Methods for expressing concentrations

The mass of substance is usually determined in such metric as kilogram (kg=1000g) , the gram (g=1000mg) , It is more convenient for chemical calculations to employ mass units which express the weight relationship or stoiciometry among reacting species in terms of small whole numbers. The gram formula weight, the gram molecular weight, and the gram equivalent weight are employed in analytical computations for this reason.

These terms are always shortened to the formula weight(fw), the molecular weight(mw) and equivalent weight(eqw).

Chemical formulas : formula weights and molecular weights.

Empirical formula: is the simplest combination of atoms in a substance.

Molecular formula: is actual expression of the structure of the substance or compound.

The formula weight may equal the empirical formula such as chemical formula of H_2. On other hand, the chemical formula may or may not actually exist. For example NaCl is not found as NaCl in its solid state or in aqueous solution and it is existed as sodium ions (Na^+) and chloride ions (Cl^-). However, the formula as NaCl is convenient for stoiciometric accounting.

Gram Formula weight: is the summation of atomic weights in grams of all the atoms in the chemical formula of a substance. Therefore, the gram formula weight of H_2 $=2\times1.008=2.016$g, for NaCl it is equal $=35.45+22.99=58.44$g.

The gram molecular weight is employed instead of gram formula weight when the real chemical species is concerned. Therefore, the gram molecular weight of H_2 is its gram formula weight (2.016g), while NaCl in water, it should be assigned as gram ionic weight of Na^+ (23.00g) and gram ionic weight of Cl^- (35.45g).

One molecular weight of a species contains 6.023×10^{23} particles of that species. This quantity refers to the mole of the species.

A mole is the amounts of molecular compounds, free elements and ions.

1 mole of	H_2O	Contains	18.01g
1 mole of	Na_2SO_4	Contains	142.04g
1 mole of	Na^+	Contains	23g

Therefore, the number of moles are calculated of grams divided by formula weight of the species.

$$\text{Moles of urea} = \frac{\text{grams}}{60.06}$$

$$\text{Moles of Sulphate } (SO_4^{2-}) = \frac{\text{grams}}{96.06}$$

$$\text{Moles of silver (Ag)} = \frac{\text{grams}}{107.87}$$

Formal concentration (Formality), F :

It is the number of formula weights of substance contained in one litre of solution. The term also expresses the number of milliformula weights per millilitre of solution.

$$F = \frac{\text{wt of substance per litre of solution}}{\text{gfw}}$$

$$F = \frac{\text{number of fw}}{\text{litre of solution}} = \frac{\text{number of fw}}{\text{ml of solution}}$$

$$F = \frac{\text{gram of solute}}{\text{litre of solution} \times \text{gfw}} = \frac{\text{gram of solute}}{\text{gfw}} \times \frac{1000}{\text{ml of solution}}$$

Ex: 4.57 of $BaCl_2.2H_2O$ (gfw=244) were dissolved in water and diluted to 250 ml in volumetric flask. Calculate the formality concentration of $BaCl_2.2H_2O$ and Cl^-.

The solution:

$$F = \frac{\text{gram of solute}}{\text{Its gfw}} \times \frac{1000}{\text{ml of solution}}$$

$$= \frac{4.57}{244} \times \frac{1000}{250} = 0.0750 \text{ mfw / ml or fw / lit}$$

$$BaCl_2 \longrightarrow Ba^{2+} + 2\,Cl^-$$

0.075 F 0.075 F 2×0.075 F

$\therefore F_{Cl^-} = 2\times0.075 = 0.15$ mfw / ml or fw / lit

Molar concentration (Molarity), M :

It is the number of molecular weights or moles of solute per litre of solution. It is also the number of millimoles per millilitre of solution.

$$M = \frac{\text{wt of solute per litre of solution}}{\text{gmw}}$$

$$M = \frac{\text{No. of moles}}{\text{litre of solution}} = \frac{\text{No. of m moles}}{\text{ml of solution}}$$

$$M = \frac{\text{gram of solute}}{\text{litre of solution} \times \text{gmw}} = \frac{\text{Wt. of solute}}{\text{Its gmw}} \times \frac{1000}{\text{ml of solution}}$$

Ex: Calculate the Formal and Molar concentrations of the constituents in:

(a) 2.30g of ethanol (gfw=46.1) in 3.50 litres of aqueous solution.

(b) 285 mg of trichloroacetic acid (gfw=163) in 10 ml of aqueous solution (its percentage of ionization = 73%).

The solution:

(a)

$$F_{\text{ethanol}} = \frac{2.30\ \text{g}}{46.1\ \text{g / fw}} \times \frac{1\ \text{litre}}{3.50\ \text{lit}} = 0.0143\ \text{fw / lit}$$

Ethanol is non-electrolyte, therefore the solute ethanol remains as it is in aqueous solution.

$$M_{\text{ethanol}} = \frac{2.30\ \text{g}}{46.1\ \text{g / mole}} \times \frac{1\ \text{ml}}{3.50\ \text{lit}} = 0.0143\ \text{moles / lit}$$

Therefore in this example F = M = 0.0143

(b)

$$F_{HA} = \frac{285\ \text{mg}_{HA}}{163\ \text{mg}_{HA}\ /\ \text{mfw}} \times \frac{1\ \text{ml}}{10\ \text{ml}} = 0.175\ \text{m fw / ml}$$

73% of trichloroacetic acid is ionized, therefore 27% of the acid is unionized .

$$M_{HA} = \frac{285 \times 0.27\ \text{mg}}{163\ \text{mg}_{HA}\ /\ \text{m mole}} \times \frac{1\ \text{litre}}{10\ \text{ml}} = 0.0472\ \text{m mole / ml}$$

$$Cl_3CCOOH \rightleftharpoons Cl_3CCOO^- + H^+$$

$M_{H^+} = MCl_3CCOO^- = 0.175-0.0472=0.128$ m mole / ml.

Molal concentration (Molality), m :

It is the number of molecular weights or moles of solute per 1000 g (or 1 kg) of solvent:

$$m = \frac{\text{Wt. of solute}}{\text{Its gmw}} \times \frac{1000\ \text{g}}{\text{Weight of solvent}}$$

Ex: Calculate the Formal and Molal concentrations of solution prepared by dissolving 8g of NaOH in 500 g of water.

<u>The solution:</u>

$$m = \frac{8}{40} \times \frac{1000}{500} = \frac{8}{40} \times \frac{1000}{500} = 0.4\ \text{mol / kg}$$

This concentration is always used in physical chemistry where the weight is not changed by temperature.