VOLUMETRIC ANALYSIS

This approach involves assessing the potency of a given solution by utilizing another solution of established strength. Quantitative analysis, specifically, is a meticulous process that involves the precise determination of the quantity or concentration of a specific substance within a sample.

Volumetric analysis is a subset of quantitative analysis, and its application relies on several criteria for the reaction employed.

These conditions include:

1. A comprehensive understanding of the chemistry underlying the reaction, which should be clearly defined by a specific chemical equation.
2. The reaction should be rapid, occurring instantaneously, and should reach completion across a broad spectrum of concentrations.

Equivalent Weight

The equivalent weight of a substance is defined as the weight that reacts with or liberates 1 gram of hydrogen (equivalent to 11.2 liters of H_2 at STP), 8 grams of oxygen, 35.5 grams of chlorine, or 80 grams of bromine.

For example:

$$\underset{28g}{N_2} + \underset{6g}{3H_2} \rightarrow \underset{34\,g}{2NH_3}$$

The equivalent weight of nitrogen is calculated as $\frac{28}{6} \times 1 = \frac{14}{3}$

The equivalent weight of ammonia is determined as $\frac{34}{6} \times 1 = \frac{17}{3}$.

A packet of substance containing the equivalent mass in grams is referred to as an equivalent. The equivalent mass for different species is defined as follows:

- Elements: The amount of an element that reacts with or displaces 1 gram of hydrogen, 8 grams of oxygen, or 35.5 grams of chlorine.

$$\text{Equivalent mass} = \frac{\text{Atomic mass}}{\text{Valency of the element}}$$

- Acids:

(a) The amount of acid that yields 6.02×10^{23} H^+ ions.

(b) The amount of acid that can neutralize 6.02×10^{23} OH^- ions.

(c) $\text{Equivalent mass of acid} = \frac{\text{Molecular mass}}{\text{Number of OH– ions which can be neutralized per molecule of acid}}$

(d) $\text{Equivalent mass of acid} = \frac{\text{Molecular mass}}{\text{Basicity of the acid}}$

- Ions:

$$\text{Equivalent mass of an ion} = \frac{\text{Formula mass of the ion}}{\text{Charge on the ion}}$$

Ionic Compounds:

$$\text{Equivalent mass of an ionic compound} = \frac{\text{Molecular mass}}{\text{Charge on the constituent cation or anion}}$$

- Base:

(a) The quantity of base required to generate 6.02 x 10^{23} OH^- ions.

(b) The amount of base capable of neutralizing 6.02×10^{23} H^+ ions.

(c) The equivalent mass of a base is determined by dividing the molecular mass by the number of replaceable OH^- ions in a molecule or the acidity of the base.

(d) Alternatively, the equivalent mass of a base can be calculated as the molecular mass divided by the number of H^+ ions that can be neutralized by one molecule of the base.

- Equivalent Weight of Metal Oxide:
  The equivalent weight of a metal oxide is calculated by adding 8 to the equivalent weight of the metal.
- Equivalent Weight of Ionic Compound:
  The equivalent weight of an ionic compound is the sum of the equivalent weight of the cation and the equivalent weight of the anion.
- Equivalent Weight of Salt:
  The equivalent weight of a salt is determined by dividing the molecular weight by the total positive charge on the cation.
- Equivalent Weight of Acidic Salt:
  For example, in Na_2HPO_4, the equivalent weight is calculated as the molecular weight divided by the number of replaceable hydrogen ions, giving $\frac{M}{1}$.

Normality

This concept is expressed as the gram equivalent of a solute dissolved in one liter of solution.
It can be mathematically represented as follows:
N = Gram equivalent of solute/Volume of solution (liters)
Further, this relationship can be expanded using the formulas:
N = W/Equivalent weight × 1000/Volume of solution (ml)
Additionally, in the context of acids, the connection between Normality (N) and Molarity (M) can be established through two equations:
N = W/Equivalent weight × 100/Volume of solution (ml) ...(i)
N = W/Molecular weight × Basicity × 1000/Volume of solution (ml) ...(ii)
Simultaneously, Molarity (M) is represented by:
M = W/Molecular weight × 1000/Volume of solution (ml) ...(iii)
By substituting the value of (iii) into equation (i), the relationship between Normality and Molarity for acids is defined as:

$$N = M \times \text{Basicity}$$

For compounds other than acids, the relationship can be expressed as:

$$N = \text{n-factor} \times M$$

n-Factor or Valence Factor

Various techniques exist for determining the equivalent weight of different compounds, but a generalized approach involves the utilization of the n-factor. The equivalent weight is calculated using the formula:

$$\text{Equivalent weight} = \frac{\text{Molecular Weight}}{\text{n−factor}}.$$

In the context of acids, the n-factor corresponds to the basicity, while in bases, it corresponds to the acidity.
It is crucial to note that, for a balanced reaction involving only two reactants, the n-factor is typically the reciprocal of the molar ratio. This reciprocal relationship aids in predicting the molar ratio of the species involved in the reaction, specifically the reactants. The molar ratio of reactants is established by taking the reciprocal of the n-factor's ratio.
For instance, if compound X, with an n-factor of 'a,' reacts with compound Y, with an n-factor of 'b,' the n-factor's ratio is expressed as a : b. Consequently, the molar ratio of X to Y is represented as b : a.
This relationship is illustrated in the balanced chemical equation as:

$$\underset{(nf=a)}{bx} + \underset{(nf=b)}{by} \rightarrow \text{Products.}$$

Volumetric or Quantitative Analysis

Volumetric analysis is a quantitative analytical method which is used widely. As the name suggests, this method involves measurement of the volume of a solution whose concentration is known and applied to determine the concentration of the analyte.

In other words, measuring the volume of a second substance that combines with the first in known proportions is known as Volumetric analysis or titration. It is this method of quantitative analysis that allows us to determine the concentration of the analyte. The first method of Volumetric Analysis was devised and found by the French chemist Jean-Baptiste-Andre-Dumas; as he was trying to determine the proportion of nitrogen combined with other elements in organic compounds. To ensure the conversion of the nitrogen compound into pure gas, the nitrogen compound was burnt in a furnace and passed along a furnace in a stream of carbon dioxide that is passed into a strong alkali solution. The mass of the nitrogen is calculated and occupies under known conditions of pressure and volume from the sample.