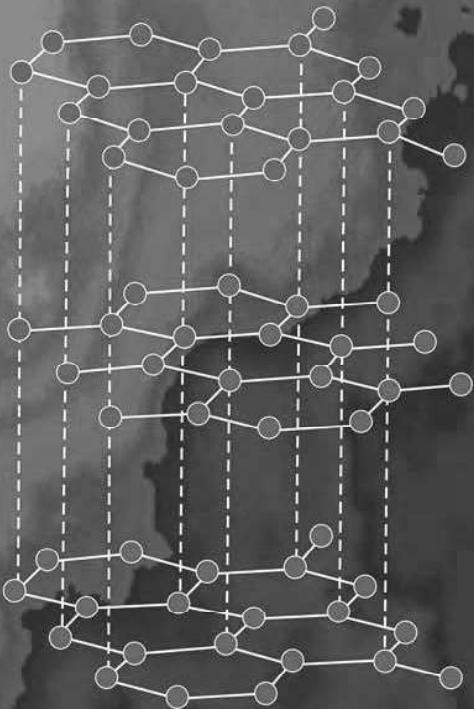
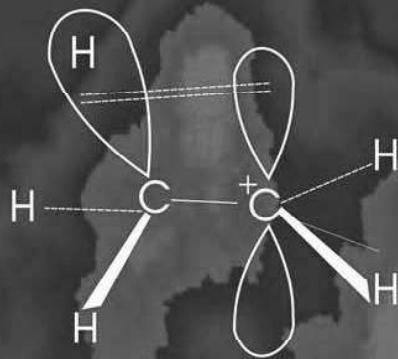


Textbook for Class XI



# Chemistry

Part 1



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## UNIT 1

# SOME BASIC CONCEPTS OF CHEMISTRY

### Objectives

After studying this unit, you will be able to

- understand and appreciate the role of chemistry in different spheres of life;
- explain the characteristics of three states of matter;
- classify different substances into elements, compounds and mixtures;
- define SI base units and list some commonly used prefixes;
- use scientific notations and perform simple mathematical operations on numbers;
- differentiate between precision and accuracy;
- determine significant figures;
- convert physical quantities from one system of units to another;
- explain various laws of chemical combination;
- appreciate significance of atomic mass, average atomic mass, molecular mass and formula mass;
- describe the terms – mole and molar mass;
- calculate the mass per cent of different elements constituting a compound;
- determine empirical formula and molecular formula for a compound from the given experimental data;
- perform the stoichiometric calculations.

*Chemistry is the science of molecules and their transformations. It is the science not so much of the one hundred elements but of the infinite variety of molecules that may be built from them ...*

*Roald Hoffmann*

Chemistry deals with the composition, structure and properties of matter. These aspects can be best described and understood in terms of basic constituents of matter: **atoms** and **molecules**. That is why chemistry is called the science of atoms and molecules. Can we see, weigh and perceive these entities? Is it possible to count the number of atoms and molecules in a given mass of matter and have a quantitative relationship between the mass and number of these particles (atoms and molecules)? We will like to answer some of these questions in this Unit. We would further describe how physical properties of matter can be quantitatively described using numerical values with suitable units.

#### 1.1 IMPORTANCE OF CHEMISTRY

Science can be viewed as a continuing human effort to systematize knowledge for describing and understanding nature. For the sake of convenience science is sub-divided into various disciplines: chemistry, physics, biology, geology etc. Chemistry is the branch of science that studies the composition, properties and interaction of matter. Chemists are interested in knowing how chemical transformations occur. Chemistry plays a central role in science and is often intertwined with other branches of science like physics, biology, geology etc. Chemistry also plays an important role in daily life.

Chemical principles are important in diverse areas, such as: weather patterns, functioning of brain and operation

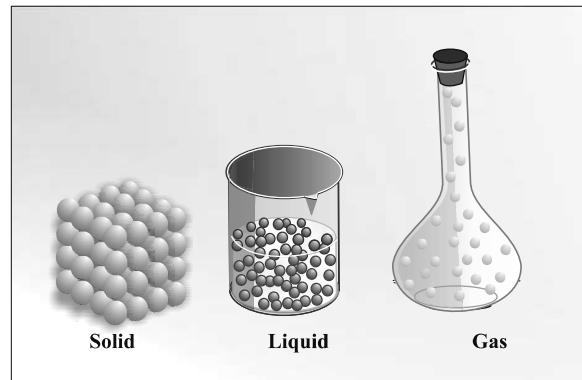
of a computer. Chemical industries manufacturing fertilizers, alkalis, acids, salts, dyes, polymers, drugs, soaps, detergents, metals, alloys and other inorganic and organic chemicals, including new materials, contribute in a big way to the national economy.

Chemistry plays an important role in meeting human needs for food, health care products and other materials aimed at improving the quality of life. This is exemplified by the large scale production of a variety of fertilizers, improved varieties of pesticides and insecticides. Similarly many life saving drugs such as **cisplatin** and **taxol**, are effective in cancer therapy and AZT (Azidothymidine) used for helping AIDS victims, have been isolated from plant and animal sources or prepared by synthetic methods.

With a better understanding of chemical principles it has now become possible to design and synthesize new materials having specific magnetic, electric and optical properties. This has lead to the production of superconducting ceramics, conducting polymers, optical fibres and large scale miniaturization of solid state devices. In recent years chemistry has tackled with a fair degree of success some of the pressing aspects of environmental degradation. Safer alternatives to environmentally hazardous refrigerants like CFCs (chlorofluorocarbons), responsible for ozone depletion in the stratosphere, have been successfully synthesised. However, many big environmental problems continue to be matters of grave concern to the chemists. One such problem is the management of the Green House gases like methane, carbon dioxide etc. Understanding of bio-chemical processes, use of enzymes for large-scale production of chemicals and synthesis of new exotic materials are some of the intellectual challenges for the future generation of chemists. A developing country like India needs talented and creative chemists for accepting such challenges.

## 1.2 NATURE OF MATTER

You are already familiar with the term **matter** from your earlier classes. Anything which has mass and occupies space is called **matter**.



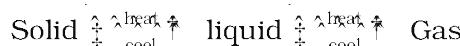
**Fig. 1.1** Arrangement of particles in solid, liquid and gaseous state

Everything around us, for example, book, pen, pencil, water, air, all living beings etc. are composed of matter. You know that they have mass and they occupy space.

You are also aware that matter can exist in three physical states *viz.* **solid**, **liquid** and **gas**. The constituent particles of matter in these three states can be represented as shown in Fig. 1.1. In **solids**, these particles are held very close to each other in an orderly fashion and there is not much freedom of movement. In **liquids**, the particles are close to each other but they can move around. However, in **gases**, the particles are far apart as compared to those present in solid or liquid states and their movement is easy and fast. Because of such arrangement of particles, different states of matter exhibit the following characteristics:

- (i) Solids have *definite volume* and *definite shape*.
- (ii) Liquids have *definite volume* but *not the definite shape*. They take the shape of the container in which they are placed.
- (iii) Gases have *neither definite volume nor definite shape*. They completely occupy the container in which they are placed.

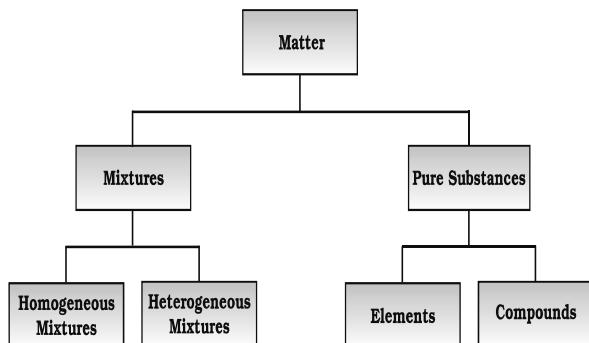
These three states of matter are interconvertible by changing the conditions of temperature and pressure.



On heating a solid usually changes to a liquid and the liquid on further heating

changes to the gaseous (or vapour) state. In the reverse process, a gas on cooling liquifies to the liquid and the liquid on further cooling freezes to the solid.

At the macroscopic or bulk level, matter can be classified as **mixtures** or **pure substances**. These can be further sub-divided as shown in Fig. 1.2.



**Fig. 1.2** Classification of matter

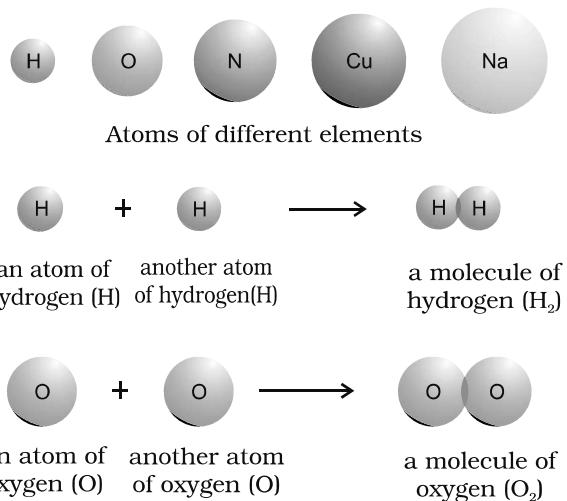
Many of the substances present around you are **mixtures**. For example, sugar solution in water, air, tea etc., are all mixtures. A mixture contains two or more substances present in it (in any ratio) which are called its components. A mixture may be **homogeneous** or **heterogeneous**. In a **homogeneous mixture**, the components completely mix with each other and its composition is uniform throughout. Sugar solution, and air are thus, the examples of homogeneous mixtures. In contrast to this, in **heterogeneous mixtures**, the composition is not uniform throughout and sometimes the different components can be observed. For example, the mixtures of salt and sugar, grains and pulses along with some dirt (often stone) pieces, are heterogeneous mixtures. You can think of many more examples of mixtures which you come across in the daily life. It is worthwhile to mention here that the components of a mixture can be separated using physical methods such as simple hand picking, filtration, crystallisation, distillation etc.

**Pure substances** have characteristics different from the mixtures. They have fixed composition, whereas mixtures may contain the components in any ratio and their

composition is variable. Copper, silver, gold, water, glucose are some examples of pure substances. Glucose contains carbon, hydrogen and oxygen in a fixed ratio and thus, like all other pure substances has a fixed composition. Also, the constituents of pure substances cannot be separated by simple physical methods.

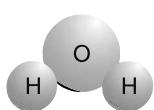
*Pure substances* can be further classified into **elements** and **compounds**. An **element** consists of only one type of particles. These particles may be **atoms** or **molecules**. You may be familiar with atoms and molecules from the previous classes; however, you will be studying about them in detail in Unit 2. Sodium, copper, silver, hydrogen, oxygen etc. are some examples of elements. They all contain atoms of one type. However, the atoms of different elements are different in nature. Some elements such as sodium or copper, contain single atoms held together as their constituent particles whereas in some others, two or more atoms combine to give **molecules** of the element. Thus, hydrogen, nitrogen and oxygen gases consist of molecules in which two atoms combine to give their respective molecules. This is illustrated in Fig. 1.3.

When two or more atoms of different elements combine, the molecule of a **compound** is obtained. The examples of some compounds are water, ammonia, carbon

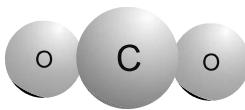


**Fig. 1.3** A representation of atoms and molecules

dioxide, sugar etc. The molecules of water and carbon dioxide are represented in Fig 1.4.



Water molecule  
(H<sub>2</sub>O)



Carbon dioxide  
molecule (CO<sub>2</sub>)

**Fig. 1.4** A depiction of molecules of water and carbon dioxide

You have seen above that a water molecule comprises two hydrogen atoms and one oxygen atom. Similarly, a molecule of carbon dioxide contains two oxygen atoms combined with one carbon atom. Thus, the atoms of different elements are present in a compound in a fixed and definite ratio and this ratio is characteristic of a particular compound. Also, the properties of a compound are different from those of its constituent elements. For example, hydrogen and oxygen are gases whereas the compound formed by their combination *i.e.*, water is a liquid. It is interesting to note that hydrogen burns with a pop sound and oxygen is a supporter of combustion, but water is used as a fire extinguisher.

Moreover, the constituents of a compound cannot be separated into simpler substances by physical methods. They can be separated by chemical methods.

### 1.3 PROPERTIES OF MATTER AND THEIR MEASUREMENT

Every substance has unique or characteristic properties. These properties can be classified into two categories – **physical properties** and **chemical properties**.

**Physical properties** are those properties which can be measured or observed without changing the identity or the composition of the substance. Some examples of physical properties are colour, odour, melting point, boiling point, density etc. The measurement or observation of **chemical properties** require a chemical change to occur. The examples of

chemical properties are characteristic reactions of different substances; these include acidity or basicity, combustibility etc.

Many properties of matter such as length, area, volume, etc., are quantitative in nature. Any quantitative observation or measurement is represented by a number followed by units in which it is measured. For example length of a room can be represented as 6 m; here 6 is the number and m denotes *metre* – the unit in which the length is measured.

Two different systems of measurement, i.e. the **English System** and the **Metric System** were being used in different parts of the world. The metric system which originated in France in late eighteenth century, was more convenient as it was based on the decimal system. The need of a common standard system was being felt by the scientific community. Such a system was established in 1960 and is discussed below in detail.

#### 1.3.1 The International System of Units (SI)

The International System of Units (in French *Le Système International d'Unités* – abbreviated as SI) was established by the 11th General Conference on Weights and Measures (CGPM from *Conference Générale des Poids et Mesures*). The CGPM is an intergovernmental treaty organization created by a diplomatic treaty known as Meter Convention which was signed in Paris in 1875.

The SI system has seven *base units* and they are listed in Table 1.1. These units pertain to the seven fundamental scientific quantities. The other physical quantities such as speed, volume, density etc. can be derived from these quantities.

The definitions of the SI base units are given in Table 1.2.

The SI system allows the use of prefixes to indicate the multiples or submultiples of a unit. These prefixes are listed in Table 1.3.

Let us now quickly go through some of the quantities which you will be often using in this book.

Table 1.1 Base Physical Quantities and their Units

Base Physical Quantity	Symbol for Quantity	Name of SI Unit	Symbol for SI Unit
Length	$l$	metre	m
Mass	$m$	kilogram	kg
Time	$t$	second	s
Electric current	$I$	ampere	A
Thermodynamic temperature	$T$	kelvin	K
Amount of substance	$n$	mole	mol
Luminous intensity	$I_v$	candela	cd

Table 1.2 Definitions of SI Base Units

<b>Unit of length</b>	<b>metre</b>	The <i>metre</i> is the length of the path travelled by light in vacuum during a time interval of $1/299\ 792\ 458$ of a second.
<b>Unit of mass</b>	<b>kilogram</b>	The <i>kilogram</i> is the unit of mass; it is equal to the mass of the international prototype of the kilogram.
<b>Unit of time</b>	<b>second</b>	The <i>second</i> is the duration of $9\ 192\ 631\ 770$ periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the caesium-133 atom.
<b>Unit of electric current</b>	<b>ampere</b>	The <i>ampere</i> is that constant current which, if maintained in two straight parallel conductors of infinite length, of negligible circular cross-section, and placed 1 metre apart in vacuum, would produce between these conductors a force equal to $2 \times 10^{-7}$ newton per metre of length.
<b>Unit of thermodynamic temperature</b>	<b>kelvin</b>	The <i>kelvin</i> , unit of thermodynamic temperature, is the fraction $1/273.16$ of the thermodynamic temperature of the triple point of water.
<b>Unit of amount of substance</b>	<b>mole</b>	1. The <i>mole</i> is the amount of substance of a system which contains as many elementary entities as there are atoms in 0.012 kilogram of carbon-12; its symbol is "mol." 2. When the mole is used, the elementary entities must be specified and may be atoms, molecules, ions, electrons, other particles, or specified groups of such particles.
<b>Unit of luminous intensity</b>	<b>candela</b>	The <i>candela</i> is the luminous intensity, in a given direction, of a source that emits monochromatic radiation of frequency $540 \times 10^{12}$ hertz and that has a radiant intensity in that direction of $1/683$ watt per steradian.

**Table 1.3 Prefixes used in the SI System**

Multiple	Prefix	Symbol
$10^{-24}$	yocto	y
$10^{-21}$	zepto	z
$10^{-18}$	atto	a
$10^{-15}$	femto	f
$10^{-12}$	pico	p
$10^{-9}$	nano	n
$10^{-6}$	micro	$\mu$
$10^{-3}$	milli	m
$10^{-2}$	centi	c
$10^{-1}$	deci	d
10	deca	da
$10^2$	hecto	h
$10^3$	kilo	k
$10^6$	mega	M
$10^9$	giga	G
$10^{12}$	tera	T
$10^{15}$	peta	P
$10^{18}$	exa	E
$10^{21}$	zeta	Z
$10^{24}$	yotta	Y

### 1.3.2 Mass and Weight

**Mass** of a substance is the amount of matter present in it while **weight** is the force exerted by gravity on an object. The mass of a substance is constant whereas its weight may vary from one place to another due to change in gravity. You should be careful in using these terms.

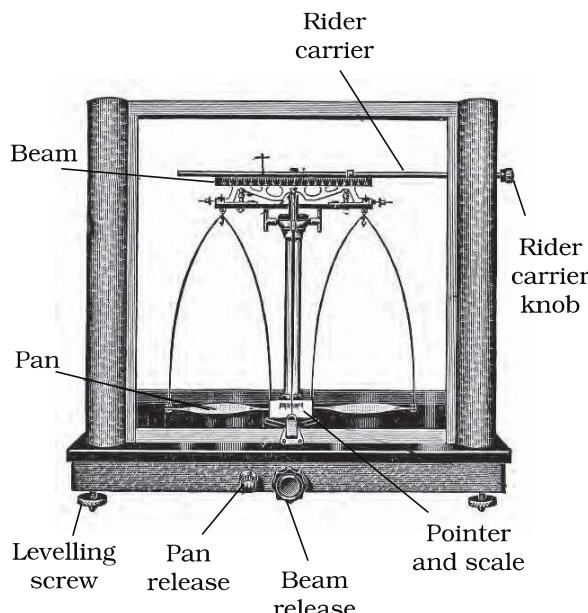
The mass of a substance can be determined very accurately in the laboratory by using an analytical balance (Fig. 1.5).

The SI unit of mass as given in Table 1.1 is kilogram. However, its fraction gram ( $1\text{ kg} = 1000\text{ g}$ ), is used in laboratories due to the smaller amounts of chemicals used in chemical reactions.

### Volume

Volume has the units of (length)<sup>3</sup>. So in SI system, volume has units of m<sup>3</sup>. But again, in

chemistry laboratories, smaller volumes are used. Hence, volume is often denoted in cm<sup>3</sup> or dm<sup>3</sup> units.



**Fig. 1.5** Analytical balance

### Maintaining the National Standards of Measurement

The system of units including unit definitions keeps on changing with time. Whenever the accuracy of measurement of a particular unit was enhanced substantially by adopting new principles, member nations of *metre treaty* (signed in 1875), agreed to change the formal definition of that unit. Each modern industrialized country including India has a National Metrology Institute (NMI) which maintains standards of measurements. This responsibility has been given to the National Physical Laboratory (NPL), New Delhi. This laboratory establishes experiments to realize the *base units* and *derived units* of measurement and maintains National Standards of Measurement. These standards are periodically inter-compared with standards maintained at other National Metrology Institutes in the world as well as those established at the International Bureau of Standards in Paris.