

# 1

# Atomic Structure and Interatomic Bonding

## 1.1 INTRODUCTION

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All substances contain matter which can exist in three states solid liquid or gas. The constituent particles are held in different ways in these states of matter and they exhibit their characteristic properties. Matter can also be classified into elements, compounds or mixtures. An element contains particles of only one type which may be atoms or molecules. The compounds are formed where atoms of two or more elements combine in a fixed ratio to each other. Mixtures occur widely and many of the substances present around us are mixtures.

**The Dalton's atomic theory states that atoms are building blocks of matter.**

**According to Dalton's atomic theory**

- ◀ **Matter consists of indivisible atoms**
- ◀ **All the atoms of a given element have identical properties including identical mass. Atoms of different elements differ in mass.**
- ◀ **Compounds are formed when atoms of different elements combine in a fixed ratio.**

### 1.1.1 Basic Term and their Defination

After having some idea about atoms, we will study the basic terms used in this entire book.

#### Atomic Number and Mass Number

Atomic number (Z) is a fundamental property of the atom and is equal to number of protons in the nucleus.

$$\begin{aligned}\text{Atomic number (Z)} &= \text{number of protons in the nucleus of an atom} \\ &= \text{number of electrons in a neutral atom}\end{aligned}$$

While the positive charge of the nucleus is due to protons, the mass of the nucleus is due to protons and neutrons.

Protons and neutrons present in the nucleus are collectively known as **nucleons**. The total number of nucleons is termed as **mass number (A)** of the atom.

$$\text{Mass number (A)} = \text{Number of protons (Z)} + \text{Number of neutrons (n)}$$

#### Atomic Weight

The atomic weight of an element is the average relative weight of its atom as compared to the weight of one atom of carbon which is taken as 12 and expressed in terms of unified atomic mass unit (amu).

$$1 \text{ u} = 1.66 \times 10^{-24}\text{g}$$

## 2 Material Science

The amu without the “unified” prefix is technically an absolute unit based on oxygen, which was replaced in 1961. However, at many places still used the term “amu” but now define it in the same way as u (i.e., based on carbon-12). In this regard, most uses of the terms “atomic mass units” and “amu” today actually refer to unified atomic mass unit. For standardization a specific atomic nucleus (carbon-12 vs oxygen-16) had to be chosen because the average mass of a nucleon depends on the count of the nucleons in the atomic nucleus due to mass defect. This is also why the mass of a proton or neutron by itself is more than (and not equal to) 1u.

The atomic mass unit is not the unit of mass in the atomic units system, which is basically the electron rest mass.

### Isotopes, Isobars and Isotones

All atoms having same atomic number (Z) but having different atomic weight (A) are termed as **isotopes**.  
For example:  $_{17}\text{Cl}^{35}$  and  $_{17}\text{Cl}^{37}$ .

Atoms having same atomic weight (A) but different atomic number (Z) i.e. different number of protons are called **isobars**. For example:  $^{40}\text{Ar}$ ,  $^{40}\text{Ca}$

Atoms having same number of neutrons but different atomic number (Z) or atomic weight (A) are called **isotones**. For example:  $^6\text{C}^{13}$  and  $^7\text{N}^{14}$ .

### Mole

A mole is the amount of matter that has a mass in grams equal to the atomic mass in amu of the atoms. Thus, a mole of oxygen has a mass of 32 grams.

### Avogadro's number ( $N_{av}$ )

The number of atoms in a mole is called **avogadro number**. The numerical value of avogadro's number is

$$N_{av} = 6.023 \times 10^{23}$$

## 1.2 FUNDAMENTAL COMPONENTS OF ATOMS

Matter is composed of tiny particles called **atoms**. These particles can be divided in three groups as stable, unstable and composite particles. The different tiny particles are given in Table 1.1

Table 1.1

Particle	State	Charge	Remarks
Electron	Stable	$-e$ where, $e = 1.602 \times 10^{-19} \text{ C}$	Carrier of electric current Rest mass $m_e = 9.1 \times 10^{-31} \text{ kg}$
Proton	Stable	$+e$	Mass of proton $m = 1.672 \times 10^{-27} \text{ kg}$ The protons and the neutron are considered to be two different charge states of the same particle which is called a nucleon.
Neutron	Stable	0	A neutral nuclear particle. Slightly heavier than proton. Mass = $1.675 \times 10^{-27} \text{ kg}$ .
Positron	Unstable	$+e$	Positive counter part of electron. Electron and positron mutually annihilate each other.
Neutrino & antineutrino	Unstable	0	Produced during radio active decay of electrons and positron.
Meson	Unstable	$+e$	Mass of meson is in between electron and proton. Two types - (i) $\pi$ -meson, which is heavier (ii) $\mu$ -meson, which is light
Deuteron	Composite	$+e$	Heavy isotope of hydrogen with mass about double that of ordinary hydrogen. Useful as bombarding agent.
Alpha ( $\alpha$ ) Particle	Composite	$+2e$	Doubly charged helium nucleus.

## 1.3 ATOMIC MODELS

Dalton's indivisible atom is composed of sub-atomic particles carrying positive and negative charges. Different atomic models were proposed to explain the distributions of these charged particles in an atom.

### 1.3.1 Thomson's Atomic Model

J.J. Thomson, proposed that an atom possesses a spherical shape (radius approximately  $10^{-10}\text{m}$ ) in which the positive charge is uniformly distributed. The electrons are embedded into it in such a manner as to give the most stable electrostatic arrangement.