Methods of expressing concentration of solution.

Concentration of solution is the amount of solute dissolved in a known amount of the solvent or
solution. The concentration of solution can be expressed in various ways as discussed below.

(1) **Percentage**: It refers to the amount of the solute per 100 parts of the solution. It can also be called as parts per hundred (pph). It can be expressed by any of following four methods:

(i) **Weight to weight percent (% w/w)** $= \frac{\text{Wt. of solute}}{\text{Wt. of solution}} \times 100$

e.g., 10% Na_2CO_3 solution w/w means $10g$ of Na_2CO_3 is dissolved in $100g$ of the solution. (It means $10g$ Na_2CO_3 is dissolved in $90g$ of H_2O)

(ii) **Weight to volume percent (% w/v)** $= \frac{\text{Wt. of solute}}{\text{Volume of solution}} \times 100$

e.g., 10% Na_2CO_3 (w/v) means $10g$ Na_2CO_3 is dissolved in $100\ cc$ of solution.

(iii) **Volume to volume percent (% v/v)** $= \frac{\text{Vol. of solute}}{\text{Vol. of solution}} \times 100$

e.g., 10% ethanol (v/v) means $10\ cc$ of ethanol dissolved in $100\ cc$ of solution.

(iv) **Volume to weight percent (% v/w)** $= \frac{\text{Vol. of solute}}{\text{Wt. of solution}} \times 100$

e.g., 10% ethanol (v/w) means $10\ cc$ of ethanol dissolved in $100g$ of solution.

(2) **Parts per million (ppm) and parts per billion (ppb)**: When a solute is present in trace quantities, it is convenient to express the concentration in parts per million and parts per billion. It is the number of parts of solute per million (10^6) or per billion (10^9) parts of the solution. It is independent of the temperature.

$$ppm = \frac{\text{mass of solute component}}{\text{Total mass of solution}} \times 10^6; \quad ppb = \frac{\text{mass of solute component}}{\text{Total mass of solution}} \times 10^9$$

(3) **Strength**: The strength of solution is defined as the amount of solute in grams present in one litre (or dm^3) of the solution. It is expressed in g/litre or (g/dm^3).

$$\text{Strength} = \frac{\text{Mass of solute in grams}}{\text{Volume of solution in litres}}$$

(4) **Normality (N)**: It is defined as the number of gram equivalents (equivalent weight in grams) of a solute present per litre of the solution. Unit of normality is gram equivalents litre^{-1}. Normality changes with temperature since it involves volume. When a solution is diluted x times, its normality also decreases by x times. Solutions in term of normality generally expressed as,

$N =$ Normal solution; $5N =$ Penta normal, $10N =$ Deca normal; $N/2 =$ semi normal

$N/10 =$ Deci normal; $N/5 =$ Penti normal

$N/100$ or $0.01\ N =$ centinormal, $N/1000$ or 0.001= millinormal

Mathematically normality can be calculated by following formulas,

(i) $\text{Normality } (N) = \dfrac{\text{Number of g.eq. of solute}}{\text{Volume of solution } (l)} = \dfrac{\text{Weight of solute in } g.}{\text{g. eq. weight of solute} \times \text{Volume of solution } (l)}$

(ii) $N = \dfrac{\text{Wt. of solute per litre of solution}}{\text{g eq. wt. of solute}}$,

(iii) $N = \dfrac{\text{Wt. of solute}}{g\text{.eq. wt. of solute}} \times \dfrac{1000}{\text{Vol. of solution in } ml}$

(iv) $N = \dfrac{\text{Percent of solute} \times 10}{\text{g eq. wt. of solute}}$,

(v) $N = \dfrac{\text{Strength in } g\ l^{-1} \text{ of solution}}{\text{g eq. wt. of solute}}$

(vi) $N = \dfrac{\text{Wt\%} \times \text{density} \times 10}{\text{Eq. wt.}}$

(vii) If volume V_1 and normality N_1 is so changed that new normality and volume N_2 and V_2 then,

$\boxed{N_1V_1 = N_2V_2}$ (Normality equation)

(viii) When two solutions of the same solute are mixed then normality of mixture (N) is

$$\boxed{N = \frac{N_1V_1 + N_2V_2}{V_1 + V_2}}$$

(ix) Vol. of water to be added i.e., $(V_2 - V_1)$ to get a solution of normality N_2 from $V_1\ ml$ of normality N_1

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

(x) If Wg of an acid is completely neutralized by $V\ ml$ of base of normality N

$$\frac{\text{Wt. of acid}}{\text{g eq. wt. of acid}} = \frac{VN}{1000}$$; Similarly, $$\frac{\text{Wt. of base}}{\text{g eq. wt. of base}} = \frac{\text{Vol. of acid} \times N \text{ of acid}}{1000}$$

(xi) When $V_a\ ml$ of acid of normality N_a is mixed with $V_b\ ml$ of base of normality N_b

(a) If $V_a N_a = V_b N_b$ (Solution neutral)

(b) If $V_a N_a > V_b N_b$ (Solution is acidic)

(c) If $V_b N_b > V_a N_a$ (Solution is basic)

(xii) Normality of the acidic mixture $= \frac{V_a N_a + V_b N_b}{(V_a + V_b)}$

(xiii) Normality of the basic mixture $= \frac{V_b N_b + V_a N_a}{(V_a + V_b)}$

(xiv) $N = \frac{\text{No. of meq}\ ^{*} \text{ of solute}}{\text{Vol. of solution in } ml}$ (* 1 equivalent = 1000 milliequivalents or meq.)

(4) **Molarity (M)**: Molarity of a solution is the number of moles of the solute per litre of solution (or number of millimoles per ml. of solution). Unit of molarity is **mol/litre** or **mol/dm^3**For example, a molar $(1M)$ solution of sugar means a solution containing 1 mole of sugar (i.e., 342 g or 6.02×10^{23} molecules of it) per litre of the solution. Solutions in term of molarity generally expressed as,

$1M$ = Molar solution, $2M$ = Molarity is two, $\frac{M}{2}$ or 0.5 M = Semimolar solution,

$\frac{M}{10}$ or 0.1 M = Decimolar solution, $\frac{M}{100}$ or 0.01 M = Centimolar solution

$\frac{M}{1000}$ or 0.001 M = Millimolar solution

- Molarity is most common way of representing the concentration of solution.
- Molarity is depend on temperature as, $\text{Molarity} \propto \frac{1}{\text{Temperature}}$
- When a solution is diluted (x times), its molarity also decreases (by x times)

Mathematically molarity can be calculated by following formulas,

(i) $$M = \frac{\text{No. of moles of solute } (n)}{\text{Vol. of solution in litres}},$$

(ii) $M = \frac{\text{Wt. of solute (in gm) per litre of solution}}{\text{Mol. wt. of solute}}$

(iii) $M = \frac{\text{Wt. of solute (in gm)}}{\text{Mol. wt. of solute}} \times \frac{1000}{\text{Vol. of solution in } ml.}$

(iv) $M = \frac{\text{No. of millimoles of solute}}{\text{Vol. of solution in } ml}$

(v) $M = \frac{\text{Percent of solute} \times 10}{\text{Mol. wt. of solute}}$

(vi) $M = \frac{\text{Strength in } gl^{-1} \text{ of solution}}{\text{Mol. wt. of solute}}$

(vii) $M = \frac{10 \times \text{Sp. gr. of the solution} \times \text{Wt.\% of the solute}}{\text{Mol. wt. of the solute}}$

(viii) If molarity and volume of solution are changed from M_1, V_1 to M_2, V_2. Then,

$M_1 V_1 = M_2 V_2$ (Molarity equation)

(ix) In balanced chemical equation, if n_1 moles of reactant one react with n_2 moles of reactant two. Then,

$$\frac{M_1 V_1}{n_1} = \frac{M_2 V_2}{n_2}$$

(x) If two solutions of the same solute are mixed then molarity (M) of resulting solution.

$$M = \frac{M_1 V_1 + M_2 V_2}{(V_1 + V_2)}$$

(xi) Volume of water added to get a solution of molarity M_2 from $V_1\ ml$ of molarity M_1 is

$$V_2 - V_1 = \left(\frac{M_1 - M_2}{M_2} \right) V_1$$

Relation between molarity and normality

Normality of solution = molarity $\times \frac{\text{Molecular mass}}{\text{Equivalent mass}}$

Normality × equivalent mass = molarity × molecular mass

For an acid, $\frac{\text{Molecular mass}}{\text{Equivalent mass}}$ = basicity

So, Normality of acid = molarity × basicity.

For a base, $\frac{\text{Molecular mass}}{\text{Equivalent mass}}$ = Acidity

So, Normality of base = Molarity × Acidity.

(6) **Formality (F):** Formality of a solution may be defined as the number of gram formula masses of the ionic solute dissolved per litre of the solution. It is represented by F. Commonly, the term formality is used to express the concentration of the ionic solids which do not exist as molecules but exist as network of ions. A solution containing one gram formula mass of solute per litre of the solution has formality equal to one and is called formal solution. It may be mentioned here that the formality of a solution changes with change in temperature.

Formality (F) = $\frac{\text{Number of gram formula masses of solute}}{\text{Volume of solution in litres}}$ =

$$\frac{\text{Mass of ionic solute } (g)}{(gm.\text{ formula mass of solute}) \times (\text{Volume of solution } (l))}$$

Thus, $$F = \frac{W_B(g)}{GFM \times V(l)} \quad \text{or} \quad \frac{W_B(g) \times 1000}{GFM \times V(ml)}$$

(7) **Mole fraction (X):** Mole fraction may be defined as the ratio of number of moles of one component to the total number of moles of all the components (solvent and solute) present in the solution. It is denoted by the letter X. It may be noted that the mole fraction is independent of the temperature. Mole fraction is dimensionless. Let us suppose that a solution contains the components A and B and suppose that $W_A g$ of A and $W_B g$ of B are present in it.

Number of moles of A is given by, $n_A = \frac{W_A}{M_A}$ and the number of moles of B is given by,

$$n_B = \frac{W_B}{M_B}$$

Where M_A and M_B are molecular masses of A and B respectively.

Total number of moles of A and $B = n_A + n_B$

Mole fraction of A, $X_A = \frac{n_A}{n_A + n_B}$; Mole fraction of B, $X_B = \frac{n_B}{n_A + n_B}$

The sum of mole fractions of all the components in the solution is always one.

$$X_A + X_B = \frac{n_A}{n_A + n_B} + \frac{n_B}{n_A + n_B} = 1 .$$

Thus, if we know the mole fraction of one component of a binary solution, the mole fraction of the other can be calculated.

Relation between molality of solution (m) and mole fraction of the solute (X_A).

$$X_A = \frac{m}{55.5 + m}$$

(8) **Mass fraction**: Mass fraction of a component in a solution is the mass of that component divided by the total mass of the solution. For a solution containing $w_A gm$ of A and $w_B gm$ of B

$$\text{Mass fraction of } A = \frac{w_A}{w_A + w_B}; \text{ Mass fraction of } B = \frac{w_B}{w_A + w_B}$$

Note: It may be noted that molality, mole fraction, mass fraction etc. are preferred to molarity, normality, etc. because the former involve the weights of the solute and solvent whereas later involve volumes of solutions. Temperature has no effect on weights but it has significant effect on volumes.

(9) **Demal unit (D):** The concentrations are also expressed in “Demal unit”. One Demal unit represents one mole of solute present in one litre of solution at $0^o C$.