MOLECULAR WEIGHT DETERMINATION

Victor Meyer's Method

A specified quantity of a volatile substance is subjected to vaporization. The resulting vapors displace an equivalent volume of air, which is then measured in a graduated tube. To standardize the data, this volume of air is adjusted to Standard Temperature and Pressure (STP) using the formula:

$$\frac{P_1 V_1}{T_1} - \frac{P_2 V_2}{T_2}$$

Consequently, the molecular mass of the volatile substance is determined by dividing the weight of the substance by the volume of air displaced at Normal Temperature and Pressure (NTP) and then multiplying the result by 22,400.

$$\text{Molecular mass} = \frac{\text{Weight.of the substance taken}}{\text{Volume of air displaced (in cm}^3\text{) at NTP}} \times 22{,}400$$

The molecular weight is also expressed as twice the vapor density. Furthermore, for acids and bases, the molecular mass is computed by multiplying the equivalent weight by the basicity (for acids) or acidity (for bases).

$$\text{Molecular mass of an acid} = \text{Equivalent weight} \times \text{Basicity}$$

$$\text{Molecular mass of a base} = \text{Equivalent weight} \times \text{Acidity}$$

Additionally, the molecular formula of a compound can be determined by multiplying the empirical formula by a whole number (denoted as 'n').

$$\text{Molecular formula} = n \times \text{Empirical formula}$$

The value of 'n' is obtained by dividing the molecular mass of the compound by the empirical formula mass of the compound.

$$n = \frac{\text{Molecular mass of the compound}}{\text{Empirical formula mass of the compound}}$$

Volumetric Method

This technique is employed to determine the equivalent weight of both acids and bases. In the case of acids, a measured mass of the acid is dissolved in water and subjected to titration against a standardized solution of a base, typically sodium hydroxide (NaOH), with phenolphthalein serving as one of the indicators.

Let's denote V_1 as the volume in cubic centimeters (cm^3) of the normal (N) alkali solution required to neutralize W grams of the acid. To calculate the equivalent weight (Eq. wt.) of the acid, the following formula is applied:

$$1000\ \text{cm}^3 \text{ of 1 N alkali} = \frac{W}{V_1 \times N_1} \times 1000 \times 1$$

This equation yields the equivalent weight of the acid. Subsequently, the molecular mass of the acid is determined by multiplying the equivalent weight by the basicity of the acid:

Molecular mass of acid = Eq. wt. of acid × Basicity of acid

Similarly, for bases, the molecular mass is calculated by multiplying the equivalent weight by the acidity of the base:

$$\text{Molecular mass of base} = \text{Eq. wt. of base} \times \text{Acidity of base}$$

In summary, this method involves titrating a known mass of an acid against a standard base solution, enabling the determination of the equivalent weight and subsequently the molecular mass of the acid. The analogous approach is applied to bases, where the equivalent weight and molecular mass are derived based on the acidity of the base.

Silver Salt Method

This method is employed to ascertain the molecular weight of organic acids, particularly carboxylic acids. The process involves treating the carboxylic acid with a solution of silver nitrate ($AgNO_3$) to yield the corresponding silver salt of the acid. This silver salt is subsequently dried and weighed. The next step involves heating the silver salt strongly to obtain metallic silver as a residue, which is then weighed.

The equivalent weight (Eq. wt.) of the carboxylic acid (RCOOH) can be determined using the formula:

$$\text{Eq. wt. of RCOOH} = \frac{\text{wt.of silver salt of acid}}{\text{Wt. of silver}} \times 108 - 107$$

Following the determination of the equivalent weight, the molecular weight of the carboxylic acid is calculated by multiplying the equivalent weight by the basicity of the acid:

$$\text{Molecular weight of carboxylic acid} = \text{Eq. wt.} \times \text{Basicity of Acid}$$

In essence, this method involves the conversion of the carboxylic acid into its silver salt, followed by the separation and weighing of metallic silver. The derived equivalent weight is then utilized to calculate the molecular weight of the carboxylic acid based on its basicity.

Chloroplatinate Method

This method is applied for the determination of the molecular weight of organic bases. The procedure involves the reaction of the organic base with chloroplatinic acid (H_2PtCl_6), resulting in the formation of a salt (B_2PtCl_6). Subsequently, this salt is subjected to intense heating to obtain metallic platinum, the weight of which is recorded.

The calculation of the equivalent weight (B) of the base is determined through the formula:

$$2B + \frac{410}{195} = \frac{\text{Weight of Platinic chloride salt}}{\text{Weight of Pt formed}}$$

Here, B represents the equivalent weight of the base.

After determining the equivalent weight, the molecular weight of the organic base is found by multiplying the equivalent weight by the acidity of the base:

$$\text{Molecular weight of base} = \text{Eq. wt.} \times \text{Acidity of base}$$

In summary, this method involves the reaction of the organic base with chloroplatinic acid, followed by the measurement of the weight of platinum obtained after heating the resulting salt. The equivalent weight of the base is calculated using the provided formula, and the molecular weight of the base is subsequently determined based on its acidity.

Relationship Between Empirical and Molecular Formula

The relationship between the molecular formula and the empirical formula of a compound is defined by the equation: Molecular formula = n × empirical formula, where n is a simple whole number taking on values such as 1, 2, 3…etc. Additionally, the value of n can be determined by the ratio of the molecular formula mass to the empirical formula mass, expressed as

$$n = \frac{\text{Molecular formula mass}}{\text{Empirical formula mass}}.$$

To elucidate the process of determining the molecular formula from empirical data, the following sequential steps are undertaken

Weighing the Sample

Commencing the procedure involves the precise weighing of a sample of the compound under investigation.

Weighing CO_2 and H_2O

- The sample is subjected to combustion to generate CO_2 and H_2O.
- The weights of CO_2 and H_2O produced during combustion are then measured.

Calculating Moles of C and H

Based on the weights of CO_2 and H_2O, the moles of carbon (C) and hydrogen (H) are calculated.

Calculating C : H Mole Ratio

The mole ratio of carbon to hydrogen (C : H) is determined by the calculated moles.

Calculating Empirical Formula

Utilizing the mole ratio obtained, the empirical formula of the compound is then calculated.