

2.4 EQUIVALENT WEIGHT

Introduction

- Definition of equivalent weight of element, acid, base and salt
- Gram equivalent weight
- Relation between equivalent weight, atomic weight and valency
- Determination of equivalent weight of metals by
 - by hydrogen displacement method
 - by direct and indirect oxide method
- Solving related simple numerical problems

Equivalent Weight

Definition: Equivalent weight is the amount of a substance that will react with or replace one equivalent of another substance in a chemical reaction. It is calculated by dividing the molecular weight of the substance by the number of equivalents it can produce or react with.

Equivalent weight is expressed in g/equiv. In numerical calculations, it is often treated simply as a numerical value without a unit.

The relation between Equivalent weight (E), atomic mass(A), and Valency (V) of an element

Consider an element with equivalent weight 'E', atomic mass 'A', and valency 'V'.

By the definition of valency,

An atom of the element combines with V atoms of hydrogen.

Or, V atoms of hydrogen combine with one atom of the element

Or, V × 1.008 parts by weight of H combines with A parts by weight of the element.

Or, 1.008 parts by wt. of H combines with A/V parts by wt. of the element.

Now, from the definition of equivalent wt.,

$$\text{Equivalent wt. of an element (E)} = \frac{\text{Atomic wt of the element (A)}}{\text{Valency (V)}}$$

1. Equivalent weight of compounds:

- a. **Equivalent weight of acid:** Equivalent weight of an acid is defined as the number of parts by weight of an acid that can supply 1.008 parts by weight of hydrogen ions. In other words, it is the ratio of the acid's molecular mass to its basicity.

$$\text{Equivalent wt. of an acid} = \frac{\text{molecular wt}}{\text{basicity}}$$

Basicity: no. of moles of H⁺ ions that 1 mole of the acid can furnish.

e.g.;

Acid	Basicity	Molecular wt.	Eq. wt.	Acid	Basicity	Molecular wt.	Eq. wt.
H ₂ SO ₄	2	98	98/2 = 49	(COOH) ₂ .H ₂ O	2	126	126/2 = 63

Now you try:

Calculate the molecular weights, find basicity and determine the equivalent weights of: CH₃COOH, HCl, HNO₃, and H₃PO₃

- b. **Equivalent weight of base:** Equivalent weight of a base is defined as the number of parts by weight of a base that can neutralise 1 gram equivalent of acid. It is the ratio of molecular mass to acidity.

$$\text{Equivalent wt. of a base} = \frac{\text{molecular wt.}}{\text{acidity}}$$

Acidity: no. of moles of H⁺ ions that 1 mole of the base can neutralise

e.g.,

Base	Acidity	Molecular wt.	Eq. wt.	Base	Acidity	Molecular wt.	Eq. wt.
NaOH	1	40	40/1=40	CaO	2	56	56/2=28

Now you try:

Calculate the equivalent weights of: Ca(OH)₂, NH₄OH, KOH, and CaO

- c. **Equivalent weight of salt:** Equivalent weight of salt is defined as the ratio of the molecular weight of salt to the total no. of +ve or -ve charges.

$$\text{Equivalent wt. of a salt} = \frac{\text{molecular wt}}{\text{total +ve or -ve charge present in the cation or anion of the salt.}}$$

Salt	+ ve or - ve charge	Molecular wt.	Eq. wt.
NaCl	1	58.5	58.5/1 = 58.5
Al ₂ (SO ₄) ₃	6	342	342/6 = 57

Now you try:

Calculate the equivalent weights of the salts: Na₂CO₃, CaCO₃, KCl, AlCl₃ and CaO

- d. **Equivalent weight of oxidising and reducing agents:** Equivalent weight of oxidising and reducing agents is the ratio of the molecular weight to the total change in oxidation number (total electrons lost or gained) during the chemical reaction.

$$\text{Equivalent wt. of the oxidizing agent or reducing agent} = \frac{\text{molecular wt}}{\text{total change in oxidation number (ON)}}$$

Here, the denominator (Basicity, Acidity, Total Charge, or ΔON) is collectively called the **n-factor**. **Equivalent weight depends on the particular chemical reaction.** It is calculated by dividing the molar mass by the appropriate n-factor for that reaction:

$$\text{equivalent wt.} = \text{molecular wt.}/\text{n-factor}$$

Calculation Problem:

- Weight of metal (w) = 0.175 g
- Volume of H_2 produced at NTP (V) = 152 ml
- Density of H_2 (ρ) = 0.089 g/l = $0.089 \times 10^{-3} \text{ g/m}^3$
- Weight of H_2 (W_1) = $\rho \times V = 0.089 \times 10^{-3} \times 152 = 0.0135 \text{ g}$
- Eq. wt of H_2 = 1.008

Using the formula:

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Weight of metal / Eq. wt of metal = Weight of H_2 at NTP / Eq. wt of H_2

$$0.175 / \text{Eq. wt of metal} = 0.0135 / 1.008$$

$$\text{Eq. wt of metal} = (0.175 \times 1.008) / 0.0135 = 13.067 \text{ g}$$

1. What do you mean by the equivalent weight of an element? [2]
2. Define equivalent weight of an element.
3. Equivalent weight of magnesium metal is 12, what does it mean?
4. What is meant by gram equivalent? 1
5. 0.54 g of a metal gives 0.90 g of its oxide. Calculate the eq. wt. of the metal. [1+1+3]
6. 0.212 gms of a reactive metal, when dissolved in dil. HCl evolved 218.2 cc of hydrogen at 17°C and 754.5 mm of Hg pressure over water. Find the eq. wt. of the metal. (Aq. tension at 17°C =14.4 mmHg) [4]
7. 3.36 gm of zinc displaced 121.0 cc of dry hydrogen measured at 10.7°C and 748.8 mmHg pressure from dilute hydrochloric acid. Calculate the equivalent weight of zinc metal. [4]
8. Describe hydrogen displacement method for the determination of equivalent weight of metal.
9. How can you determine the Equivalent weight by indirect oxide formation method. [5]
How can you determine equivalent weight of metal by indirect oxide formation method? [5]
10. How does equivalent weight determined by oxide formation method. (Explain direct and indirect oxide formation method). [5]
11. Explain the equivalent weight of an acid. [2]
12. Define equivalent weight. Find out the equivalent weight of followings: i) H_2SO_4 ii) $Ca(OH)_2$ [4]
13. 0.175 gm of a metal gave 152 ml of H_2 at NTP on treatment with dil. H_2SO_4 . Calculate the equivalent wt. of the metal. [2]
14. 0.0396 gram of metal was completely decomposed in hydrochloric acid and the hydrogen evolved gas mixed with O_2 and sparked to form water. 13.75 cc of dry H_2 at 27°C and 680mm Hg pressure were required for complete combination. Find the equivalent weight of metal. [4]
15. 0.212 gram of metal where dissolved in dilute HCl evolves 218.2cc of hydrogen at 17°C and 745.5 mm Hg pressure over water. Find the equivalent weight of the metal (Aq. tension at 17°C =14.4 mm Hg). [4]
16. 0.175 gm of a metal gave 152 ml of H_2 at NTP on treatment with dil. H_2SO_4 . Calculate the equivalent wt of metal. [2]

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