# CH-3: - Atoms and Molecules

**Laws of Chemical Combination:**
The process of combination of two or more elements to form new compounds is governed by certain laws called laws of chemical combination. These are:

1. Law of conservation of mass.

2. Law of constant proportions.

**Law of conservation of mass (by Lavoisier in 1744):**

This law states that mass can neither be created nor destroyed in a chemical reaction.

**Law of constant proportions (by Proust in 1797):**

This law states that in a chemical substance the elements are always present in definite proportions by mass.

For example, the ratio of hydrogen and oxygen in pure water is always 1: 8 by weight.

This law is also called *law of definite proportions* or *law of constant proportions*.

**Dalton's Atomic Theory**

According to Dalton's atomic theory, all matter, whether an element, a compound or a mixture is composed of small particles called atoms

**Postulates of Dalton's atomic theory:**

- Matter is made up of extremely small indivisible particles called atoms that can neither be created nor destroyed.
- Atoms of the same substance are identical in all aspects, i.e., they possess same size, shape, mass, chemical properties etc.
- Atoms of different substances are different in all aspects, i.e., they possess different size, shape, mass etc.
- Atom is the smallest particle that takes part in a chemical reaction.
- Atoms of different elements combine with each other in a simple whole number ratio to form compound.
- The relative number and kinds of atoms are constant in a given compound.

**Try the following questions:**

**Q.** 3 g of carbon on burning in 8 g oxygen produces 11 g of carbon dioxide. What mass of carbon dioxide will be formed when 3 g of carbon is burnt in 50 g of oxygen?

**Q.** Hydrogen and oxygen combine in the ratio of 1:8 by mass to form water. What mass of oxygen gas would be required to react completely with 3 g of hydrogen gas? Which law of combination will govern the answer?

**Q.** Which postulate of Dalton's atomic theory explains the law of definite proportions?

**Q.** 12 g of magnesium powder was ignited in a container having 20 g of pure oxygen. After the reaction was over, it was found that 12 g of oxygen was left unreacted. Show that it is according to law of constant proportions.

$$2Mg + O_2 \rightarrow 2MgO$$

## Atoms:

The smallest tiny particles of matter which can't be divided further is called atom, i.e., an atom is the smallest building block of matter.

For example: Sodium (Na), Hydrogen (H), Oxygen (O), etc.

**Names of Atoms or Elements and Their Symbols:**

- IUPAC (International Union of Pure and Applied Chemistry) approves names of elements.
- The abbreviation used for lengthy names of elements are termed as their symbols.
- The symbol of an element is formed by writing only the first letter or first letter followed by the second or some other letter of English name or Latin name of the element.
- While writing a symbol, the first letter is always capital and the second is always small.
- Symbols used for some common elements are given below:

| Element | Symbol | Element | Symbol | Element | Symbol |
|---|---|---|---|---|---|
| Aluminium | Al | Copper | Cu | Nitrogen | N |
| Argon | Ar | Fluorine | F | Oxygen | O |
| Barium | Ba | Gold | Au | Potassium | K |
| Boron | B | Hydrogen | H | Silicon | Si |
| Bromine | Br | Iodine | I | Silver | Ag |
| Calcium | Ca | Iron | Fe | Sodium | Na |
| Carbon | C | Lead | Pb | Sulphur | S |
| Chlorine | Cl | Magnesium | Mg | Uranium | U |
| Cobalt | Co | Neon | Ne | Zinc | Zn |

## Atomic Mass

Atomic mass of an element may be defined as the average relative mass of an atom of the element as compared with the mass of an atom of carbon (C-12 isotope) taken as 12 amu.

$$\text{Atomic mass} = \frac{\text{Mass of 1 atom of an element}}{1/12 \text{ of the mass of an atom of C-12}}$$

**Gram Atomic Mass:** The atomic mass of an element expressed in grams is known as gram atomic mass.

## Molecules:

A group of two or more than two atoms of the same or different elements that are chemically bonded together is called a molecule.

For example: Two atoms of hydrogen ($H_{2)}$ and one atom of oxygen ($O_2$) react with each other and form one molecule of water.

## Atomicity:

The number of atoms present in a molecule of an element or a compound is known as its atomicity.

For example, atomicity of oxygen ($O_2$) is 2 while atomicity of ozone ($O_3$) is 3.

### Molecules of Elements:

The molecules of an element are constituted by the same type of atoms.

For example, a molecule of oxygen consists of two atoms of oxygen to form a diatomic molecule $O_2$.

### Molecules of Compounds:

Atoms of different elements join together in definite proportions to form molecules of compounds.

For example, a molecule of water consists of two atoms of hydrogen and one atom of oxygen to form a triatomic molecule $H_2O$.

## Ion:

It is an electrically charged atom or group of atoms. It is formed by the loss or gain of one or more electrons by an atom.

## Ions are of two types:

**Cation**: It is positively charged ion and is formed by the loss of one or more electrons from an atom

**Eg:** sodium atom, loses one electron to form a sodium ion Na

$$Na - e^- \rightarrow Na^+$$

**Anion**: It is a negatively charged ion and is formed by the gain of one or more electrons by an atom.

**Eg**: a chlorine atom gains one electron to form a chloride ion $Cl^-$.

$$Cl + e^- \rightarrow Cl^-$$

## Valency:

It is defined by the combining power (or capacity) of an element.

Depending on their valency, elements can be classified as following:

### I

**Monovalent cation**: Having cationic valency of 1.
**eg**: Sodium ion ($Na^+$). Potassium ion ($K^+$), Hydrogen ion ($H^+$).

**Monovalent anion**: Having anionic valency of -1.
**eg**: Chloride ion ($Cl^-$), Bromide ion ($Br^-$)

### II

**Divalent cation**: Having cationic valency of 2.
**eg**: Magnesium ion ($Mg^{2+}$), Ferrous ion ($Fe^{2+}$).

**Divalent anion**: Having anionic valency of −2.
**eg**: Oxide ion ($O^{2-}$), Sulphide ion ($S^{2-}$).

### III

**Trivalent cations**: Having cationic valency of 3.
**eg**: Aluminium ion ($Al^{3+}$), Ferric ion ($Fe^{3+}$).

**Trivalent anion**: Having anionic valency of -3.
**eg**: Nitride ion ($N^{-3}$), Phosphate ion ($PO_4^{3-}$) etc.

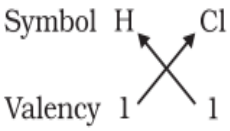
## Formula of Simple and Molecular Compounds:

**Steps to construct the chemical formula of a compound:**

(i) While writing the chemical formulae for compounds, write the constituent elements with their valencies written down the respective elements.

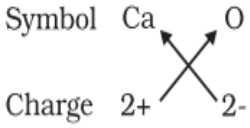
(ii) Then crossover the valencies of the combining atoms as shown in the following examples.

1. Formula of hydrogen chloride




Formula of the compound would be HCl.

2. Formula for aluminium oxide:




Formula of the compound would be: $Al_2O_3$

**Steps to represent the chemical formula of a compound:**

- The valencies or charges on the ions must be balanced.
- For a compound made up of a metal and a non-metal, the symbol of metal is written first.
- In compounds formed with polyatomic ions, the ion is enclosed in a bracket before writing the number to indicate the ratio.

## Molecular Mass:

The number of times a molecule of a compound is heavier than the 1/12 of the mass of C-12 atom, is known as its molecular mass.

The molecular mass is equal to the sum of the atomic masses of all atoms present in one molecule of the substance.

For example, Molecular mass of $H_2O$= 2 × Mass of one H-atom + Mass of one O-atom = 2 ×1 + 16 = 18 u.

**Formula unit mass:**

It is the sum of the atomic masses of all atoms in a formula unit of a compound.

Formula unit mass is used for those substances whose constituent particles are ions.

For example, formula unit mass of ionic NaCl = 23 + 35.5 = 58.5 u.

## Mole Concept:

- **Mole:** A collection of $6.023 \times 10^{23}$particles is named as one mole.
  1 mole = $6.023 \times 10^{23}$ particles = Mass of 1 mole particles in grams

- The mass of 1 mole particles is equal to its mass in grams.
  1 mole atoms = gram atomic mass
  1 mole molecules = gram molecular mass

- **Avogadro's constant or Avogadro's number:**
  The number of particles present in one mole (i.e. 6.023 x $10^{23}$ particles) is called Avogadro's number or Avogadro's constant.

- $\text{Number of moles in a substance} = \frac{\text{Mass of substance in grams}}{\text{grams molecular mass}}$

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**Try the following questions:**

**Q.** Distinguish between atoms and molecules.
**Q.** Define the mole concept and molar mass.
**Q.** Represent the following molecules with the help of chemical formula:
   a. Aluminium chloride
   b. Calcium carbonate
   c. Copper nitrate
   d. Nitric acid

**Q.** Convert 20 g of water into moles.
**Q.** Calculate the number of molecules of sulphur (S8) present in 16 g of solid sulphur.