EQUIVALENT WEIGHT

Introduction of Equivalent Weight

Equivalent weight, a fundamental concept in physical chemistry, is a widely used term in the field of chemistry. Also referred to as gram equivalent, it is defined as the mass of one equivalent, representing the amount of a given substance that will either combine with or displace a fixed quantity of another substance. In simpler terms, the gram equivalent or equivalent weight of a substance is the mass of the substance capable of displacing 1.008 grams of hydrogen, 8.0 grams of oxygen, or 35.5 grams of chlorine. To calculate the equivalent weight, the atomic weight of the substance is divided by its valence. For instance, the equivalent weight of oxygen is determined as 16.0 g / 2 = 8.0 g.

Equivalent Weight of an element

In acid-base reactions, the equivalent mass of an acid or base corresponds to the mass that supplies or reacts with one mole of hydrogen ions (H^+). Similarly, in redox reactions, the equivalent weight of a substance is the mass that provides or reacts with one gram-mole of electrons (e^-) produced in the redox reaction. Unlike atomic mass, which is dimensionless, the equivalent weight has a unit mass dimension. Determination of equivalent weight can be achieved experimentally or derived from the molar mass of the substance. Alternatively, it can be calculated by dividing the molecular mass by the number of positive or negative electrical charges resulting from the compound's dissolution.

This discussion covers significant aspects related to the equivalent weight of a metal. In chemistry, the equivalent weight is defined as the number of substances that fully react with each other in a reaction. When answering the question, "What is equivalent weight?" it's crucial to consider two factors: the molar mass and valency factor of the compound.

Equivalent Weight of Acid

Taking an example of sulfuric acid as follows:

$$H_2SO_4 + 2OH^- \rightarrow 2H_2O + SO_4^{2-}$$

The acid's equivalent weight can be established by calculating the individual molecular weight of each element from the periodic table and then aggregating them. This summation provides the molecular weight of the acid.

$$2(1) + (32) + 4(16) = 98.0.$$

The acid is seen to be donating two protons as the sulfate ion is seen to acquire negative charges. Therefore, the equivalent weight of the acid would be

$$98.0/2 = 49.0.$$

In the case of hydrochloric acid (HCl)

$$HCl \rightarrow H^+ + Cl^-$$

The number of hydrogen ions or hydronium ions released by hydrochloric acid is one.

So, the valency factor will be one.

The molecular weight of hydrochloric acid = 36.45

As we know, Equivalent weight = molecular weight / X

The equivalent weight of hydrochloric acid = 36.45 / 1 = 36.45

Equivalent Weight of Base

The reasoning for the base is the same. For example, ammonium hydroxide can accept a proton in solution to become an ammonium ion.

$$NH_4OH + H^+ \rightarrow H_2O + NH_4^+$$

The molecular weight of the hydroxide will be as follows.

$$(14) + (4)(1) + (16) + 1 = 35.0.$$

Here, since only one proton is accepted, thus the equivalent weight is equal to

$$35.0/1 = 35.0.$$

For the base, X (valency factor) is the acidity

Acidity- Acidity is the number of hydroxyl ions or hydroxide ions released by a base.

In the case of calcium hydroxide base $Ca(OH)_2$

$$Ca(OH)_2 \rightarrow Ca^{+} + 2\ OH^{-}$$

The number of hydroxyl ions released by the calcium hydroxide base is 2. Therefore, its valency factor or X value will be two.

The molecular weight of the calcium hydroxide base is 74.

As we know, Equivalent weight = molecular weight / X

The equivalent weight of calcium hydroxide base= 74 / 2 = 37

In the case of Aluminium hydroxide base $Ca(OH)_2$

$$Al(OH)_3 \rightarrow Al^{+3} + 3\ OH^{-}$$

The number of hydroxyl ions released by the Aluminium hydroxide base is 3. Therefore, its valency factor or X value will be three.

The molecular weight of the Aluminium hydroxide base is 78 g/mol.

As we know, Equivalent weight = molecular weight / X

The equivalent weight of calcium hydroxide base = 78 / 3 = 26.

Equivalent Weight of Salt

Equivalent Weight of the Metal in Salt or Compounds

1. Aluminium Chloride

Step-by-step Calculation to Determine the Equivalent Weight of Aluminium Salts For metals, X (valency factor) represents the overall positive charge on the positive ion (cation).

In the case of Aluminium chloride salt $Al(Cl)_3$

$$AlCl_3 \rightarrow Al^{3+} + 3Cl^{-}$$

The Aluminium cation carries three positive charges, resulting in a valency factor or X value of three.

The molecular weight of the Aluminium chloride base is 133.34 g/mol.

As we know, Equivalent weight = molecular weight / X

The equivalent weight of Aluminium chloride salt = 133.34 / 3 = 44.44.

2. Silver Carbonate (Ag_2CO_3)

Step-by-step Calculation to Determine the Equivalent Weight of Silver Salts For these salts, X (valency factor) is the overall positive charge on the positive ion (cation).

In the case of silver carbonate salt Ag_2CO_3

$$Ag_2CO_3 \rightarrow 2Ag^{+} + CO^{3-}$$

The collective positive charge of the silver cation amounts to two. As a result, its valency factor or X value is two.

The molecular weight of the silver carbonate salt is 275.75 g/mol.

As we know, Equivalent weight = molecular weight / X

The equivalent weight of silver carbonate salt = 275.75 / 2 = 137.87.

Did You Know?

Equivalent weight plays a role in normality calculations. The normality of a solution, denoted by the symbol N, is defined as the number of gram equivalents of the solute per Liter of the solution.

The calculation for normality is expressed as follows:

$$\text{Normality} = \frac{\text{gram equivalent of the solute}}{\text{volume of the solution in litres}}$$

the number of gram equivalents of the solute is calculated as follows:

$$\text{No. of gram equivalents} = \frac{\text{mass of solute in grams}}{\text{equivalent mass of the solute}}.$$

Summary

The equivalent masses for acids, bases, and salts are computed using the following formulas:

Equivalent mass of an acid = Molecular mass of the acid divided by basicity.

Equivalent mass of a base = Molecular mass of the base divided by acidity.

Equivalent mass of a salt = Molecular mass of the salt divided by the total positive valency of metal atoms.

Equivalent Weight of reducing agent

"A substance that undergoes electron loss to other substances in a redox reaction, resulting in oxidation to a higher valency state, is termed a reducing agent." A reducing agent is one of the reactants in an oxidation-reduction reaction that diminishes the other reactant by donating electrons to it. If the reducing agent fails to transfer electrons to other substances during a reaction, the reduction process cannot take place.

For example, in the given reaction;

$$H_2(g) + F_2(g) \rightarrow 2HF(g)$$

Hydrogen acts as a reducing agent because it donates its electrons to fluorine, which allows fluorine to be reduced.

Characteristics of Reducing Agent

- Reducing agents are characterized by their tendency to release electrons. Elements found in the s-block of the periodic table, particularly metals, are recognized as effective reducing agents.
- Following electron loss, a reducing agent undergoes oxidation, simultaneously facilitating the reduction of the opposing reactant by supplying electrons.
- Exceptional reducing agents are often associated with atoms possessing low electronegativity (the capacity to attract bonding electrons), and elements with relatively small ionization energies exhibit similar characteristics.
- The entirety of oxidation and reduction reactions involves the exchange of electrons.
- When a substance undergoes oxidation, it is observed to lose electrons, while the substance receiving electrons is termed as reduced.
- A substance exhibiting a strong inclination to lose electrons is referred to as a robust reducing agent, as it effectively reduces other substances by donating electrons.
- Atoms characterized by larger atomic radii typically display enhanced reductive properties.

The more potent the reducing agent, the less potent is its counterpart, the oxidizing agent. Fluorine gas is acknowledged for its robust oxidizing properties, while F^- is recognized as a less potent reducing agent. It's established that the strength of an acid is inversely proportional to the strength of its conjugate base. Likewise, the less potent the oxidizing agent, the more potent is its counterpart, the reducing agent, as illustrated in the figure below.

$$\underset{\text{strong oxidisigg agent}}{F_2(g)} + 2e^- \longrightarrow \underset{\text{Weakest redueng agent}}{2F^-}$$

$$\underset{\text{Weakesst oxidising agent}}{Na^+} + e^- \longrightarrow \underset{\text{Strongest reducing agent}}{Na}$$

Reducing Agent Example

Various common reducing agents encompass metals such as Na, Fe, Zn, Al, and non-metals including C, S, and H_2. Additionally, some compounds and hydracids such as HCl, HI, HBr, and H_2S exhibit effective reducing agent properties. A brief overview of specific reducing agents is provided below:

- **Lithium:** An element with atomic number 3, symbol Li, presenting as a soft and silvery-white metal, belongs to the alkali metal group in the periodic table. Lithium demonstrates robust reducing agent properties when immersed in solutions.
- **Iodides:** Salts of iodides function as mild reducing agents, engaging in reactions with oxygen to yield iodine. They also possess diverse antioxidant properties.
- **Reducing Sugars:** This category includes sugars that act as reducing agents due to the presence of a free ketone group or a free aldehyde group. All types of sugars, including monosaccharides, disaccharides, polysaccharides, and oligosaccharides, are recognized as reducing sugars.