## Chapter - 3

## **Atoms and Molecules**

#### Laws of Chemical Combination

⇒ Antoine L. Lavoisier gave important laws of chemical combination which law the foundation of chemical science. There are two important laws of chemical combination:

#### (a) Law of conservation of mass:

The Law of conservation of mass states that mass can neither be created nor destroyed in a chemical reaction. In a chemical reaction,

Total Mass of the Reactants = Total Mass of the Products

#### (b) Law of constant proportions:

According to this law, the elements are always present in definite proportions by mass in a chemical substance. This law is also called the law of definite proportions.

# Dalton's Atomic Theory:

- The matter is made up of tiny particles which are called an atom.
- The atoms can neither be created nor be destroyed in a chemical reaction.
- The atoms of the given element have similar mass and chemical properties and vice versa.
- The compound can be formed when atoms of the same or different elements combine in a fixed ratio.
- The relative number and kinds of atoms are constant in a given compound.

**Question:** The magnesium metal burn in air to form magnesium oxide as shown in the reaction given below:

$$Mg(2.5g) + O_2(xg) \rightarrow MgO(6.7g)$$

Calculate the amount of oxygen required in this reaction.

Answer: Law of conservation of mass states that mass can neither be created nor destroyed in a chemical reaction. In a chemical reaction, Total Mass of the Reactants = Total Mass of the Products

$$2.5 + x = 6.7$$
$$x = 6.7 - 2.5 = 4.2g O_2$$

#### What is an Atom?

- ⇒ The matter is made up of tiny particles which are called an atom.
- ⇒ Atoms are very small, they are smaller than anything that we can imagine or compare with. Atomic radius is measured in nanometers. (nm).
- ♦ Chemical Symbol:
- ⇒ A chemical symbol is defined as the notation of one or two letters which represent a chemical element.
- ⇒ The chemical symbol of some elements is derived from the first letter of the name and a letter appearing later in the name of that element. For example, the symbol of carbon is C.
- ⇒ Some symbols are derived from the Latin name of that element. For example, the symbol of sodium is 'Na' which is derived from its Latin name, which is 'Natrium.'
- ⇒ The list of the chemical symbol of certain elements are shown below:

Name of the element	Chemical Symbol
Chlorine	Cl
Cobalt	Co
Silver	Ag
Gold	Au
Mercury	Hg
Lead	Pb
Aluminium	Al
Copper	Cu
Potassium	K
Sodium	Na
Iron	Fe
Zinc	Zn

#### ♦ Atomic mass:

- $\Rightarrow$  The atomic mass of an element gives us the mass of one atom of that element in atomic mass units (u).
- $\Rightarrow$  One atomic mass unit is equal to 1/12 the mass of one atom of carbon-12.
- $\Rightarrow$  The chemical symbol and atomic mass of the given elements are shown below:

Atomic number	Element	Atomic mass (u)
1	Hydrogen (H)	1
2	Helium (He)	4
3	Lithium (Li)	7
4	Beryllium (Be)	9
5	Boron (B)	11
6	Carbon (C)	12
7	Nitrogen (N)	14
	-	

8	Oxygen (O)	16	
9	Fluorine (F)	19	
10	Neon (Ne)	20	

#### What is a Molecule?

- ⇒ A molecule is, in general, a group of two or more atoms that are chemically bonded together, that is, tightly held together by attractive forces.
- ⇒ The number of atoms constituting a molecule is known as its atomicity.
- $\Rightarrow$  The molecule that contains two atoms is diatomic while the triatomic molecule contains 3 atoms. The polyatomic molecule contains more than 3 atoms.

#### ♦ Molecule of element.

- ⇒ The molecule of an element contains two or more atoms of similar atoms.
- ⇒ A list of certain molecules are given below:

Name	Chemical formula	Atomicity
Helium	Не	Monoatomic
Oxygen	02	Diatomic
Ozone	O <sub>3</sub>	Triatomic
Phosphorus	P <sub>4</sub>	Polyatomic
Sulphur	S <sub>8</sub>	Polyatomic

#### *♦ Molecule of compound:*

- $\Rightarrow$  The molecule of compound contains two or more atoms of different elements.
- ⇒ A list of certain molecules are given below:

Compound	Molecular formula	Atomicity
Carbon monoxide	со	Diatomic
Carbon dioxide	CO <sub>2</sub>	Triatomic
Ammonia	NH <sub>3</sub>	Triatomic

⇒ The ionic compound contains positively charged ion (cation) and negatively charged ion (anion). For example, sodium chloride contains Na<sup>+</sup> ion and Cl<sup>-</sup> ion. Sodium loses an electron to form Na<sup>+</sup> ion while chlorine accepts an electron to form Cl<sup>-</sup> ion.

### **Writing Chemical Formulae**

- ⇒ The chemical formula is the notation used to show the number and type of atom present in a molecule using chemical symbols and numerical subscripts.
- ⇒ The charged species is called an ion. The negatively charged ion is called anion while the positively charged ion is called a cation.
- $\Rightarrow$  A group of atoms carrying a charge is known as a polyatomic ion. The chemical formula must contain a balanced charge.

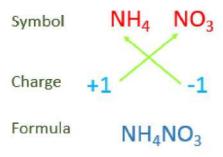
List of univalent anion	
Name of anion	Symbol of anion
Fluoride	F-
Chloride	Cl-
Bromide	Br⁻
lodide	1-
Hydrogen carbonate	HCO <sub>3</sub>
Hydride	Н-
Hydroxide	OH <sup>-</sup>

List of Divalent anion	
Name of anion	Symbol of anion
Oxide	02-
Sulphide	S <sup>2-</sup>
Sulphate	SO <sub>4</sub> <sup>2-</sup>
Sulphite	SO <sub>3</sub> <sup>2-</sup>
Carbonate	CO <sub>3</sub> <sup>2-</sup>

List of Trivalent anion	
Name of anion	Symbol of anion
Nitride	N <sup>3-</sup>
Phosphate	PO <sub>4</sub> <sup>3-</sup>

 $\Rightarrow$  The aluminum has +3 charge while chlorine has -1 charge. The formation of aluminum chloride is shown below:

⇒ Similarly, the formation of ammonium nitrate is shown below:



**Question:** What will the chemical formula of the compound which is formed between metal which have +2 charge and phosphate anion?

Answer: The metal (M) has +2 charge while the phosphate has -3 charge. The formation of metal phosphate is shown below:

Symbol M 
$$PO_4$$
Charge  $+2$   $-3$ 
Formula  $M_3(PO_4)_2$ 

The chemical formula will be  $M_3(PO_4)_2$ 

#### Molecular Mass and Mole Concept

#### ♦ Molecular mass:

The molecular mass of a substance is the sum of the atomic masses of all the atoms in a molecule of the substance. For example, the molecular mass of water is calculated as shown below:

Mass of H<sub>2</sub>O = 2(Atomic Mass of H) + Atomic mass of O

$$= 2(1u) + 16u = 18u$$

#### ♦ Formula unit mass:

The formula unit mass of a substance is a sum of the atomic masses of all atoms in a formula unit of a compound. It is commonly used for ionic compounds. For example, sodium chloride is an ionic compound whose mass is calculated as shown below:

Mass of NaCl = Atomic mass of Na + Atomic mass of Cl

$$= 23u + 35.5u = 58.5 u$$

#### ♠ Mole concept:

A mole is commonly used to describe a collection of particles that is, atoms, molecules, or ions.

$$Number of moles = \frac{Given mass}{Molecular mass}$$

- ⇒ When the atomic mass is expressed in grams, it is called Gram atomic mass. Similarly, when molecular mass is expressed in grams, it is called gram molecular mass.
- $\Rightarrow$  The number of particles (atoms, molecules, or ions) present in 1 mole of any substance is fixed, with a value called the Avogadro Constant or Avogadro Number (N<sub>A</sub>). This number was named after the famous scientist, Amedeo Avogadro. The value of Avogadro Constant is 6.023x10<sup>23</sup>.

1 mole of element = Atomic mass of element =  $6.023 \times 10^{23}$  particles of element

Question: Calculate the number of particles present in 64g of oxygen gas.

Answer: The gram atomic mass of oxygen is 16g. The molecular mass of  $O_2 = 2$  (atomic mass of  $O_1 = 2 \times 16 = 32$ g

The number of moles=  $\frac{64}{32}$ =2 moles

1 moles of oxygen gas contain 6.023x10<sup>23</sup> particles. The number of particles in 2

mole of oxygen gas =  $\frac{6.023\times10^{23}}{1}\times2=1.20\times10^{24}$ 

Thus, 64g of oxygen gas contain 1.20x10<sup>24</sup> particles.