

2. Normality: Symbol (N)

Normality (N) is the number of equivalents of solute per liter of solution or the number of milliequivalents in one milliliter. Normality has the dimensions of eq L⁻¹.

$$N = \frac{n_{\text{eq}}}{V(\text{L})} \quad , \quad n_{\text{eq}} = \frac{\text{mass}}{\text{eq.mass}} \quad ; \quad \text{eq.mass} = \frac{M.\text{mass}(\text{g mol}^{-1})}{n(\text{eq mol}^{-1})}$$

$$N = \frac{\text{mass}}{\text{eq.mass}} \times \frac{1000}{V(\text{mL})} \quad \longleftrightarrow \quad \text{mass} = \frac{N \times \text{eq.mass} \times V(\text{mL})}{1000}$$

$$N = n \times M$$

n_{eq} = number of equivalents (eq), **eq.wt** = equivalent weight (g eq⁻¹)

✚ Equivalent mass (eq.mass):

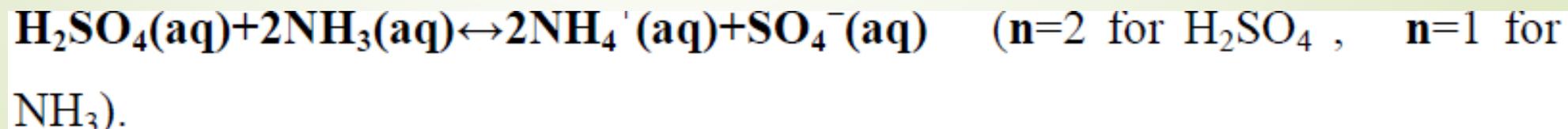
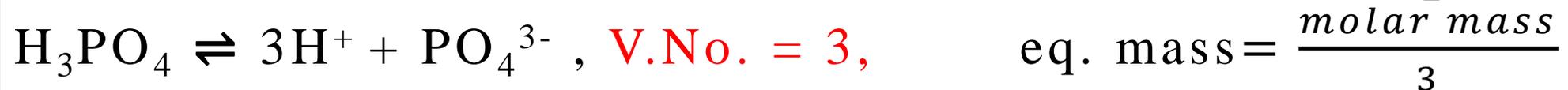
- The equivalent mass for a substance is always based on its behavior in a specific chemical reaction.

Note: eq. wt. = molar mass (m.wt)/valance number(n)

The equivalents (n) are based on a reaction unit, which is that part of a chemical species involved in a reaction.

✓ **In an acid-base reaction**, the reaction unit is the number of H⁺ ions donated by an acid or accepted by a base.

- For Acid : valance number = hydrogen atom liberated.



- For Base: valance number = hydrogen atom reacted



- For Salts: valance number = hydrogen atom reacted with the salts.



- ✓ **In a precipitation reaction**, for example, the reaction unit is the charge of the action or anion involved in the reaction.

Example



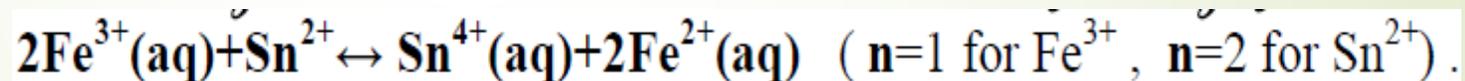
- ✓ **For a complexation reaction**, the reaction unit is the number of electron pairs that can be accepted by the metal or donated by the ligand.

Example



- ✓ **In an oxidation-reduction reaction**, the reaction unit is the number of electrons released by the reducing agent or accepted by the oxidizing agent.

Example



For Redox: valance number = the consumed or produced number of electrons.



$$(+1+x-8=0) \Rightarrow x = +7, \quad \therefore +7 + y = +2 \Rightarrow y = -5 (\text{e}^-).$$

Example 4:-

Calculate the number of equivalents in 2.84 g of KMnO_4 (M.wt=158.04 g mol⁻¹) with respect to the half reaction:



Solution:

$$\text{eq. mass} = \frac{\text{M.mass (g mol}^{-1}\text{)}}{n \text{ (eq mol}^{-1}\text{)}} = \frac{158.04 \text{ (g mol}^{-1}\text{)}}{5 \text{ (eq mol}^{-1}\text{)}} = 31.608 \text{ g eq}^{-1}$$

$$n_{\text{eq}} = \frac{\text{mass}}{\text{eq.mass}} = \frac{2.84 \text{ g}}{31.06 \text{ g eq}^{-1}} = 0.0899 \text{ eq KMnO}_4$$



Example 5:-

Calculate the equivalent weight and the normality for a solution of 6 M H_3PO_4 given the following reaction:



Solution:

$$\text{eq. mass} = \frac{\text{M.mass}}{n} = \frac{97.994 \text{ (g mol}^{-1}\text{)}}{2 \text{ (eq mol}^{-1}\text{)}} = 48.997 \text{ g eq}^{-1}$$

$$N = n \times M = 2 \times 6 = 12 \text{ eq L}^{-1}$$

3-Percent Concentration

Chemists express concentrations in terms of percent (part per hundred). Percent composition of a solution can be expressed in several ways. Three common methods are:

a) Weight percent (%w/w): Grams of solute per 100 g of solution

$$\%w/w = \frac{\text{mass solute}}{\text{mass solution}} \times 100$$

For example, hydrochloric acid is sold as a 37% solution which means that reagent contains 37 g of HCl per 100 g of solution.

b) Volume percent (%v/v): mL of solute per 100 mL of solution.

$$\%v/v = \frac{\text{volume solute}}{\text{volume solution}} \times 100$$

Example, a 10 % aqueous solution of methanol means diluting 10 mL of pure methanol with enough water to give 100 mL.

c) Weight-to-volume (%w/v): Grams of solute per 100 mL of solution.

$$\%w/v = \frac{\text{weight solute (g)}}{\text{volume solution (mL)}} \times 100$$

For example, 5% aqueous sodium chloride refers to a solution prepared by dissolving 5 g of NaCl in sufficient water to give 100 mL of solution.

Example 6:-

How would you prepare:

- 500 mL of 16.0 % (w/v) aqueous ethanol?
- 500 mL of 16.0 % (v/v) aqueous ethanol?
- 500 g of 16.0 % (w/w) aqueous ethanol?

Solution:

$$(a) \%w/v = \frac{\text{mass (g)}}{V \text{ (mL)}} \times 100 \implies \text{mass} = \frac{\%w/v \times V}{100} = \frac{16 \text{ g mL}^{-1} \times 500 \text{ mL}}{100} = 80 \text{ g}$$

$\text{C}_2\text{H}_5\text{OH}$

Dilute 80 g ethanol to 500 mL with water.

$$(b) \%v/v = \frac{V \text{ (mL)}}{V \text{ (mL)}} \times 100 \implies v = \frac{\%v/v \times V}{100} = \frac{16 \times 500 \text{ mL}}{100} = 80 \text{ mL } \text{C}_2\text{H}_5\text{OH}$$

Dilute 80 mL ethanol to 500 mL with water.

$$(b) \%w/w = \frac{\text{wt (g)}}{\text{wt (g)}} \times 100 \implies \text{wt} = \frac{\%w/w \times \text{wt}}{100} = \frac{16 \times 500 \text{ g}}{100} = 80 \text{ g } \text{C}_2\text{H}_5\text{OH}$$

Dilute 80 g ethanol with 420 g water.

4-Parts per million(ppm) and Parts per billion(ppb)

Parts per million (ppm): Milligrams of solute per liter of solution.

$$\text{ppm} = \frac{\text{weight solute}(\text{mg})}{\text{volume solution}(\text{L})} = \frac{\text{weight solute}(\mu\text{g})}{\text{volume solution}(\text{mL})}$$

$$\text{ppm} = \frac{\text{wt}(\text{g})}{\text{V}(\text{mL})} \times 10^6$$

$$\text{ppm} = \text{M} \times \text{M.wt} \times 1000$$

$$\text{ppm} = \frac{\text{mol}}{\text{L}} \times \frac{\text{g}}{\text{mol}} \times 10^3 \frac{\text{mg}}{\text{g}} = \frac{\text{mg}}{\text{L}}$$

Example 7:-

Calculate the molar concentration of $\text{K}_4\text{Fe}(\text{CN})_6$ in a solution that contain 75 ppm of $\text{K}_4\text{Fe}(\text{CN})_6$ (M.wt=368 g mol^{-1}).

Solution:

$$\begin{aligned} \text{ppm} &= M \times \text{M.wt} \times 1000 \quad \implies \quad M = \frac{\text{ppm}}{\text{M.wt} \times 1000} = \frac{75 \text{ mg L}^{-1}}{368 \text{ g mol}^{-1} \times 1000 \text{ mg g}^{-1}} \\ &= 2.04 \times 10^{-4} \text{ mol L}^{-1} \text{ K}_4\text{Fe}(\text{CN})_6 \end{aligned}$$

what are the molar concentration of K^+ ion in the solution?

$$[\text{K}^+] = 2.04 \times 10^{-4} \text{ mol L}^{-1} \text{ K}_4\text{Fe}(\text{CN})_6 \times \frac{4 \text{ mol K}^+}{1 \text{ mol K}_4\text{Fe}(\text{CN})_6} = 8.16 \times 10^{-4} \text{ mol L}^{-1}$$

K^+

✚ Density and the specific gravity

➤ **Density (D)** is the mass of a substance per unit volume.

$$\text{(Density of water (D}_w\text{) = } \frac{1 \text{ kg}}{\text{L}} = \frac{1 \text{ g}}{\text{mL}} \text{)}$$

$$D = \frac{\text{Kg}}{\text{L}} = \frac{\text{g}}{\text{mL}}$$

Specific gravity (sp.gr) is the ratio of the mass of a substance to the mass of an equal volume of water.

$$\text{Specific gravity} = \frac{\text{Density of matter}}{\text{Density of water}}$$

$$D = \text{sp.gr.} \times D_w \implies D = \frac{\text{kg}}{\text{kg}} \times \frac{1 \text{ kg}}{\text{L}} = \frac{\text{kg}}{\text{L}} \implies D = \text{sp.gr.} = \text{kg L}^{-1}$$

Molarity and Normality of commercial concentrated acids and bases:

$$M = \frac{\text{sp.gr} \times \left(\frac{\%w}{w}\right) \times 1000}{\text{M.wt}} \quad \text{and} \quad N = \frac{\text{sp.gr} \times \left(\frac{\%w}{w}\right) \times 1000}{\text{eq.wt}}$$

Example 8:-

Calculate the molarity of H_2SO_4 (98 g mol^{-1}) in a solution that has a specific gravity of 1.198 and is 27% H_2SO_4 (%w/w), and describe the preparation of 250 mL of 0.5 M H_2SO_4 solution from concentrated solution of H_2SO_4 .

Solution:

$$M = \frac{\text{sp. gr} \times \left(\% \frac{\text{W}}{\text{W}}\right) \times 1000}{\text{M. wt}} \Rightarrow M = \frac{1.198 \times \frac{27}{100} \times 1000}{98} = 3.3 \text{ mol L}^{-1}$$

$$M_{\text{concd}} \times V_{\text{concd}} = M_{\text{dil}} \times V_{\text{dil}}$$

$$3.3 \times V_{\text{concd}} = 0.5 \times 250 \quad \Longrightarrow \quad V_{\text{concd}} = 37.9 \text{ mL}$$



Thank you