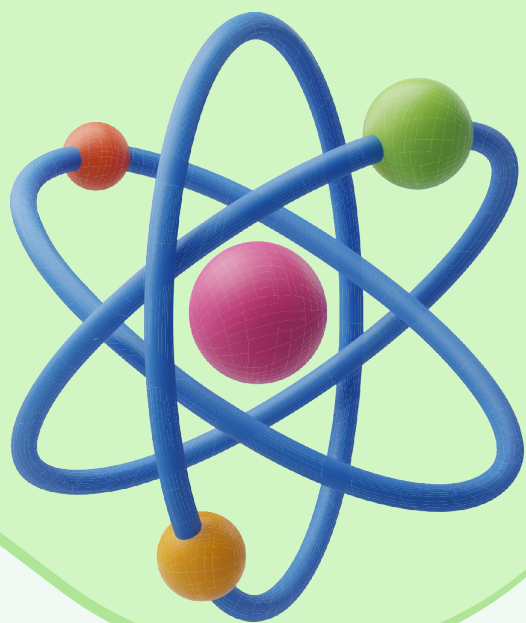


# ATOMS & MOLECULES



## Key Points



## Introduction

An Indian philosopher Maharishi Kanad, postulated that if we go on dividing matter (padarth), a time will come when we shall come across the smallest particles beyond which further divisions will not be possible. He named these particles **Parmanu**.

## Laws of Chemical Combination

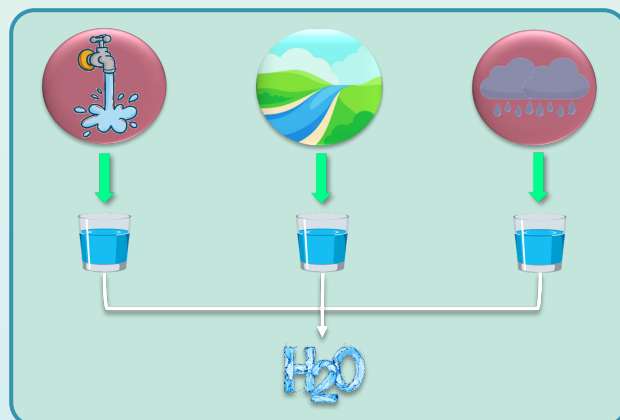
By studying the result of quantitative measurement of many reactions it was observed that whenever substances react, they follow certain laws. These laws are called the laws of chemical combination.

### (i) Law of Conservation of Mass

This law of conservation of mass is given by the French chemist A. Lavoisier in 1774. The total mass of the products of a chemical reaction is equal to the total mass of the reactants that have combined. This law is also known as the law of indestructibility of matter.

### (ii) Law of Constant Proportions

This law was stated by Joseph Proust and A.L. Lavoisier as "In a chemical substance the elements are always present in definite proportions by mass". This means that a particular compound may be formed or obtained from a number of different sources.

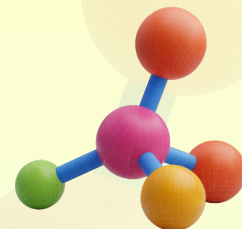


Example of law of constant proportion

## Dalton's Atomic theory

The next problem faced by scientists was to give appropriate explanations of these laws. British chemist John Dalton provided a theory about the nature of matter in 1808.

His theory was based on the laws of chemical combination. Dalton's atomic theory provided an explanation for the law of conservation of mass and the law of definite proportion.



## Postulates of Dalton's atomic theory

1. Every matter is made up of very small particles known as atoms.
2. Atoms are the ultimate particles of matter which cannot be created or destroyed in a chemical reaction and cannot be further subdivided into smaller particles.
3. All atoms of a particular element are identical in all respects. This means that they have same mass, size and also same chemical properties
4. Atoms of different elements have different masses, sizes and also chemical properties.
5. Atoms are the smallest particles of matter which can take part in chemical combination.
6. Atoms of the same or different elements combine in small whole number ratios to form molecules of a element/compound.
7. The relative number and kinds of atoms are constant in a given compound.
8. Atoms of two different elements may combine in different ratios to form more than one compound. For example, carbon and oxygen may combine to form carbon monoxide (CO) and carbon dioxide (CO<sub>2</sub>) in which the ratios of the combining atoms (C and O) are 1 : 1 and 1 : 2 respectively.

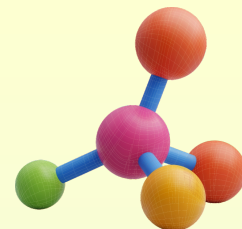
## Drawbacks of Dalton's atomic theory

1. According to Dalton's atomic theory, atoms were thought to be indivisible. But atoms can be further divided into electrons, protons and neutrons.
2. Dalton's atomic theory said that all the atoms of an element have exactly the same mass but atoms of the same element can have slightly different masses, as in case of isotopes.
3. Dalton's atomic theory said that atoms of different elements have different masses. But atoms of different elements can have the same mass as in case of isobars.
4. Substances made up of the same kind of atoms may have different properties. For example, charcoal, graphite and diamond are all made up of carbon atoms but have different physical properties.

## What is an atom ?

An atom is defined as the smallest particle of an element which may or may not be capable of free existence. However, it is the smallest particle that takes part in a chemical reaction. An atom maintains its identity in all physical changes and chemical reactions.

| Relative Radii (in nm) | Example                 |
|------------------------|-------------------------|
| $10^{-10}$             | Atom of hydrogen        |
| $10^{-9}$              | Molecule of water       |
| $10^{-8}$              | Molecule of haemoglobin |
| $10^{-4}$              | Grain of sand           |
| $10^{-2}$              | Ant                     |
| $10^{-1}$              | Watermelon              |



## Atomic symbol

Symbol means a short hand method of representing the full name of an element. Dalton's symbols of elements:

- Dalton identified some elements and compounds by using circles as the symbols.
- In order to differentiate between them, he put certain signs inside the circles. Dalton's symbols for a few elements and compounds are given below.
- Modern symbols for the elements were introduced by J.J. Berzelius.
- These are also known as chemical symbols.

Hydrogen

Copper

Oxygen

Iron

Carbon

Silver

Sulphur

Phosphorus

Lead

Mercury

## Symbols obtained from other languages

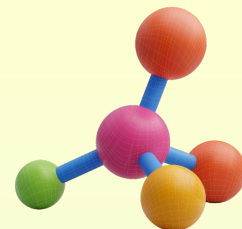
| Common name (of the element) | Symbol | Latin (L) or Greek (G) name |
|------------------------------|--------|-----------------------------|
| Gold                         | Au     | Aurum (L)                   |
| Silver                       | Ag     | Argentum (L)                |
| Copper                       | Cu     | Cuprum (L)                  |
| Lead                         | Pb     | Plumbum (L)                 |
| Mercury                      | Hg     | Hydrargyrum (L)             |
| Iron                         | Fe     | Ferrum (L)                  |
| Potassium                    | K      | Kalium (L)                  |
| Tin                          | Sn     | Stannum (L)                 |
| Nitrogen                     | N      | Nitrogenium (L)             |
| Carbon                       | C      | Carbonium (L)               |
| Oxygen                       | O      | Oxygenium (L)               |
| Silicon                      | Si     | Silex (L)                   |
| Calcium                      | Ca     | Clax (L)                    |
| Hydrogen                     | H      | Hydrogenium (L)             |
| Antimony                     | Sb     | Stibium (L)                 |
| Sodium                       | Na     | Natrium (L)                 |
| Chromium                     | Cr     | Chromos (G)                 |
| Krypton                      | Kr     | Kryptos (G)                 |

## Atomic mass

Atom is so small in size that it may not be possible to isolate a single atom and then weight it.

## Carbon-12 as standard reference

It was found that the atomic mass of the most common isotope of carbon,  $^{12}\text{C}$  is a whole number 12. Thus, the mass of  $1/12$  of  $^{12}\text{C}$  is equivalent to 1 atomic mass unit (a.m.u.) or unified atomic mass. Atomic mass of a substance when expressed in terms of grams is called gram atomic mass.



## What is molecule?

- The atoms of the same or different elements are bonded together tightly by strong forces of attraction also called chemical bonds to form molecules.

| Element  | Symbol | Atomic mass |
|----------|--------|-------------|
| Hydrogen | H      | 1           |
| Carbon   | C      | 12          |
| Lithium  | Li     | 7           |
| Nitrogen | N      | 14          |
| Oxygen   | O      | 16          |
| Fluorine | F      | 19          |

### Molecules are of two types

#### Molecules of elements

These are formed by the combination of two or more atoms of the same element.

The number of the atoms present in the molecule represent its atomicity

For example, Diatomic →  $H_2, O_2$   
 Triatomic →  $O_3$   
 Tetra-atomic →  $P_4$   
 Monoatomic →  $Ar, He$

#### Molecules of compounds

In these the atoms of different elements are combined or bonded together by chemical bonds. These are present in definite proportion by mass according to law of constant proportion. For example,

Diatomic → Hydrogen chloride (HCl)  
 Triatomic → Water ( $H_2O$ )  
 Tetra atomic → Ammonia ( $NH_3$ )

## What is ion ?

### Classification of ion

#### 1. On the basis of number of atoms.

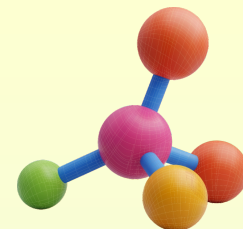
The ion consisting of only single atom are called monoatomic ions, whereas an ion consisting of a group of atoms having some definite charge on them are called polyatomic ion. The compounds consisting of cations and anions are called ionic compounds.

#### 2. On the basis of nature of charge.

The ions carrying positive charge are called cations while ions that carry negative charge are called anions.

#### 3. On the basis of number (amount) of charges.

If an ion contains +1 or -1 charge then it is monovalent, if it contains +2 or -2 it is divalent similarly for +3 or -3 ion is called trivalent ion. The ions which carry 3 or more charge can also be called polyvalent ions.



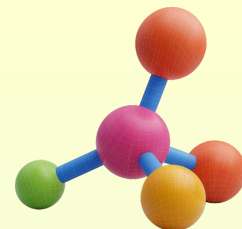
## LIST OF COMMON IONS WITH POSITIVE VALENCY

| Positive Valency-1         | Symbol          |
|----------------------------|-----------------|
| 1. Ammonium                | $\text{NH}_4^+$ |
| 2. Hydrogen                | $\text{H}^+$    |
| 3. Lithium                 | $\text{Li}^+$   |
| 4. Sodium                  | $\text{Na}^+$   |
| 5. Potassium               | $\text{K}^+$    |
| 6. Cuprous [Copper (I)]    | $\text{Cu}^+$   |
| 7. Argentous [Silver (I)]  | $\text{Ag}^+$   |
| 8. Mercurous [Mercury (I)] | $\text{NH}_4^+$ |
| 9. Aurous [Gold (I)]       | $\text{H}^+$    |

| Positive Valency-3     | Symbol           |
|------------------------|------------------|
| 1. Aluminium           | $\text{Al}^{3+}$ |
| 2. Chromium            | $\text{Cr}^{3+}$ |
| 3. Bismuth             | $\text{Bi}^{3+}$ |
| 4. Arsenic             | $\text{As}^{3+}$ |
| 5. Ferric [Iron (III)] | $\text{Fe}^{3+}$ |
| 6. Auric [Gold (III)]  | $\text{Au}^{3+}$ |

| Positive Valency-2            | Symbol           |
|-------------------------------|------------------|
| 1. Magnesium                  | $\text{Mg}^{2+}$ |
| 2. Calcium                    | $\text{Ca}^{2+}$ |
| 3. Zinc                       | $\text{Zn}^{2+}$ |
| 4. Barium                     | $\text{Ba}^{2+}$ |
| 5. Nickel                     | $\text{Ni}^{2+}$ |
| 6. Uranium                    | $\text{U}^{2+}$  |
| 7. Cupric [Copper (II)]       | $\text{Cu}^{2+}$ |
| 8. Argentic [Silver (II)]     | $\text{Ag}^{2+}$ |
| 9. Mercuric [Mercury (II)]    | $\text{Hg}^{2+}$ |
| 10. Ferrous [Iron (II)]       | $\text{Fe}^{2+}$ |
| 11. Plumbous [Lead (II)]      | $\text{Pb}^{2+}$ |
| 12. Stannous [Tin (II)]       | $\text{Sn}^{2+}$ |
| 13. Platinous [Platinum (II)] | $\text{Pt}^{2+}$ |

| Positive Valency-4          | Symbol           |
|-----------------------------|------------------|
| 1. Stannic [Tin (IV)]       | $\text{Sn}^{4+}$ |
| 2. Plumbic [Lead (IV)]      | $\text{Pb}^{4+}$ |
| 3. Platinic [Platinum (IV)] | $\text{Pt}^{4+}$ |



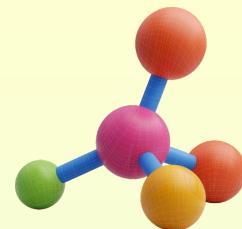
## IONS WITH NEGATIVE VALENCY

| Positive Valency-1 |                                   | Symbol        |
|--------------------|-----------------------------------|---------------|
| 1.                 | Fluoride                          | $F^{-}$       |
| 2.                 | Chloride                          | $Cl^{-}$      |
| 3.                 | Bromide                           | $Br^{-}$      |
| 4.                 | Iodide                            | $I^{-}$       |
| 5.                 | Hypochlorite                      | $ClO^{-}$     |
| 6.                 | Chlorate                          | $ClO_3^{-}$   |
| 7.                 | Bicarbonate or hydrogen carbonate | $HSO_3^{-}$   |
| 8.                 | Bisulphite or hydrogen sulphite   | $HSO_3^{-}$   |
| 9.                 | Bisulphide or hydrogen sulphide   | $HS^{-}$      |
| 10.                | Bisulphate or hydrogen sulphate   | $HSO_4^{-}$   |
| 11.                | Hydride                           | $H^{-}$       |
| 12.                | Hydroxide                         | $OH^{-}$      |
| 13.                | Aluminate                         | $AlO_2^{-}$   |
| 14.                | Permanganate                      | $MnO_4^{-}$   |
| 15.                | Cyanide                           | $CN^{-}$      |
| 16.                | Nitrite                           | $NO_2^{-}$    |
| 17.                | Nitrate                           | $NO_3^{-}$    |
| 18.                | Acetate                           | $CH_3COO^{-}$ |

| Positive Valency-4 |         | Symbol   |
|--------------------|---------|----------|
| 1.                 | Carbide | $C^{4-}$ |

| Positive Valency-2 |              | Symbol         |
|--------------------|--------------|----------------|
| 1.                 | Sulphate     | $SO_4^{2-}$    |
| 2.                 | Sulphite     | $SO_3^{2-}$    |
| 3.                 | Sulphide     | $S^{2-}$       |
| 4.                 | Thiosulphate | $S_2O_3^{2-}$  |
| 5.                 | Zincate      | $Zn_2^{2-}$    |
| 6.                 | Plumbate     | $PbO_2^{2-}$   |
| 7.                 | Oxide        | $O^{2-}$       |
| 8.                 | Peroxide     | $O_2^{2-}$     |
| 9.                 | Manganate    | $MnO_4^{2-}$   |
| 10.                | Dichromate   | $Cr_2O_7^{2-}$ |
| 11.                | Carbonate    | $CO_3^{2-}$    |
| 12.                | Silicate     | $SiO_3^{2-}$   |
| 13.                | Stannate     | $SnO_3^{2-}$   |
| 14.                | Oxalate      | $(COO)_2^{2-}$ |

| Positive Valency-3 |           | Symbol      |
|--------------------|-----------|-------------|
| 1.                 | Nitride   | $N^{3-}$    |
| 2.                 | Phosphide | $P^{3-}$    |
| 3.                 | Phosphite | $PO_3^{3-}$ |
| 4.                 | Phosphate | $PO_4^{3-}$ |



## Chemical Formulae

Chemical formula of a molecular compound represents the actual number and kind of atoms of different elements present in one molecule of the compound. For example,  $\text{H}_2\text{O}$ .

Valency of an element is defined as the combining capacity of the element.

Important points

### Naming of ionic compounds

Cation is always named first followed by the anion. The number of cations and anions are not written in the name. For example,  $\text{Al}_2(\text{SO}_4)_3$  is called aluminium sulphate and not di aluminium tri sulphate.

### Naming of molecular compounds

They formed by the combination between two different non-metals, are written in such a way that the less electronegative element is written on the left hand side while the more electronegative element is written on the right hand side. In naming molecular compounds, the name of the less electronegative non-metal is written as such but the name of the more electronegative element is changed to have the ending 'ide'. For example, Carbon dioxide

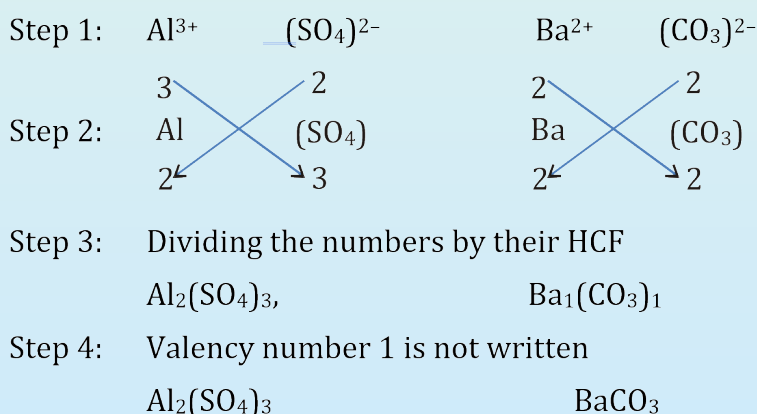
### How to write the formula of compound

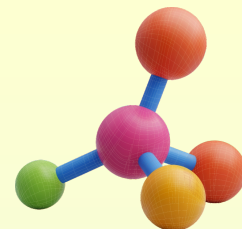
The molecular formula of a compound is electrically neutral, that is, the positive and the negative valencies of the ions or the radicals present in the compounds add up to zero.

The following steps should be taken while attempting to write a formula:

- Write the symbols side by side, usually the one with the positive valency first.  
The ion containing more than one atom should be written within brackets.
- Write the valency of each ion on the top of its symbol.
- Divide the valency numbers by their Highest Common Factor to get the simple ratio. Ignore the (+) or (-) signs of the radicals. If the valency number is one, it need not be written.
- Write the interchanged valency numbers to the lower right of the radicals, if the radical is a group of atoms and receives a valency number of more than one then enclose it within brackets.

Take the case of aluminium sulphate and barium carbonate.





## Significance of molecular formula of a substance

- It tells the name of the substance.
- It tells about the names of the different elements present in the substance.
- It represents one molecule of the substance.
- It tells about the number of atoms of each element present in one molecule of substance.
- It tells about atomicity of the substance.

## Molecular mass

The mass of a molecule of a chemical compound is known as the molecular mass. Thus, molecular mass of a compound may be defined as. The average relative mass of its molecule as compared to the  $1/12$  of the mass of carbon-12 taken as 1 u.

**Calculation of molecular mass:** The molecular mass of a substance can be calculated as the sum of the atomic masses of all the atoms which constitute a molecule of that substance. For example,

$$\begin{aligned}\text{Molecular mass of NH}_3 &= \text{atomic mass of N} + 3 \times \text{atomic mass of H} \\ &= 14 + 3 \times 1 = 17 \text{ u}\end{aligned}$$

## Formula unit mass

**Formula unit:** Ionic compounds consist of a very large but equal number of cations and anions arranged in a definite order in the crystal lattice. The formula of ionic compound represent only the simplest formula and not the actual formula, which is known as one formula unit.

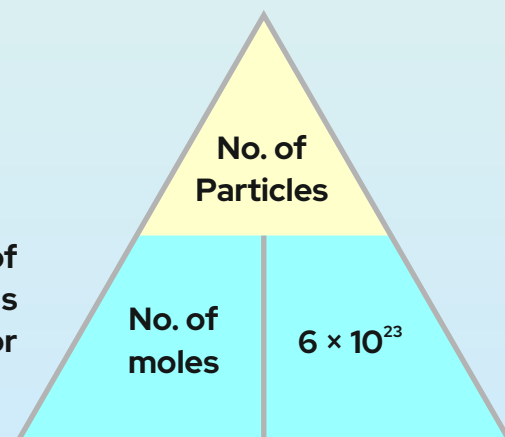
**For example,** the formula unit mass of NaCl =  $(23 + 35.5) = 58.5 \text{ u}$ .

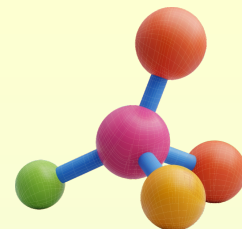
## Mole Concept

There is a very close analogy or similarity between the terms mole and dozen. A dozen always represents 12 articles. They may be apples, oranges, pens, etc. In a similar way, a mole represents  $6.022 \times 10^{23}$  particles. They may be atoms, molecules, ions, electrons, protons, etc. Gram atomic mass of an element contains  $6.022 \times 10^{23}$  atoms. Similarly the gram molecular mass of a compound also contains the same number of molecules. The number of C-atoms in 12 g of carbon will be,

$$\begin{aligned}\text{No. of C-atoms} &= \frac{\text{Gram atomic mass of carbon}}{\text{Mass of one carbon atom}} \\ &= \frac{12(\text{g})}{1.9924 \times 10^{-23}(\text{g})} = 6.022 \times 10^{23}\end{aligned}$$

By calculating number of moles we can estimate number of particles present. This  $6.022 \times 10^{23}$  is known as Avogadro's number or Avogadro's constant and is denoted by either ' $N_0$ ' or ' $N_A$ '. A mole denotes Avogadro's number of particles.





- Number of moles of molecules =  $\frac{\text{Weight in gram}}{\text{Molecular mass}}$
- Number of mole of atoms =  $\frac{\text{Weight in gram}}{\text{Atomic mass}}$
- Number of mole of gases =  $\frac{\text{Volume at NTP}}{\text{Standard molar volume}}$
- Number of moles of atoms / molecules / ions / electrons =  $\frac{\text{Volume of gas in dm}^3 \text{ at NTP}}{22.4 \text{ dm}^3}$
- Weight of one atom of an element =  $\frac{\text{Atomic weight}}{6.023 \times 10^{23}}$
- Weight of one atom of an compound =  $\frac{\text{Molecular weight}}{6.023 \times 10^{23}}$

## Necessity of mole concept

A mole of particles is therefore, defined as that amount of the substance which contains Avogadro's number of particles.

## MEMORY CHART

