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:

⇒ The atomic mass of an element gives us the mass of one atom of that element in atomic mass units (u).

⇒ One atomic mass unit is equal to 1/12 the mass of one atom of carbon-12.

⇒ 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.

⇒ 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	He	Monoatomic
Oxygen	O_2	Diatomic
Ozone	O_3	Triatomic
Phosphorus	P_4	Polyatomic
Sulphur	S_8	Polyatomic

♦ *Molecule of compound:*

⇒ 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	CO	Diatomic
Carbon dioxide	CO_2	Triatomic
Ammonia	NH_3	Triatomic

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

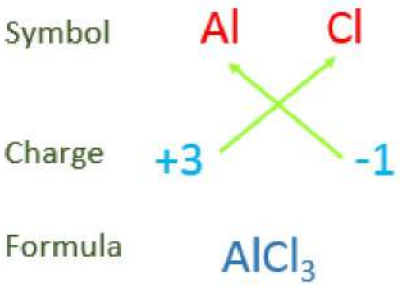
⇒ A group of atoms carrying a charge is known as a polyatomic ion. The chemical formula must contain a balanced charge.

List of univalent anion	
Name of anion	Symbol of anion
Fluoride	F^-
Chloride	Cl^-
Bromide	Br^-
Iodide	I^-
Hydrogen carbonate	HCO_3^-
Hydride	H^-
Hydroxide	OH^-

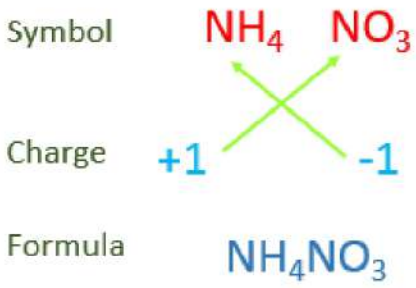
List of Divalent anion	
Name of anion	Symbol of anion
Oxide	O^{2-}
Sulphide	S^{2-}
Sulphate	SO_4^{2-}
Sulphite	SO_3^{2-}
Carbonate	CO_3^{2-}

List of Trivalent anion	
Name of anion	Symbol of anion
Nitride	N^{3-}
Phosphate	PO_4^{3-}

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

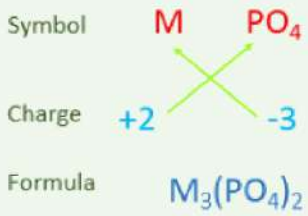


⇒ Similarly, the formation of ammonium nitrate is shown below:



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:



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_2O= 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.

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

⇒ 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.

⇒ 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_A). This number was named after the famous scientist, Amedeo Avogadro. The value of Avogadro Constant is 6.023×10^{23}.

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

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) = 2x16= 32g

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

1 moles of oxygen gas contain 6.023×10^{23} particles. The number of particles in 2 mole of oxygen gas = $\frac{6.023 \times 10^{23}}{1} \times 2 = 1.20 \times 10^{24}$

Thus, 64g of oxygen gas contain 1.20×10^{24} particles.