50 = 1$
 c) 2.3 gm of Na \Rightarrow no. of gm eqv = $2.3/23 = 0.1$
 d) 73 gm of HCl \Rightarrow no. of gm eqv = $73/36.5 = 2$

Summary

$$\text{Eq. mass} = \frac{\text{At. mass} \times \text{mol. mass}}{V_f}$$

where, V_f = valency \rightarrow for element

= Basicity \rightarrow for acid

= Acidity \rightarrow for base

= Total charge on cation & anion \Rightarrow for salt

= change in ON for OA and RA

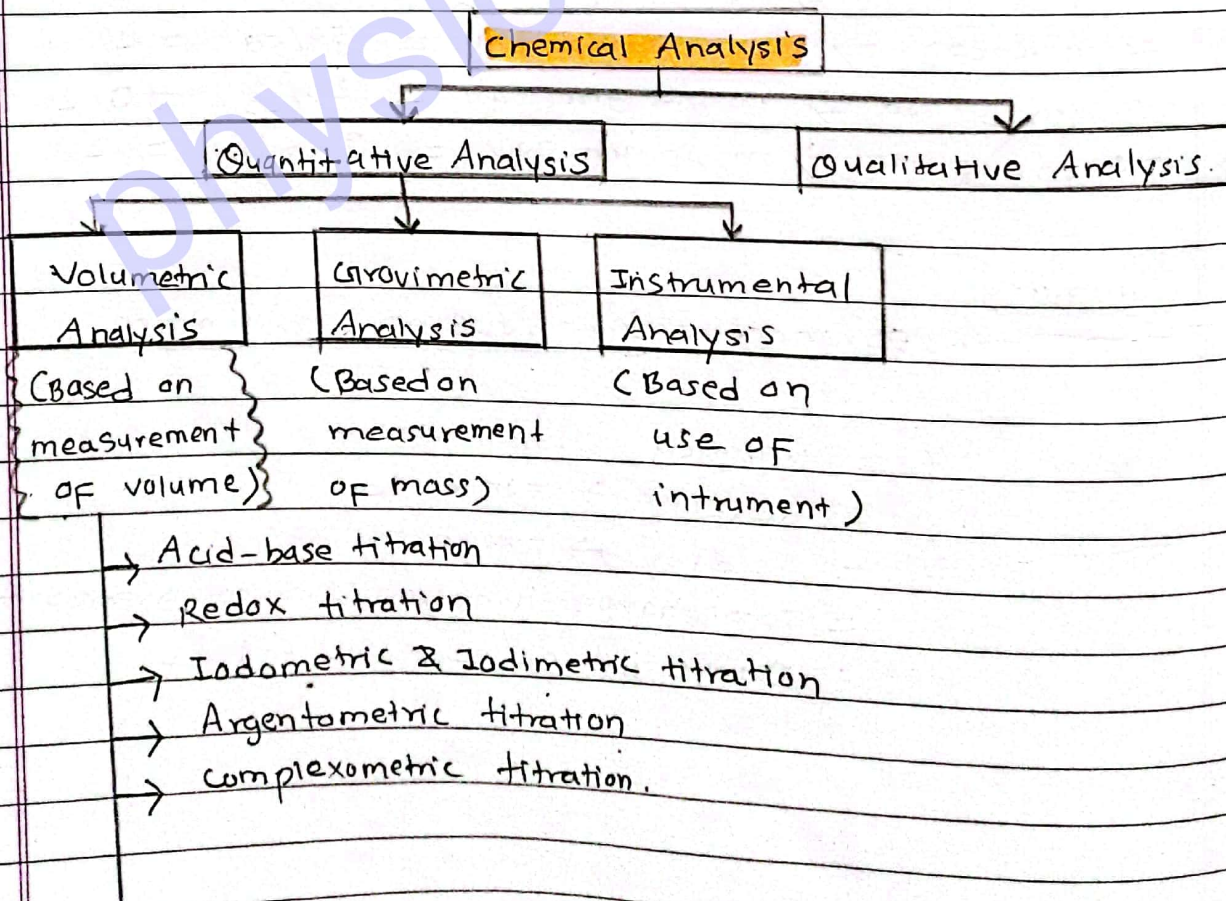


Volumetric Analysis :-

- One of the important aspect of chemistry is the chemical analysis. Chemical analysis can be done by two ways.

a) **Qualitative Analysis** :- This involves the identification of constituents or the composition of a given chemical substance. Foreg: salt analysis (i.e. Acid radical test and basic radical test).

b) **Quantitative Analysis** :- This involves the measurement of amount of substances & it involves the determination of relative proportion of different constituents present in given chemical substance. Further it is classified as follows :-



- **Volumetric Analysis** :- It is a part of quantitative analysis which involves the determination of concentration of an unknown solution by measuring its volume, that would exactly react with definite volume of standard solution. The common laboratory tool of the volumetric analysis is the titration or titrimetric analysis.

Types of solution :

① **Standard solution** → (The solution with known concentration is called standard solution). It is further of 2 types.
a) Primary standard solution
b) Secondary standard solution.

- **Primary standard solution** :- (Those solution whose concentration is known at the time of its preparation is called primary standard solution). Such solution are prepared by direct weighing the required amount of solute and dissolving them in definite volume of solution.

The substances that are employed for the prepⁿ of primary standard solution are called primary standard substance. The chemical composition of these substances do not undergo any change while weighing them or they are not affected by air.

Some examples of primary standard solution are:

- Oxalic acid $(\text{COOH})_2$
- Na_2CO_3
- $\text{K}_2\text{Cr}_2\text{O}_7$
- Mohr's salt etc. → $(\text{NH}_4)_2 \cdot \text{Fe}(\text{SO}_4)_2 \cdot 6\text{H}_2\text{O}$



Seco Criteria for a substance to become a primary standard substance.

- They should be easily available in pure & dry state
- They shouldn't be toxic.
- They shouldn't be hygroscopic, deliquescent, efflorescent.
- The composition should be invariant during weighing & on long standing.
- They should have high equivalent mass, so that weighing error can be minimized.

Secondary Standard Solution:

Those solution whose concentration is unknown at the time of its prepⁿ but later it's concentration is determined with the help of primary standard solution are called secondary standard solution. An approximate ^{required} weight of solute is taken and are dissolved in definite volume of solution, to prepare the secondary standard solution. Later, the concentration is determined with the help of primary standard solution.

The substances which are used in prepⁿ of secondary standard solution are called secondary standard substance. For eg: HCl, $KMnO_4$

Qn) Define primary standard solution and secondary standard solution.



Q7) Write the requisites for a substance to be a primary standard substance.

Q8) Differentiate primary standard substance and secondary standard substance.

Q9) Is $KMnO_4$ a primary standard substance?

↳ No, it is not because it is not easily available in pure and dry state.

Primary standard substances	Secondary standard substance.
↳ Their concentration is known at the time of preparation.	↳ Their concentration is unknown at the time of preparation.
↳ No other solution is needed to measure the concentration.	↳ Primary solution is needed to measure the concentration.
↳ Less reactive	↳ more reactive.

Concentration terms:

Concentration of the solution is defined as the (amount of solute dissolved in given amount/volume of solution). Simply it is a ratio of amount of solute to the amount of solution. It can be expressed in following ways:

- | | |
|-------------------|----------------------|
| a) Percentage | e) Formality |
| b) Gram per litre | f) Molarity |
| c) Normality | g) parts per million |
| d) Molarity | h) Mole fraction. |



a) **Percentage:**

It is defined as the no. of parts of solute present in 100 parts of its solution. It is further divided into three types:

i) **Percentage weight by volume (% w/v):-**

↳ It is defined as the weight of solute in gram dissolved in 100ml of its solution. It is denoted by (% w/v). Mathematically:

$$\% (w/v) = \frac{\text{wt. of solute in gm}}{\text{Vol. of solution in ml}} \times 100$$

Eg: 5% (w/v) NaOH soln means, 5gm of NaOH is dissolved in 100ml of its soln.

Ex) 225 ml of Na_2CO_3 soln is prepared by dissolving 25 gm of Na_2CO_3 . Find its concn. in % (w/v)

⇒ solution:

$$\% (w/v) = \frac{\text{wt. of solute}}{\text{Vol. of soln}} \times 100$$

$$= \frac{25}{225} \times 100 = 11.11\%$$

ii) **Percentage volume by volume (% v/v) :-** It is defined as the volume of solute in ml dissolved in 100ml of its solution. Mathematically.

$$\% \left(\frac{V}{V} \right) = \frac{\text{Volume of solute in ml}}{\text{Volume of soln in ml}} \times 100$$

For eg: 5% $\left(\frac{V}{V} \right)$ H_2SO_4 soln means 5ml of H_2SO_4 is dissolved in 100 ml of its solution.



8n) A bottle of beer is labelled as 65% by volume of ethyl alcohol. If a person consumes whole bottle of beer of 650 ml. Then find the net volume of alcohol consumed by the person.

→ $(\%V/V) = 65\%$ $V = 650 \text{ mL}$

$$(\%V/V) = \frac{V'}{V} \times 100 \Rightarrow 65 = \frac{V'}{650} \times 100$$

$$\therefore V' = \frac{65 \times 650}{100}$$

$$= 42.25 \text{ mL}$$

iii) Percentage weight by weight (% w/w).

It is defined as the wt. of solute dissolved in gram dissolved in 100 gm of its solution. Mathematically,

$$\% (W/W) = \frac{\text{wt. of solute in gm}}{\text{wt of soln in gm}} \times 100$$

foreg:- 5% (w/w) H_2SO_4 means 5gm of H_2SO_4 is dissolved in 100 gm of its solution.

Note: यदि प्रश्न मा % मात्र भनेको छ र density वा specific gravity दिएको छ भने त्यो % चाही (% w/w) हो



2. Gram per litre :

It is defined as the wt. of solute in gram dissolved in 1 litre of its solution.

mathematically,

$$g L^{-1} = \frac{\text{wt of solute in gm}}{\text{Vol}^n \text{ of sol}^n \text{ in litre}}$$

$$g L^{-1} = \frac{\text{wt. of solute in gm} \times 1000}{\text{Vol}^n \text{ of sol}^n \text{ in ml}}$$

$$g L^{-1} = \frac{\text{wt of solute (in gm)} \times 1000 \times 10}{\text{vol. of sol}^n \text{ in ml}}$$

$$\therefore g L^{-1} = \% (w/v) \times 10$$

3. Normality (N) :-

It is defined as the no. of gram equivalent of solute dissolved in 1L of its soln. It is denoted by N. mathematically.

$$N = \frac{\text{No. of gram equivalent of solute}}{\text{Volume of sol}^n \text{ in Ltr.}}$$

$$= \frac{\text{Wt. of solute in gm}}{\text{Eq. mass} \times \text{Volume of sol}^n \text{ in ltr}} = \frac{g L^{-1}}{\text{Eq. mass}}$$

$$= \frac{(\% w/v) \times 10}{\text{Eq. mass}}$$

$$= \frac{\text{wt of solute in gm (W)} \times 1000}{\text{Eq. mass (E)} \times \text{Volume of sol}^n \text{ in ml}}$$

$$\therefore N = \frac{W \times 1000}{E \times V} \Rightarrow \boxed{W = \frac{V E N}{1000}}$$



Define the following terms:

- | | |
|---------------------------------|---------------------------------|
| a) Normal solution (N) | c) seminormal soln ($N/2$) |
| b) Binormal solution ($2N$) | d) pentinormal soln ($N/5$) |
| e) Decinormal soln ($N/10$) | f) centinormal soln ($N/100$) |
| g) Milinormal soln ($N/1000$) | |

→ **Normal solution (N)**

The solution which is prepared by dissolving 1g equivalent of solute in 1L of its soln is called normal solution. For eg:- Normal soln of H_2SO_4 means, 49gm equivalent of H_2SO_4 (i.e. 49g) is dissolved in 1Ltr of its solution)

→ **Binormal solution ($2N$)**

The solution which is prepared by dissolving 2g equivalent of solute in 1L of its solution is called Binormal solution. For eg:- Binormal solution of H_2SO_4 means, 2 gram equivalent of H_2SO_4 (i.e. 98 gm) is dissolved in 1ltr of its solution.

→ **Seminormal solution ($N/2$)**

The solution which is prepared by dissolving half gram equivalent of solute in 1L of its solution is called seminormal solution ($N/2$). For eg:- seminormal soln of H_2SO_4 means, $1/2$ gm equivalent of H_2SO_4 (i.e. 24.5 g) is dissolved in 1Ltr of its soln.

→ **Pentinormal solution ($N/5$)**

The solution prepared by dissolving $1/5$ th gram equivalent of solute in 1L of its solution is



is called pentinormal solution. For eg: pentinormal solution of H_2SO_4 means $\frac{1}{5}$ gram equivalent of H_2SO_4 is dissolved in 1L of its soln.

→ Decinormal solution (N/10)

The solution which is prepared by dissolving $\frac{1}{10}$ gram equivalent of solute in 1L of its solution is called decinormal solution. For eg: Decinormal solution of H_2SO_4 means $\frac{1}{10}$ gram equivalent of H_2SO_4 (i.e. 4.9 gm) is dissolved in 1L of its soln.

→ Centinormal solution (N/100)

The solution which is prepared by dissolving $\frac{1}{100}$ gram equivalent of solute in 1L of its soln. is called centinormal solution. For eg: centinormal soln of H_2SO_4 means $\frac{1}{100}$ gram equivalent of H_2SO_4 is dissolved in 1L of its soln.

→ Millinormal solution (N/1000)

The solution which is prepared by dissolving $\frac{1}{1000}$ gram equivalent of solute in 1L of its solution is called millinormal solution (N/1000). For eg: millinormal solution of H_2SO_4 means $\frac{1}{1000}$ gram equivalent of H_2SO_4 is dissolved in 1L of its soln.

Molarity (M);

It is defined as the no. of moles of solute dissolved in 1L of its soln. It is denoted by 'M'. Mathematically,

$$M = \frac{\text{no. of moles of solute}}{\text{Vol}^n \text{ of soln in litre.}}$$

$$= \frac{\text{wt of solute in gm}}{\text{mol. wt} \times \text{Vol}^n \text{ of soln in L}} = \text{g L}^{-1} = \frac{(w/v) \times 10}{\text{mol. wt}}$$

$$M = \frac{\text{wt of solute in (gm)} (w) \times 1000}{\text{mol. wt} (M_w) \times \text{volume of soln in mL} (V)}$$

$$\therefore M = \frac{w \times 1000}{M_w \times V} \Rightarrow w = \frac{V \times M_w \times M}{1000}$$

Define the following terms:

- | | |
|----------------------------|----------------------------|
| a) Molar soln (M) | b) Bimolar soln (2M) |
| c) Semi molar soln (M/2) | d) Pentimolar soln (M/5) |
| e) Deci molar soln (M/10) | f) Centimolar soln (M/100) |
| g) Milimolar soln (M/1000) | |

→ **Molar soln (M)** → The soln which is prepared by dissolving 1 mole of solute in 1L of its soln is called Molar soln (M). For eg:- Molar soln of H_2SO_4 means. 1 mole of H_2SO_4 (i.e. 98g) is dissolved in 1L of its soln.

→ **Bimolar soln (2M)** → The soln which is prepared by dissolving 2 mole of solute in 1L of its soln is called Bimolar soln (2M). For eg: Bimolar soln of H_2SO_4 means 2 mole of H_2SO_4 (i.e. 196 gram) is dissolved in 1L of its soln.



→ Semimolar soln (M/2)

The soln which is prepared by dissolving half mole of solute in 1L of its soln is called semimolar soln (M/2). For eg: semimolar soln of H_2SO_4 means $\frac{1}{2}$ mole of H_2SO_4 (i.e. 49g) is dissolved in 1L of its soln.

→ Pentimolar soln (M/5)

The soln which is prepared by dissolving $\frac{1}{5}$ mole of solute in 1L of its soln is called pentimolar soln (M/5). For eg: pentimolar soln of H_2SO_4 means $\frac{1}{5}$ mole of H_2SO_4 is dissolved in 1L of its soln.

→ Decimolar soln (M/10)

The solution which is prepared by dissolving $\frac{1}{10}$ mole of solute in 1L of its soln is called Decimolar soln (M/10). For eg:- decimolar soln of H_2SO_4 means $\frac{1}{10}$ mole of H_2SO_4 is dissolved in 1L of its soln (9.8 gm).

→ Centimolar soln (M/100)

The solution which is prepared by dissolving $\frac{1}{100}$ mole of solute in 1L of its soln is called centimolar soln (M/100). For eg:- centimolar soln of H_2SO_4 means $\frac{1}{100}$ mole of H_2SO_4 (i.e. 0.98g) is dissolved in 1L of its soln.

→ Milimolar soln (M/1000)

The solution which is prepared by dissolving $\frac{1}{1000}$ mole of solute in 1L of its soln is called milimolar soln (M/1000). For eg: milimolar soln of H_2SO_4 means $\frac{1}{1000}$ mole of H_2SO_4 is dissolved in 1L of its soln.



Relation between Normality and Molarity :

Since, $\text{Normality} = \frac{\text{g L}^{-1}}{\text{Eq. weight}} \Rightarrow \text{g L}^{-1} = \text{Normality} \times \text{Eq. wt}$ ----- (I)

Also, $\text{Molarity} = \frac{\text{g L}^{-1}}{\text{mol. wt}} \Rightarrow \text{g L}^{-1} = \text{Molarity} \times \text{mol. wt}$ ----- (II)

From (I) and (II)

$\therefore \text{Normality} \times \text{Eq. wt} = \text{Molarity} \times \text{mol. wt}$
 or, $\text{Normality} = \text{Molarity} \times \frac{\text{mol. wt}}{\text{Eq. wt}}$

$\therefore \text{Normality} = \text{Molarity} \times \text{V.F.}$

where, V.F. is basicity for acid.
 → Acidity for base.

- total no. of +ve or -ve charge for salt.
- change in O.N per molecule for O.A/R.A.

Formality (F) :

The term formality is very similar to the molarity but it is used in the case ionic soln.

It is defined as the no. of gram formula wt. of solute dissolved in 1L of its soln. It is denoted by 'F'. Mathematically ;

$$F = \frac{\text{no. of gm formula wt. of solute}}{\text{vol}^n \text{ of soln in litre.}}$$

$$= \frac{\text{wt. of solute in gm}}{\text{formula wt} \times \text{volume of soln in ltr}}$$



For eg: formal soln of NaCl means, 1gm formula wt of NaCl (58.5gm) is dissolved in 1ltr. of its soln.

Molarity (M) :-

It is defined as the no. of moles of solute dissolved in per kg of solvent. It is denoted by (M).

Mathematically,

$$m = \frac{\text{no. of moles of solute}}{\text{wt. of solvent in kg.}}$$

$$\text{or } m = \frac{\text{wt. of solute in gm}}{\text{Mol wt} \times \text{wt of solvent in gm}} \times 1000$$

For eg :- molar solution of Na_2CO_3 means, 1mole of Na_2CO_3 (106gm) is dissolved in 1kg of water. or, 1ltr of water.

Relation btr. M and m.

$$\text{We have, } m = \frac{\text{wt. of solute in gm} \times 1000}{\text{mol. wt} \times \text{wt of solvent in gm}}$$

$$\text{And } M = \frac{\text{wt. of solute in gm} \times 1000}{\text{mol. wt} \times \text{voln of soln in ml}}$$

$$\text{Now, } \frac{M}{m} = \frac{\text{wt. of solvent in gm}}{\text{voln of soln in ml.}}$$



Parts per million (ppm)

Whenever the concentration of the soln is too dilute, the concentration of such soln is expressed in ppm.

It is defined as the no. of parts by weight of solute present in 1 million parts by weight of soln.

$$\text{i.e. ppm} = \frac{\text{wt of solute in gm}}{\text{wt of soln in gm}} \times 10^6$$

For too dilute soln:

$$\text{wt of soln in gm} \approx \text{voln of soln in ml}$$

[∵ density of water = 1 gm/ml]

$$\therefore \text{PPM} = \frac{\text{wt of solute in gm}}{\text{voln of soln in ml}} \times 10^6$$

A toothpaste has 0.2 gL^{-1} fluoride ion. The concn of F^- ion in ppm is

- a) 20 b) 200 c) 2000 d) 40

soln: wt of $\text{F}^- = 0.2 \text{ g}$

voln of soln = 1 ltr = 1000 ml

$$\therefore \text{PPM} = \frac{0.2}{1000} \times 10^6 = 200$$

$$\text{ppm} = \text{gL}^{-1} \times 10^3$$

Mole fraction [X]:

It is defined as the ratio of no. of moles of one component to the total no. of moles.

Let, n_A be the no. of moles of solute and n_B be the no. of moles of solvent. then,

$$\text{mole fraction of solute } (X_A) = \frac{n_A}{n_A + n_B}$$



And mole fraction of ^{solvent} solute $(X_B) = \frac{n_B}{n_A + n_B}$

$$X_A + X_B = 1$$

∴ sum of mole fraction of solvent of a solⁿ is unity.

Temp^r dependent and temp^r independent concentration:

↳ Those concentration terms that involves the volume of solution are called temp^r dependent because the volⁿ of solⁿ changes with chng. in the temperature.
For eg: (y.w/v), N, g L⁻¹, M etc.

Those concentration terms that do not involves the volⁿ of solⁿ are called temp^r independent because mass remains same at all temperature. For eg: (y.w/w), m, mole fraction etc.

Q.N. Why is it better to express the concⁿ of solⁿ in terms of molality than in Molarity (M)?

↳ It is because molarity is temp^r dependent concentration. Hence it's volume alter with change in temp^r but molality is temp^r independent one^r so its volume doesnot change due to change in temp^r.
(to minimize experimental error)

Note:- Most used concentration term is Molarity (M)



Preparation of standard solution :

To prepare 250 ml of $\frac{1}{10}N$ Na_2CO_3 solⁿ :

→ The required wt. of Na_2CO_3 for the prepⁿ of decⁿ. 250 ml of its decinormal solⁿ can be calculated as

$$W = \frac{VEN}{1000} = \frac{250 \times 53 \times \frac{1}{10}}{1000} = 1.325 \text{ gm.}$$

First of all 1.325 gm of Na_2CO_3 is weight out accurately and it is transferred to the volumetric flask carefully. The solute is then dissolved by adding little quantity of water. Later more water is added to make the solⁿ up to the mark. This prepared solⁿ is called standard decinormal solⁿ of Na_2CO_3 .

It may not be feasible all the time to take the exact required wt of solute for the prepⁿ of standard solution due to different technical problem. In such cases, a term Normality factor is introduced.

Normality factor (f) :

It is defined as the no. that shows how many times the concentration of prepared solⁿ differs from the concⁿ of solⁿ that is to be prepared. It is denoted by f . Mathematically, it is defined as the ratio of wt of solute taken to the wt. to be taken. Or, It is the ratio of practical wt. to the theoretical wt.

$$\text{i.e. } f = \frac{\text{wt. taken}}{\text{wt. to be taken}}$$



or $f = \frac{\text{Experimental wt.}}{\text{Theoretical wt.}}$

It is always written in the bracket along with the concⁿ of the solution to be prepared. The product of normality factor and concⁿ of solⁿ to be prepared gives the concⁿ of prepared solⁿ.

Significance of f

* If $f=1$; that means the concⁿ of ^{prepared} solⁿ is equal to concⁿ of solⁿ to be prepared.

* If $f > 1$; that means the concⁿ of prepared solⁿ is more than concⁿ of solⁿ to be prepared.

* If $f < 1$; that means the concⁿ of prepared solⁿ is less than concⁿ of solⁿ to be prepared.

Principle of volumetric analysis:

i) Law of chemical equivalence: (1MP)

It states that chemical substances always react with each other in their equivalent proportion.

It means 1gm equivalent of any chemical species always reacts with 1gm equivalent of other species.

Let us consider two chemical substances be exactly reacts with each other. Then,

According to law of chemical equivalence,

No. of gm equivalent of A = No. of gm equivalent of B

Since, $\text{Normality (N)} = \frac{\text{No. of gm equivalent}}{\text{Volume of solⁿ in Volume (V)}}$

$\therefore \text{No. of gm equivalent} = N \times V$



Let no. of gm. eqv. of A = $N_1 V_1$ and

no. of gm eqv of B = $N_2 V_2$

Now above eqn becomes.

$$N_1 V_1 = N_2 V_2.$$

This eqn is called normality eqn and it remains valid for all values. cases.

For molarity eqn: A balanced chemical eqn is required.

i.e. $aA + bB = \text{Product}$

Now, $\frac{\text{no. of moles of A}}{\text{no. of moles of B}} = \frac{a}{b}$

$$\text{or, } \frac{M_1 \cdot V_1}{M_2 \cdot V_2} = \frac{a}{b} \quad (\because \text{no. of moles} = M \times V)$$

$$\text{or, } b (M_1 \cdot V_1) = a (M_2 V_2)$$

\therefore

$M_1 V_1 = M_2 V_2$ remains valid only if $a=b$

The eqn $M_1 V_1 = M_2 V_2$ is called molarity eqn.

Q1) State law of chemical equivalence & derive normality equation.

Q2) Why normality eqn remains valid for all cases but molarity eqn may not?



27 Law of dilution :-

It states that, the no. of gm eqv. of any soln remains same before & after the dilution. It means,

If the volⁿ of any soln is increased by 'y' times then the concⁿ of soln is decreased by 'y' times. for eg:

$$\begin{aligned}
 100 \text{ ml} \cdot 1 \text{ N NaOH} &= 1000 \text{ ml} \cdot \frac{1}{10} \text{ N NaOH} \\
 &= 200 \text{ ml} \cdot \frac{1}{2} \text{ N NaOH} \\
 &= 50 \text{ ml} \cdot 2 \text{ N NaOH}
 \end{aligned}$$

Note:

In case of dilution, we can use both normality eqn and molarity eqn.

3) For mixture :-

① For the mixture of same type of substances (Acid-Acid or Base-Base)

If same type of substances, either acid-acid or base-base are mixed together. Then the no. of gram equivalent of mixture gets increased. i.e.

if two or more acids (or bases) are mixed together, then the no. of gram equivalent of mixture becomes equal to the sum of no. of gram equivalent of each acid. for example:

If a mixture contains three acids. Then,

$$N_{\text{mix}} V_{\text{mix}} = N_1 V_1 + N_2 V_2 + N_3 V_3$$

where $V_{\text{mix}} = V_1 + V_2 + V_3$; (no dilution)

$V_{\text{mix}} =$ final volⁿ (dilution)



① For the mixture of acid and base,

If acid and base are mixed together, then the no. of gram equivalent of mixture becomes ~~excess~~^{equal} to the difference in the no. of gram equivalent of acid and base.

re. No. of gm eqv (mix) = No. of gm. eq^v of acid - no. of gm eq^v of base.

$$\text{or, } N_{\text{mix}} V_{\text{mix}} = N_a V_a - N_b V_b$$

where $V_{\text{mix}} = V_a + V_b$ (no dilution)

$V_{\text{mix}} = \text{final vol}$ (dilution)

20ml - 0.5N H_2SO_4 is mixed with 40ml of 0.15N NaOH
what is the Normality of mixture.

→ We have,

$$N_{\text{mix}} V_{\text{mix}} = N_a V_a - N_b V_b$$

(-ve) → basic ✓

$$\text{or, } N_{\text{mix}} \cdot 60 = 10 - 6$$

(+ve) → acidic ✓

$$\text{or, } N_{\text{mix}} = \frac{4}{60}$$

The value of N_{mix} and V_{mix} helps to determine the nature of solution. i.e.

if $N_{\text{mix}} V_{\text{mix}} = 0 \rightarrow$ (neutral)

if $N_{\text{mix}} V_{\text{mix}} = +ve \rightarrow$ (acidic)

if $N_{\text{mix}} V_{\text{mix}} = -ve \rightarrow$ (basic).

Note :-

concentration of a solution cannot be -ve.



Terms involved in titration.

- a) Titrand
- b) Titrant
- c) End point
- d) Eq. point
- e) Titration error.

↳ **Titrand** :- The substance whose concentration is to be determined by titration is called **titrand** (titrate or titre) (conical flask)

↳ **Titration** :- It is the method of quantitative chemical analysis which involves the determination of concentration of unknown solution with the help of standard solution by using an indicator.

↳ **Titrant / titrator** :- The solution of known concentration used to determine concentration of titrand during titration is called **titrant**. (burette)

↳ **End point** :- The point in the titration at which titrant and titrand reacts completely which is shown by sharp change in colour of indicator is called **end point**.

↳ **Equivalence point** :- The point in the titration at which the equivalent quantity of titrant and titrand reacts completely is called **equivalence point**.

↳ **Titration error** :- It is the difference between end point and equivalence point. To minimize titration error, a suitable indicator must be selected.



Equivalence point	End point
- Definition	- Definition.
- Not visible during titration	- visible during titration.
- Theoretical point / Exact point	- Practical point.
- It is slightly before the visual end point	- It is always slightly beyond / after the Equivalence point, because of necessity of seeing the color change by eye

Types of Titration.

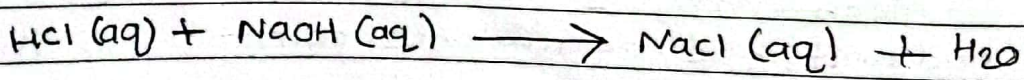
- 1) Acid-base titration.
 - 2) Redox titration.
- Acidimetry

→ Alkalimetry

Acid base Titration

↳ Those titration in which the concentration of an acid is determined by neutralizing it completely with standard alkali solution in presence of indicator or vice-versa are called acid-base titrations.

Indicators used for acid-base titration is called **acid base indicator** or **pH indicator**. for eg i- phenolphthalein, methyl orange etc.



→ Acidimetry

↳ It is the process of determining the strength of an acid solution with the help of standard alkali solution in the presence of an indicator.

→ Alkalimetry

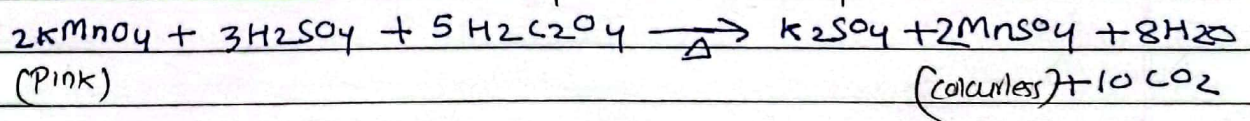
↳ It is the process of determining the strength of an alkali solution with the help of standard acid solution in the presence of an indicator.

Redox titration

↳ Those titrations in which the strength of an oxidizing agent is determined by the standard solution of reducing agent or viceversa.

→ Permanganometry

↳ The titration involving $KMnO_4$ is called permanganometry. The titration of acidified $KMnO_4$ solution against oxalic acid with $KMnO_4$ as a self-indicator is a typical example.



→ Dichromatometry

↳ Titration involving $K_2Cr_2O_7$.



Some Important Formulas

1) Normality (N)

$$N = \frac{\text{no. of gm eqv}}{\text{voln of soln in l}} = \frac{W \times 100}{E \times V} = \frac{(\%w/v) \times 10}{E} = \frac{(\%w/w) \times S \times 10}{E}$$
$$= \frac{g L^{-1}}{E} = m \times v.f.$$

2) Molarity (M)

$$M = \frac{W \times 100}{M_w \times V} = \frac{(\%w/v) \times 10}{M_w} = \frac{(\%w/w) \times S \times 10}{M_w} = \frac{g L^{-1}}{M_w} = \frac{N}{v.f.}$$

3) Gram per litre ($g L^{-1}$)

$$= \frac{wt \text{ in gm}}{\text{vol. (l)}} = \frac{(\%w/v) \times 10}{1} = N \times E = m \times M_w$$

$$4) \left(\frac{\%w}{v} \right) = \frac{wt \text{ in gm}}{V \text{ (ml)}} \times 100 = \frac{g L^{-1}}{10}$$

$$5) W = \frac{V \times N}{1000} = \frac{V \times M_w \times M}{100}$$

$$6) \% \text{ by weight} \times S = \% \text{ by volume} \times d$$

Equivalent Mass

Name	molecular mass	B	Eq. mass
HCl	36.5	1	36.5 [M/B]
HNO ₃	63	1	63
CH ₃ COOH (Acetic acid)	60	1	60
HCOOH (Formic acid)	46	1	46
H ₂ SO ₄	98	2	49
oxalic acid (anhydrous) $\begin{cases} \text{COOH} \\ \text{COOH} \end{cases}$	90	2	45
oxalic acid (hydrated) $\begin{cases} \text{COOH} \cdot \text{H}_2\text{O} \\ \text{COOH} \cdot \text{H}_2\text{O} \end{cases}$	126	2	63
Phosphoric acid [H ₃ PO ₄]	98	3	32.6
phosphorous acid [H ₃ PO ₃]	82	2	41.
pyro phosphonic acid [H ₄ P ₂ O ₇]	178	4	44.5
metaphosphonic acid [HPO ₃]	80	1	80
sodium hydroxide (NaOH)	40	^A 1	40
Ammonium hydroxide (NH ₄ OH)	35	1	35
Potassium hydroxide (KOH)	56	1	56
calcium hydroxide (Ca(OH) ₂)	74	2	37
Magnesium hydroxide [Mg(OH) ₂]	58	2	29
Sodium chloride [NaCl]	58.5	1	58.5
potassium chloride [KCl]	74.5	1	74.5
Sodium carbonate [Na ₂ CO ₃]	106	2	53
Sodium Bicarbonate [NaHCO ₃]	84	1	84
Silver Nitrate [AgNO ₃]	169.8	1	169.8
Potassium Nitrate [KNO ₃]	101	1	101
Sodium Sulphate [Na ₂ SO ₄]	142	2	71

	mol. mass	change in ON	Eq. wt	
KMnO ₄ → 158		5 (acid)	31.6	m/5
		3 (neutral)	52.6	m/3
		1 (alkaline)	158	m

K₂Cr₂O₇ → 294.2 → 6 → 49.03

Numerical Problems

GOOD MORNING

PAGE NO :

DATE : / /

Type 1:- For the problem involving unit change and prepⁿ of standard solⁿ:

Formulae

$$N = \frac{\text{No. of gm eqV}}{\text{Volⁿ of solⁿ in ltr}} = \frac{w \times 1000}{E \times V} = \frac{\% (w/v) \times 10}{E}$$
$$= \frac{(\% w/w) \times 5 \times 10}{E} = \frac{9L^{-1}}{E} = M \times v.f.$$

$$M = \frac{\text{No. of voln in ltr}}{V(L)} = \frac{w \times 1000}{M_w \times V} = \frac{(\% w/v) \times 10}{m_w}$$
$$= \frac{\% (w/w) \times 5 \times 10}{m_w} = \frac{9L^{-1}}{m_w} = N/v.f.$$

$$9L^{-1} = \frac{w + \text{in gm}}{V(L)} = (\% w/v) \times 10$$

$$\left(\frac{\% w}{V}\right) = \frac{w + \text{in gm}}{V(ml)} \times 100 = \frac{9L^{-1}}{10}$$

$$w = \frac{V \times E}{1000} = \frac{V \times M_w \times M}{1000}$$



Q) 2.5 g of sodium carbonate is dissolved in 50 ml of its solution. Find the concentration of this solution in terms of:

- a) % (w/v)
- b) $g L^{-1}$
- c) Normality
- d) Molarity.

★ Solution:

Given, wt. of solute in gm (w) = 2.5 g

Volⁿ of solⁿ (v) = 50 ml

$$\text{Now, } \% (w/v) = \frac{\text{wt in gm}}{v (ml)} \times 100$$

$$= \frac{2.5}{50} \times 100 = 5 \%$$

$$b) \text{ } g L^{-1} = \% (w/v) \times 10 = 5 \times 10 = 50 \%$$

$$c) \text{ Normality (N)} = \frac{g L^{-1}}{\text{Eq. wt}} = \frac{50}{53} = 0.94 \%$$

$$d) \text{ Molarity (M)} = \frac{g L^{-1}}{m_w} = \frac{50}{106} = 0.47 \%$$



IMPORTANT NUMERICALS

1) What mass of Na_2CO_3 is required to prepare 100 ml of its decinormal solution?

→ Solution: Given that,

$$\text{Volume (V)} = 100 \text{ ml}$$

$$N = 1/10$$

$$\text{Eq. Mass of } \text{Na}_2\text{CO}_3 = \frac{106}{2} = 53.$$

$$\text{Since } W = \frac{VEN}{100} = \frac{100 \times 53 \times 0.1}{1000} = 0.53 \text{ gm}$$

2) A commercial sulphuric acid is 96% by mass and has specific gravity 1.84. Find the normality and molarity of the acid.

→ Solution:

Given that: (% w/w) of $\text{H}_2\text{SO}_4 = 96\%$.

Specific gravity (S) = 1.84

$N = ?$

$m = ?$

$$\text{We have, } N = \frac{(\% \text{ w/w}) S \times 10}{E} = \frac{96 \times 1.84 \times 10}{49} = 36.04 \#$$

$$\text{Now, molarity (M)} = \frac{(\% \text{ w/w}) \times S \times 10}{M_w} = \frac{96 \times 1.84 \times 10}{98} = 18.024$$

3) Find the molarity of water if its density is 1 gm/ml.

→ Given that, density = 1 gm/ml

$$\therefore \text{mass (m)} = 1 \text{ gm}$$

$$\text{Volume (V)} = 1 \text{ ml}$$

$$\text{molarity (M)} = \frac{g/L}{M_w} = \frac{1 \times 1000}{18} = 55.55 \#$$

Problem involving ~~the~~ dilution. ($N_1 V_1 = N_2 V_2$)

4) 100 ml of NaOH having concentration 4 g L^{-1} is diluted to 225 ml. Find the normality of the diluted solution.

→ Before dilution

$$V_1 = 100 \text{ ml}$$

$$\text{g L}^{-1} = 4$$

$$N_1 = \frac{\text{g L}^{-1}}{E} = \frac{4}{40}$$

$$= 0.1$$

Now using $N_1 V_1 = N_2 V_2$

$$\text{or, } 0.1 \times 100 = N_2 \times 225$$

$$\therefore N_2 = \frac{0.1 \times 100}{225} = 0.044 \checkmark$$

After dilution.

$$V_2 = 225 \text{ ml}$$

$$N_2 = ?$$

5) What volume of water should be added to the 50 ml of 0.5 N ($f = 1.08$) HCl to make it exactly decinormal.

→ Before dilution

$$V_1 = 50 \text{ ml}$$

$$N_1 = (0.5 \times 1.08)$$

$$= 0.54$$

Now, $N_1 V_1 = N_2 V_2$

$$\text{or, } 0.54 \times 50 = 0.1 \times V_2$$

$$\therefore V_2 = \frac{0.54 \times 50}{0.1} = 270 \text{ ml}$$

Volume of water that should be added = $V_2 - V_1$

$$= (270 - 50) \text{ ml}$$

$$= 220 \text{ ml} \checkmark$$

Short trick;

$$V_2 - V_1 = V_1 \left(\frac{N_1 - N_2}{N_2} \right)$$

6) What volume of 96.4% H_2SO_4 having specific gravity 1.84 is required to prepare 1L of its ~~def~~ normal solution.

→ Before dilution

$$V_1 = ?$$

$$N_1 = ?$$

$$N_1 = \frac{(\%w/w) \times \rho \times 10}{E}$$

$$= \frac{96.4 \times 1.84 \times 10}{49} = 36.2$$

After dilution.

$$V_2 = 1 \text{ Ltr.} = 1000 \text{ mL}$$

$$N_2 = 1$$

Now using $N_1 \cdot V_1 = N_2 \cdot V_2$

$$\text{or } 36.2 \times V_1 = 1000 \times 1$$

$$\text{or } V_1 = \frac{1000}{36.2} = 27.62 \text{ mL} \#$$

7) Atomic mass of a monovalent element is 23. What is its equivalent mass?

→ For monovalent element,

$$\text{Valency } (V) = 1$$

$$\text{Given, At. mass } (A) = 23.$$

$$\text{We have, } E = \frac{A}{V} = \frac{23}{1} = 23$$

∴ Required atomic mass = 23 ✓

8) Atomic mass of divalent element is 65.30. What is its equivalent mass?

→ For divalent element Valency $(V) = 2$

$$\text{Given, Atomic mass } (A) = 65.30.$$

Equivalent mass (E) = 2

we have, $E = \frac{A}{V} = \frac{65.30}{2} = 32.65$ ✓

9. Atomic mass of Aluminium is 27. Calculate its equivalent mass.

→ Solution: Here.

Atomic mass (A) = 27

Valency (V) = 3

Then Equivalent mass (E) = $\frac{A}{V} = \frac{27}{3} = 9$ ✓

10) 1g of divalent metal reacts with hydrogen to form 1.0504 g of compound. Calculate the atomic mass of metal.

→ Let molecular formula of metal compound be MH_2

Here, wt. of metal = 1g

wt. of compound = 1.0504 g

∴ wt of hydrogen = 1.0504 - 1
= 0.0504 g.

1g of metals combines with 0.0504g of hydrogen

$\frac{1}{0.0504}$ g of metals combines with 1g of hydrogen

$\frac{1}{0.0504} \times 1.008$ g of metals combines with 1.008 g of hydrogen
→ 20g. ✓

∴ Eq. weight of metal = 20

Now, Atomic mass (A) = Valency × Eq. mass

= 2 × 20

= 40 gram ✓

11) 4.8g of divalent metal reacts with oxygen to form 8g. its oxide. Calculate the molecular mass of the metal chloride. [Let molecular formula of metal

nt \rightarrow Solution: Here, chloride be MCl_2]

$$\text{wt. of divalent metal} = 4.8 \text{ g}$$

$$\text{wt. of metal oxide} = 8 \text{ g}$$

$$\therefore \text{wt of oxygen} = 8 - 4.8 = 3.2 \text{ g}$$

Thus, 3.2g of oxygen combines with 4.8g metal

$$1 \text{ g of oxygen combines with } \frac{4.8}{3.2} \text{ g of metal}$$

$$1 \text{ g of oxygen combines with } \frac{4.8}{3.2} \times 8 \text{ g of metal}$$

$$= 12 \text{ g of metal.}$$

$$\therefore \text{Equivalent mass of metal (E)} = 12$$

$$\begin{aligned} \text{Now atomic mass of metal (A)} &= \text{Eq mass} \times \text{valency} \\ &= 12 \times 2 \\ &= 24 \text{ g} \end{aligned}$$

Now, Again Equivalent mass of metal chloride

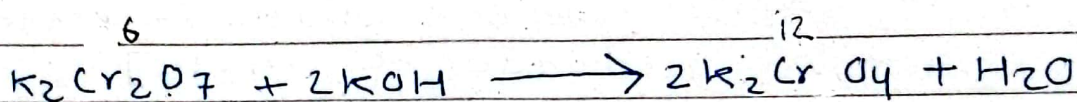
$$\begin{aligned} MCl_2 &= 24 + 2 \times 35.5 \\ &= 95 \text{ gram} \end{aligned}$$

12) calculate the equivalent mass of carbonic acid.

\rightarrow Solution :-

$$\begin{aligned} \text{For any acid its eq. mass} &= \frac{\text{Molecular mass}}{\text{basicity}} \\ &= \end{aligned}$$

13) calculate the equivalent mass of $K_2Cr_2O_7$ in the reaction.



→ change in oxidation number per Cr atom = 6
since a molecule of $K_2Cr_2O_7$ has 2 atoms of Cr
∴ change in ON per molecule = $2 \times 6 = 12$

$$\therefore \text{Eq. mass} = \frac{M}{12}$$

14) 100 ml of oxalic acid solution consists of 2.45 g of oxalic acid. calculate the percentage strength.

→ mass of oxalic acid (M) = 2.45 g

Volume of oxalic acid solution (V) = 100 ml

$$\text{Now, percentage strength (\% w/v)} = \frac{M}{V} \times 100$$

$$= \frac{2.45}{100} \times 100$$

$$= 2.45\%$$

15) A bottle of beer is labelled as 6.5% by volume of ethyl alcohol. If a person consumes whole bottle of beer of 650 ml. Then find the net volume of alcohol consumed by him.

→ A bottle is labelled 6.5% by volume

∴ 6.5 ml of ethyl alcohol is dissolved in 100 ml of beer

or, $\frac{6.5}{100} \times 650$ ml of ethyl alcohol is dissolved in 650 ml of beer

or, 42.25 ml

$$\text{we have } (\%V/V) = \frac{\text{vol}^n \text{ of solute}}{\text{vol}^n \text{ of solution}} \times 100$$

$$\text{or, } 6.5 = \frac{\text{vol}^n \text{ of solute}}{650} \times 100$$

$$\therefore \text{vol}^n \text{ of solute} = \frac{6.5 \times 650}{100} = 42.25 \text{ mL}$$

16) what do you mean by 90% (V/V) methanol solution in water?

→ It means that 90 mL methyl alcohol is mixed with 10 mL water to prepare 100 mL of methanol solution.

17) calculate the molarity of 250 mL solution prepared by dissolving 1.375 g of anhydrous sodium carbonate.

→ molecular mass of Na_2CO_3 is 106 amu

$$\therefore 106 \text{ g of } \text{Na}_2\text{CO}_3 \text{ in } 1000 \text{ mL} = 1 \text{ M}$$

$$1.375 \text{ g of } \text{Na}_2\text{CO}_3 \text{ in } 1000 \text{ mL} = \frac{1}{106} \times 1.375$$

$$1.375 \text{ g of } \text{Na}_2\text{CO}_3 \text{ in } 250 \text{ mL} = \frac{1}{106} \times 1.375 \times \frac{250}{1000}$$

$$= 0.00324 \text{ M}$$

18) calculate the amount of NaHCO_3 in 500 mL of 0.25 M solution.

→ solution :- Here,

$$\text{volume (V)} = 500 \text{ mL}$$

$$\text{molarity (M)} = 0.25 \text{ M}$$

$$\text{mass of } \text{NaHCO}_3 = ?$$

we have, $M = \frac{w \times 1000}{m_w \times V}$

$$0.25 = \frac{w \times 1000}{84 \times 500}$$

$$\begin{aligned} \therefore \text{wt. of solute} &= \frac{0.25 \times 84 \times 5}{100} \\ &= 10.5 \text{ g} \end{aligned}$$

19) calculate the molarity of pure water.

→ The density of pure water is 1 g/mL

∴ 1L of water = 1000 mL = 1000 gram.

For 1L of water.

$$\begin{aligned} \text{No. of moles} &= \frac{\text{Mass of 1L water}}{\text{Molecular mass of water}} \\ &= \frac{1000}{18} = 55.55 \text{ mol} \end{aligned}$$

∴ molarity of pure water is 55.55 mol per litre.

20) 25 millimole of glucose is present in 250 mL solution. Calculate the molarity of solution.

→ We have,

$$\begin{aligned} M &= \frac{\text{no. of mole}}{\text{Volume in L}} = \frac{25 \times 10^{-3}}{250 \times 10^{-3}} = \frac{1}{10} \\ &= 0.1 \text{ M} \end{aligned}$$

21) 29.25 g of sodium chloride is dissolved in 500 g water. What is the molarity of solution.

→ solution:

$$\text{we have: no. of moles} = \frac{\text{given mass}}{\text{mol. mass}} = \frac{29.25}{58.5} = \frac{1}{2}$$

$$\begin{aligned} \text{molarity (M)} &= \frac{\text{no. of moles}}{\text{mass of solvent in kg}} = \frac{0.5}{0.5} \\ &= 1 \text{ M} \end{aligned}$$

22) A sulphuric acid soln is 9.8% by mass. calculate its molality.

→ solution:

9.8% by mass of sulphuric acid means 9.8 g of H_2SO_4 is dissolved to prepare 100g of its solution.

$$\begin{aligned} \therefore \text{mass of water} &= 100 - 9.8 \\ &= 90.2 \text{ g} \end{aligned}$$

∴ 90.2g water dissolves 9.8 g H_2SO_4

1g water dissolves $\frac{9.8}{90.2}$ g H_2SO_4

1000g water dissolves $\frac{9.8}{90.2} \times 1000$ g H_2SO_4

$$= 108.64 \text{ g}$$

Now, molality (m) = $\frac{\text{conc}^n \text{ in g per kg solvent}}{\text{mol. mass}}$

$$= \frac{108.64}{98}$$

$$= 1.10 \text{ m}$$

23) what volume of water should be added to 50 mL of seminormal NaOH to make it

Same type of Question is asked many times

IMP

34) 0.012 g of divalent metal is completely dissolved in 40 cc of $N/10$ HCL. The excess of acid required 15 cc of $N/5$ NaOH for neutralization. Find the atomic weight of the metal. [2014]

→ Solution:

panha reacted acid nikalne ($N_1 V_1 = N_2 V_2$) bata

ani $W = \frac{VEW}{100}$ bata ~~weight~~ nikalne.
 \rightarrow Eqv wt \checkmark

tes bata. Atomic wt nikalne.

$$\boxed{E = \frac{A}{V}} \quad A \rightarrow EXV \checkmark$$

For HCL

For NaOH

$$Normality (N_1) = 1/10 = 0.1 N$$

$$Normality (N_2) = 0.2 N$$

$$Volume (V_1) = ?$$

$$Volume (V_2) = 15 ml$$

$$\text{using, } N_1 V_1 = N_2 V_2$$

$$V_1 = \frac{0.2 \times 15}{0.1} = 30 \text{ mL (unreacted)}$$

$$\text{unreacted acid} = 40 \text{ mL} - 30 \text{ mL}$$

$$= 10 \text{ mL} \checkmark$$

10 mL $N/10$ HCL reacts with 0.012 g divalent metal

now we have $W = \frac{VEW}{1000}$

$$\text{or } 0.012 = \frac{10 \times E \times 0.1}{1000}$$

$$\text{or } E = 12$$

$$\text{or } \frac{\text{Atomic mass}}{\text{valency}} = 12$$

$$\text{or } \text{Atomic mass} = 12 \times 2 = 24 \text{ amu} \checkmark$$

Type 111) Problem involving 1 step neutralization.

Formulae

$$N_1 V_1 = N_2 V_2$$

(if both are in soln form)

$$\frac{N \times V}{1000} = \frac{W}{E}$$

(if one is in soln & other in mass)

37) 100 mL of seminormal soln of H_2SO_4 is neutralized by 80 mL of NaOH. What is the concentration of NaOH in $g L^{-1}$?

→ Solution:

For H_2SO_4

$$N_1 = N/2 = 0.5$$

$$V_1 = 100 \text{ mL}$$

For NaOH

$$N_2 = ?$$

$$V_2 = 80 \text{ mL}$$

$$\text{By using } N_1 V_1 = N_2 V_2$$

$$\text{or, } 0.5 \times 100 = N_2 \times 80$$

$$\therefore N_2 = 0.625 \text{ N.}$$

$$\text{Again, } g L^{-1} = \text{Normality} \times \text{Eq. wt}$$

$$= 0.625 \times 40$$

$$= 25 \text{ g/L}$$

38) 0.18 g of a divalent metal completely neutralizes 100 mL of 0.15 N HCl solution. Find the atomic mass of metal.

→ Solution:

$$\text{Here } W = 0.18 \text{ g}$$

$$V = 100 \text{ mL}$$

$$E = 38.5$$

$$N = 0.15 \text{ N}$$

$$\text{we have, } \frac{W}{E} = \frac{V \times N}{100}$$

$$\Rightarrow \frac{W}{E \times V \times N} =$$

$$W = \frac{VEN}{1000}$$

$$\text{or, } 0.18 = \frac{100 \times E \times 0.15}{1000}$$

$$\therefore E = 12$$

$$\text{Now } E = \frac{A}{V}$$

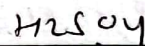
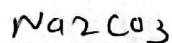
$$\therefore A = E \times V$$

$$= 12 \times 2$$

$$= 24 \text{ amu} \checkmark$$

3) 0.71g of $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$ completely neutralizes 100ml of decinormal solⁿ of H_2SO_4 . find the value of x. (2)

→



$$W = 0.71$$

$$N = 0.1 \text{ N}$$

$$E = ?$$

$$V = 100 \text{ ml}$$

$$\left(\frac{W}{E} \right)_{\text{Na}_2\text{CO}_3} = \left(\frac{N \times V}{1000} \right)_{\text{H}_2\text{SO}_4}$$

$$\text{or, } \frac{0.71}{E} = \frac{0.1 \times 100}{1000}$$

$$\text{or, } 7.1 = 0.1 \times E$$

$$\text{or, } E = 71$$

$$\text{or, } \frac{A}{V} = 71$$

$$\text{or, } \frac{106 + 18x}{2} = 71$$

$$\therefore x = \frac{142 - 106}{18} = 2 \checkmark$$

For the problem involving Mixture.

$$N_{\text{mix}} V_{\text{mix}} = N_1 V_1 + N_2 V_2 + N_3 V_3$$

$$V_{\text{mix}} = V_1 + V_2 + V_3 \quad ; \quad (\text{No dilution})$$

$$V_{\text{mix}} = \text{use final vol}^n \quad ; \quad (\text{dilution})$$

40) 100 mL of 0.28 N ($f=0.9$) H_2SO_4 , 120 mL of 2 g L^{-1} HCL and 180 mL of 5% (w/v) HNO_3 are mixed together in a vessel.

a) What will be the normality of the mixture

b) If the mixture is diluted to 1 L, what will be its normality.

→ Given

For H_2SO_4

$$V_1 = 100 \text{ mL}$$

$$N_1 = (0.28 \times 0.9) \\ = 0.252$$

For HCL

$$V_2 = 120 \text{ mL}$$

$$\text{g/L} = 5$$

$$N_2 = \text{g/L} / \frac{1}{2}$$

$$= 2/36.5$$

$$= 0.054$$

For HNO_3

$$V_3 = 180 \text{ mL}$$

$$1 \cdot (\text{w/v}) = 5$$

$$N_3 = \frac{1 \cdot (\text{w/v}) \times 10}{E}$$

$$= \frac{50}{63}$$

$$= 0.79$$

For mixture.

$$N_{\text{mix}} = ?$$

$$V_{\text{mix}} = V_1 + V_2 + V_3$$

$$= 400 \text{ mL}$$

$$\text{Now, } N_{\text{mix}} V_{\text{mix}} = N_1 V_1 + N_2 V_2 + N_3 V_3$$

$$N_{\text{mix}} = \frac{N_1 V_1 + N_2 V_2 + N_3 V_3}{V_{\text{mix}}}$$

$$= \frac{25.2 + 6.48 + 142.2}{400}$$

$$= \frac{173.88}{400}$$

$$= 0.4347 \text{ N} \quad \checkmark \quad 0.43 \text{ N} \quad \checkmark$$

$$\text{Again. } N_{\text{mix}} V_{\text{mix}} = 173.88$$

$$N_{\text{mix}} \times 1000 = 173.88$$

$$N_{\text{mix}} = 0.17388 \text{ N}$$

4) What volume of 2M HCl and 10^M molar HCl are needed to be mixed to get 5M HCl to get 10L of 5M HCl

$$\rightarrow V_{\text{mix}} = 10 \text{ L} = 10,000 \text{ mL}$$

$$N_{\text{mix}} = 5 \text{ N}$$

$$\text{Let } V_1 \text{ be } x \text{ L (2M)} \text{ then } V_2 = 10 - x \text{ L (10M)}$$

$$\text{We have, } N_{\text{mix}} V_{\text{mix}} = N_1 V_1 + N_2 V_2$$

$$10 \times 5 = 2 \times x + 10(10 - x)$$

$$50 = 2x + 100 - 10x$$

$$8x = 50$$

$$\therefore x = 6.25 \text{ L}$$

\therefore 6.25 L of 2M HCl is mixed.

For acid-base mixture.

$$N_{\text{mix}} V_{\text{mix}} = N_a V_a - N_b V_b \quad (\text{Both soln})$$

$$\frac{N_{\text{mix}} V_{\text{mix}}}{1000} = \left(\frac{N \cdot V}{1000} \right)_{\text{acid}} - \left(\frac{N \cdot V}{1000} \right)_{\text{base}}$$

$$\text{OR} \quad \text{OR} \\ = \left(\frac{W}{E} \right)_{\text{acid}} - \left(\frac{W}{E} \right)_{\text{base}}$$

42) 100 mL of 0.28 N HCl is mixed with 60 mL of 4 g L^{-1} NaOH. What will be the normality of the mixture.

→ For HCl

$$V_1 = 100 \text{ mL}$$

$$N_1 = 0.28 \text{ N}$$

$$N_1 V_1 = 28$$

For NaOH

$$V_2 = 60 \text{ mL}$$

$$9 \text{ g L}^{-1} = 4$$

$$N_2 = \frac{9 \text{ g L}^{-1}}{40} = \frac{4}{40} = 0.1$$

$$N_2 V_2 = 0.1 \times 60 = 6$$

$$\frac{N_{\text{mix}} V_{\text{mix}}}{1000} = \left(\frac{N \cdot V}{1000} \right)_{\text{acid}} - \left(\frac{N \cdot V}{1000} \right)_{\text{base}}$$

$$\frac{N_{\text{mix}} \times 160}{1000} = \left(\frac{28}{1000} - \frac{6}{1000} \right)$$

$$N_{\text{mix}} = 0.0375 \text{ N}$$

43) 0.5 g of Na_2CO_3 is dissolved in 100 mL of 0.1 N HCl solⁿ. Will the resulting solⁿ be acidic or basic. Also find the normality of acidic or basic solⁿ?

→ solution:

For Na_2CO_3

$$W = 0.5 \text{ g}$$

$$E = 53$$

For HCl

$$V = 100 \text{ mL}$$

$$N = 0.1 \text{ N}$$

$$\begin{aligned} \text{Now, } \frac{N_{\text{mix}} \times V_{\text{mix}}}{1000} &= \left(\frac{N \cdot V}{1000} \right)_{\text{acid}} - \left(\frac{W}{E} \right)_{\text{base}} \\ &= \left(\frac{10}{1000} \right) - \left(\frac{0.5}{53} \right) \end{aligned}$$

$$\left[\frac{NXV}{1000} \right]_A = \left(\frac{NXV}{1000} \right)_B \text{ or } \left(\frac{W}{E} \right)_B + \left(\frac{NXV}{1000} \right)_C.$$

$$\frac{N_{mix} V_{mix}}{1000} = 5.66 \times 10^{-4}$$

$$N_{mix} \times 100 = 0.566$$

$$N_{mix} = 5.66 \times 10^{-3}$$

∴ the soln is acidic. ✓

Type-6) Problem involving Residual soln or) Double step neutralization. [Imp]

case I) To the soln of A, a substance B is added that partially neutralize A. The mixture is now called residual solution of A. To the residual of A, Another substance C is added. which neutralizes it completely.

Now At neutralization point,

No. of gm. eqv of A = no. of gm eqn of (B+C)

$$\text{or } \left(\frac{NXV}{1000} \right)_A = \left(\frac{NXV}{1000} \right)_B + \left(\frac{W}{E} \right)_B + \left(\frac{NXV}{1000} \right)_C.$$

case II) To the soln of A, a substance B is added that partially neutralizes A, Then ^{sample of} residual soln of A is withdrawn and is treated with C. Here C neutralizes the sample of residual soln of A. In this case first we determine the volⁿ of C required to neutralize whole residual solution of A and we use the above formula.

(where volⁿ of C is calculated volⁿ)

44) 0.18g of a divalent metal is added to the 100ml of 0.65 N HCl. The residual soln of HCl then required 60ml of 0.42 N NaOH for complete neutralization. find the Atomic mass of metal?

→ For HCl

$$V_1 = \text{?}$$

$$N_1 = 0.65N$$

For NaOH

$$V_2 = 60\text{ml}$$

$$N_2 = 0.42$$

$$N_1 V_1 = N_2 V_2$$

$$V_1 = \frac{N_2 V_2}{N_1} = \frac{0.42 \times 60}{0.65}$$

$$= 38.767 \text{ ml}$$

$$\text{Reacted acid} = 100 - 38.77$$

$$= 61.23 \text{ mL}$$

Now, we have,

$$\frac{w}{z} = \frac{VN}{1000}$$

$$\text{or, } \frac{0.18}{z} = \frac{61.23 \times 0.65}{1000} = 0.0398$$

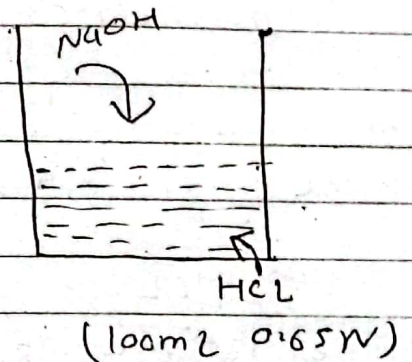
$$\text{or, } E = 4.5 \text{ \AA}$$

Now, Atomic mass = valency \times Eq. wt

$$= 2 \times 4.5$$

$$= 9 \text{ amu \AA}$$

45) 0.4g of oxalic acid ($M=90$) is added to the 100ml of normal soln of NaOH after the acid being completely dissolved, the soln is diluted to 150 ml. 15 ml of diluted soln required



12 ml of HCl solⁿ for complete neutralization. Find the normality of HCl.

→ Solution:

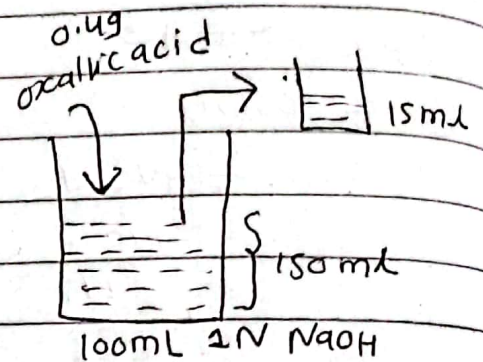
Here,

15 ml diluted solⁿ required 12 ml of HCl solⁿ for complete neutralization.

Then,

150 ml residual solⁿ required $\frac{12 \times 150}{15}$ ml of HCl

i.e. 120 ml of HCl



If 120 ml of HCl was added to the 150 ml of diluted NaOH, then it would have been completely neutralized.

$$\left(\frac{N \times V}{1000}\right)_{\text{NaOH}} = \left(\frac{w}{E}\right)_{\text{oxalic acid}} + \left(\frac{N \times V}{1000}\right)_{\text{HCl}}$$

$$\left(\frac{1 \times 100}{1000}\right) = \left(\frac{0.4}{40}\right) + \left(\frac{N \times 120}{1000}\right)$$

$$0.1 = 0.01 + 0.12N$$

$$\therefore N = 0.75 \text{ N}$$

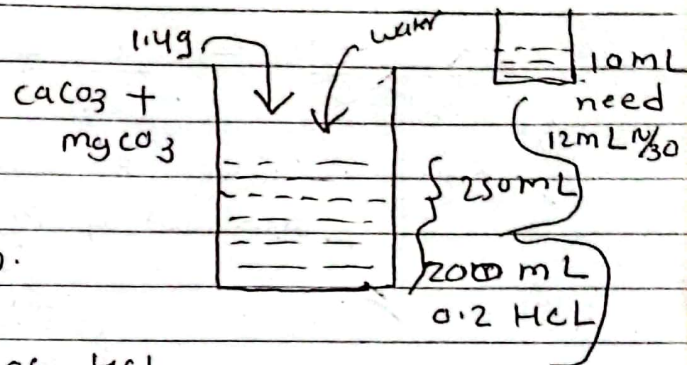
~~\therefore Normality of HCl is 0.75 N~~

46) 1.4g of a mixture of CaCO_3 and MgCO_3 was dissolved in 200ml of 0.2N HCl solution. After the rxn was completed the solution was diluted to 250 mL and 10mL of this soln required 12mL of $N/30$ NaOH for complete neutralization. Find the % of CaCO_3 and MgCO_3 in the mixture. (Dolomite)

→ Solution:

Here

10 mL diluted soln required
12 mL $N/30$ NaOH for
complete ~~soln~~ neutralization.



Then,

$$250 \text{ mL requires } \frac{12 \times 250}{10} \text{ of HCl} \\ = 300 \text{ mL}$$

Now) ~~Let~~ Let the mass of CaCO_3 be x gm.
Then mass of $\text{MgCO}_3 = (1.4 - x)$ gm.

Now

$$\left(\frac{N \times V}{1000} \right)_{\text{HCl}} = \left(\frac{w}{E} \right)_{\text{CaCO}_3} + \left(\frac{w}{E} \right)_{\text{MgCO}_3} + \left(\frac{N \times V}{1000} \right)_{\text{NaOH}}$$

$$0.2 \times \frac{200}{1000} = \frac{x}{50} + \frac{1.4 - x}{42} + \frac{1/30 \times 1200}{1000}$$

$$0.04 = \frac{x}{50} + \frac{1.4 - x}{42} + 0.01$$

$$\text{or)} \quad \frac{42x + 50(1.4-x)}{42 \times 50} = 0.03$$

$$\text{or)} \quad 42x + 70 - 50x = 63$$

$$\text{or)} \quad -8x = -7$$

$$\text{or)} \quad x = \frac{-7}{-8} = 0.875 \text{ g}$$

$$\frac{0.2 \times 200}{1000} = \frac{x}{50} + \frac{1.4-x}{4}$$

Now \therefore wt of CaCO_3 is 0.875 g

$$\text{Then wt of } \text{MgCO}_3 = 1.4 - 0.875$$

$$= 0.525 \text{ g}$$

47) Calculate the weight of sodium carbonate decahydrate ($\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$) required to make 500 ml of decinormal solution.

→ solution:

$$\text{we have, Mol. weight of } \text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O} = 106 + 10 \times (18) = 286$$

$$\text{Now, Equivalent weight (E)} = \frac{286}{2} = 143$$

$$\text{weight (w)} = \frac{V \times N}{1000} = \frac{500 \times 143 \times 0.1}{1000} = 7.158 \text{ g}$$

48) What volume of 95% sulphuric acid ($d = 1.859 \text{ g/cc}$) is required and mass of water must be taken to prepare 100 cc of 15% sulphuric acid ($d = 1.1 \text{ g/cc}$) [2071]

→ Solution.

For H_2SO_4

$$V_1 = ?$$

$$V_2 = 100 \text{ cc}$$

$$= 100 \text{ mL}$$

$$N_1 = \frac{\% (w/w) \times \rho \times 10}{E}$$

$$N_2 = \frac{\% (w/w) \times \rho \times 10}{E}$$

$$= \frac{95 \times 1.859 \times 10}{49}$$

$$= \frac{15 \times 1.1 \times 10}{49}$$

$$= 35.86 \text{ N}$$

$$= 3.367 \text{ N}$$

We know that,

$$N_1 V_1 = N_2 V_2$$

$$\text{or } 35.86 \times V_1 = 3.367 \times 100$$

$$\text{or } V_1 = 9.38 \text{ mL}$$

$$\text{Vol. of water to be added} = (100 - 9.38) \text{ mL}$$

$$= 90.61 \text{ mL} \checkmark$$

$$\text{mass of water to be added (m)} = \rho \times V$$

$$= 1 \times 90.61$$

$$= 90.61 \text{ g} \checkmark$$

49) What volume of water must be evaporated off from a certain volume of centimolar H_2SO_4 solution to prepare 1 mL of its semimolar solution?

→ Soln:

$$V_1 = ?$$

$$V_2 = 1 \text{ mL}$$

$$M_1 = m/100$$

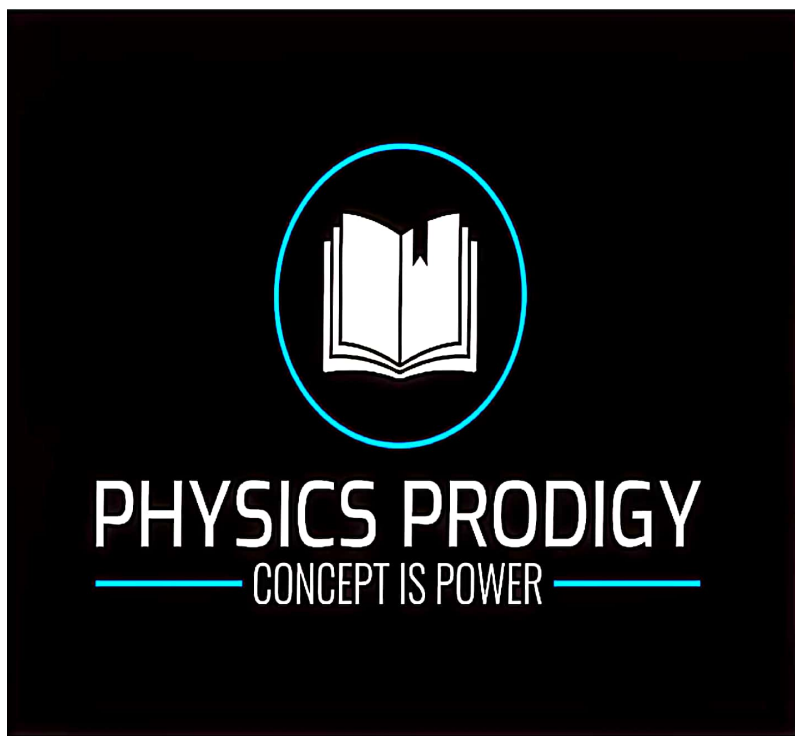
$$M_2 = m/2$$

$$\text{Now, } V_1 M_1 = V_2 M_2$$

$$V_1 \times \frac{1}{100} = 1 \times \frac{1}{2} \Rightarrow V_1 = 50 \text{ mL}$$

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