# Some Basic Concepts of Chemistry

## IMPORTANCE OF CHEMISTRY

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.

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

2. 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.

3. 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 lifesaving 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.

4. 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 led to the production of superconducting ceramics, conducting polymers, optical fibres and large scale miniaturization of solid state devices.

5. 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.

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.

**Chemistry:**

Chemistry is the branch of science that deals with the composition, structure and properties of matter.

Chemistry is called

The science of atoms and molecules.

## NATURE OF MATTER

Anything which has mass and occupies space is called **matter.**

example, book, pen, pencil, water, air, all living beings etc.

Matter can exist in three physical states *viz.* **solid**, **liquid** and **gas**.

The properties of these three physical states can be understood with the help of following table

| Properties | Solid | Liquid | Gas |
|---|---|---|---|
| **1. volume** | Definite | Definite | **Indefinite** |
| **2. Shape** | Definite | Indefinite | **Indefinite** |
| **3. Inter molecular force of attraction** | Very high | Moderate | **Negligible / Very low** |
| **4. arrangement of molecules** | Orderly arranged | Free to move within the volume | **Free to move every where** |
| **5. Inter molecular space** | Very small | Slightly greater and approx. equal | **Very great** |
| **6. Free surfaces** | According to their geometry | Only one | **None** |
| **7. Compressibility** | Not compressible | Not compressible | **Highly compressible** |
| **8. Expansion on heating** | Very little | Very little | **Highly expand** |
| **9. Rigidity** | Very rigid | Not rigid and known as fluid | **Not rigid and known as fluid** |
| **9. Fluidity** | Can't flow | Can flow | **Can flow** |
| **10. Diffusion** | **They can diffuse due to kinetic energy of liquid/gases** | **Can diffuse And rate of diffusion is very fast** | **Can diffuse And rate of diffusion is very fast** |

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

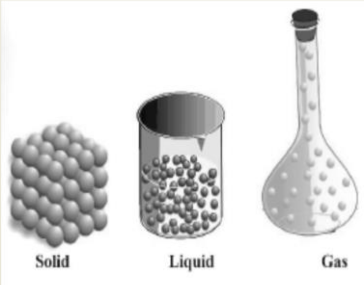



Fig: Arrangement of particles in solid, liquid and gaseous state

A mixture contains two or more substances present in it (in any ratio) which are called its **components.** Many of the substances present around you are **mixtures**. For example, sugar solution in water, air, tea etc.,

A mixture may be classify as **homogeneous** or **heterogeneous**.

**Homogeneous mixture**, the components completely mix with each other and its composition is uniform throughout. e.g. Sugar solution, and air .

**Heterogeneous mixtures**, the composition is not uniform throughout and sometimes the different components can be observed. E.g. the mixtures of salt and sugar, grains and pulses along with some dirt (often stone) pieces,

Components of a mixture can be separated by using physical methods such as simple hand picking, filtration, crystallisation, distillation etc.

**Pure substance/Substances** have fixed composition e.g. Copper, silver, gold, water, glucose e.tc. *Pure substances* can be classified as **elements** and **compounds**.

An **element** consists of only one type of particles. These particles may be **atoms** or **molecules**. E.g. Sodium, copper, silver, hydrogen, oxygen etc.

However, the atoms of different elements are different in nature.

**Compound**

When two or more atoms of different elements combine, the molecule of a **compound** is obtained. E.g. water, ammonia, carbon dioxide, sugar etc.

**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**.

**Definitions of SI Base Units**

**Unit of length—metre**

The *metre* is the length of the path travelled by light in vacuum during a time interval of 1/299 792 458 of a second.

**Unit of mass-- kilogram**

it is equal to the mass of the international prototype of the kilogram.

**Unit of time—second**

The *second* 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.

**Unit of electric current ampere**

The *ampere* 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.

**Unit of thermodynamic temperature-- kelvin**

The *kelvin*, unit of thermodynamic temperature, is the fraction 1/273.16 of the thermodynamic temperature of the triple point of water.

**Physical properties** are those properties which can be measured or observed without changing the identity or the composition of the substance. E.g. colour, odour, melting point, boiling point, density etc.

The measurement or observation of **chemical properties** requires a chemical change to occur. e.g. Burning of Mg-ribbon in air

**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.

**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 so it is in detail.

**The International System of Units (SI)**

The International System of Units (in French Le Systeme International d'Unités – abbreviated as SI) was established by the 11th General Conference on Weights and Measures (CGPM from *Conference Generale des Poids at Measures*). The CGPM is an inter-governmental treaty organization created by a diplomatic treaty known as Metre Convention which was signed in Paris in 1875.The SI system has seven *base units* and they are listed in Table

| 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 |

**(Triple point**- Temperature at which all three physical states of water can exist **i.e. $0^0$C)**

**Unit of amount of substance-- mole --**1. The *mole* 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."

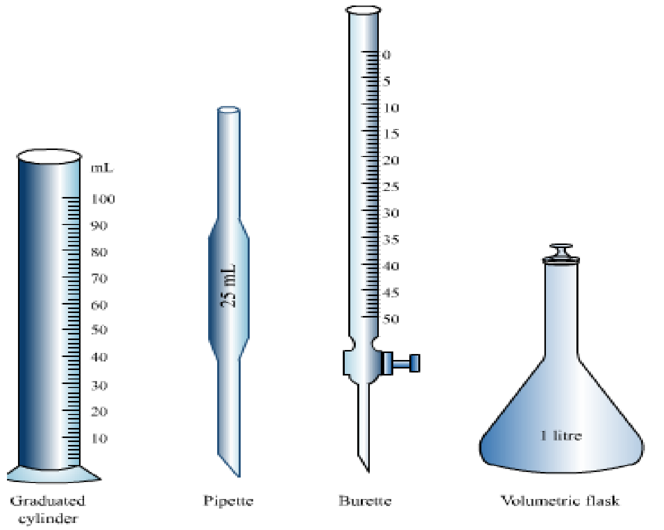
2. When the mole is used, the elementary entities must be specified and may be atoms, molecules, ions, electrons, other particles, or specified groups of such particles.

**Unit of luminous intensity-- candela --**The *candela* is the luminous intensity, in a given direction, of a source that emits monochromatic radiation of frequency 540 × $10^{12}$ hertz and that has a radiant intensity in that direction of 1/683 watt per steradian.

**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.

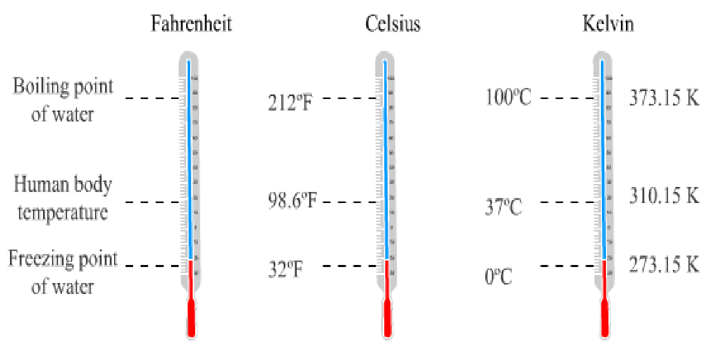
The mass of a substance can be determined very accurately by using an analytical balance.

In the laboratory, volume of liquids or solutions can be measured by graduated cylinder, burette, pipette etc. A volumetric flask is used to prepare a known volume of a




solution.

The thermometers based on these scales are shown in Fig.




Generally, the thermometer with Celsius scale is calibrated from 0° to 100° where these two temperatures are the freezing point and the boiling point of water respectively.

The Fahrenheit scale is represented between 32° to 212°.

The temperatures on two scales are related to each other by the following relationship:

$$°F = \frac{9}{5}(°C) + 32$$

The Kelvin scale is related to Celsius scale as follows:

$$K = °C + 273.15$$

**Maintaining the National Standards of Measurement**

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.

Derived units—Units derived with the help of base units of measurement.

**Volume**

Volume has the units of (length) $^3$. So volume has units of $m^3$ or $cm^3$ or $dm^3$.

A common unit, litre (L) is not an SI unit, is used for measurement of volume of liquids.

1 L = 1000 mL, 1000 $cm^3$ = 1 $dm^3$

**Density**

Density of a substance is its amount of mass per unit volume.

SI unit of density = SI unit of mass/SI unit of volume

= $kg/m^3$ or $kg\ m^{-3}$

This unit is quite large and a chemist often expresses density in $g\ cm^{-3}$.

**Temperature--**There are three common scales to measure temperature — °C (degree Celsius), °F (degree Fahrenheit) and K (kelvin).

LAWS OF CHEMICAL COMBINATIONS

The combination of elements to form compounds is governed by the following five basic laws.

**Law of Conservation of Mass**:

(Given by Antoine Lavoisier in 1789)

It states that **matter (mass) can neither be created nor destroyed.**

**Law of Definite Proportions:**

**(G**iven by, a French chemist, Joseph Proust.)

He stated that **a given compound always contains exactly the same proportion of elements by weight. (**Proust worked with two samples of cupric carbonate one of which was of natural origin and the other was synthetic one. He found that the composition of elements present in it was same)

**Law of Multiple Proportions (**Given by Dalton in 1803.)

According to this law, **if two elements combine together and form two or more than two compounds, the masses of one element that combine with a fixed mass of the other element, are in the simple ratio of small whole numbers.**

| **Oxide of N** | **reacting mass of N** | **reacting mass of O** | **fix mass of N** | **reacting mass of O with fix mass of N** | **Ratio of reacting mass of O with fix mass of N** |
|---|---|---|---|---|---|
| **$N_2O$** | 28g | 16g | 14g | 8g | **1** |
| **NO** | 14g | 16g | 14g | 16g | **2** |
| **$N_2O_3$** | 28g | 48g | 14g | 24g | **3** |
| **$NO_2$** | 14g | 32g | 14g | 32g | **4** |
| **$N_2O_5$** | **28g** | **80g** | **14g** | **40g** | **5** |

# Note :

Temperature below 0 °C (i.e. negative values) is possible in Celsius scale but in Kelvin scale, negative temperature is not possible.

**Law of Conservation of Mass:**

**Eg:** **$C + O_2 \dashrightarrow CO_2$**

12g + 32g = 44g

**Law of Definite Proportions:**

**E.g**. If we collect water from different sources or prepare in lab, It always has H & O in fix ratio by mass or by volume or by no. of atoms.

**Law of Multiple Proportions:**

**E.g.** N and O combine together and form five oxides $N_2O$, NO, $N_2O_3$, $NO_2$, and $N_2O_5$

**Gay Lussac's Law of Gaseous Volumes**:

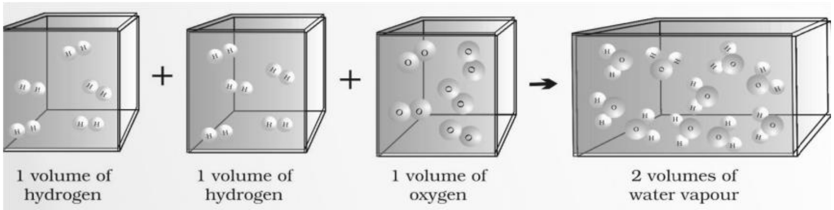
(Given by Gay Lussac in 1808.)

According to this law **when gases combine or are produced in a chemical reaction they do so in a simple ratio by volume provided all gases are at same temperature and pressure.**

**Avogadro Law (**In 1811, Given by Avogadro)

According to this law **equal volumes of gases at the same temperature and pressure should contain equal number of molecules.**

Avogadro made a distinction between **atoms** and **molecules** Avogadro could explain the result of chemical reactions by considering the molecules to be **polyatomic.**




*Two volumes of hydrogen react with one volume of oxygen to give two volumes of water vapour*

**DALTON'S ATOMIC THEORY--**In 1808, Dalton published 'A New System of Chemical Philosophy' in which he proposed the following:

1. Matter consists of indivisible atoms.

2. All the atoms of a given element have identical properties including identical mass. Atoms of different elements differ in mass.

3. Compounds are formed when atoms of different elements combine in a fixed ratio.

4. Chemical reactions involve reorganization of atoms. These are neither created nor destroyed in a chemical reaction.

Dalton's theory could explain the laws of chemical combination.

**Gay Lussac's Law of Gaseous Volumes**

E.g:

$H_2$ (g) + $Cl_2$ (g) ---→ 2HCl (g)

1V 1V 2V

All reactants and products have simple ratio 1:1:2.

# Note:

Gay-Lussac's discovery of integer ratio in volume relationship is actually the law of definite proportions by volume.

## ATOMIC AND MOLECULAR MASSES

Today, we use mass spectrometry technique for determining the atomic masses.

Since 1961 C-12 (isotope of a carbon) taken as standard to calculate relative masses of other elements.

In this system, $^{12}C$ is assigned a mass of exactly 12 atomic mass unit (**amu**) and masses of all other atoms are given relative to this standard.

**One atomic mass unit is defined as a mass exactly equal to one twelfth the mass of one carbon - 12 atom.**

**Average Atomic Mass--**Many naturally occurring elements exist as more than one isotope. When we take into account the existence of these isotopes and their relative abundance (per cent occurrence), the average atomic mass of that element can be calculated. For example, (C.W.)

**Molecular Mass**

Molecular mass is the sum of atomic masses of the elements present in a molecule. E.g. (c.w.)

## MOLE CONCEPT AND MOLAR MASSES

**One mole is the amount of a substance that contains as many particles or entities (i.e. atoms, molecules or ions) as there are atoms in exactly 12 g (or 0.012 kg) of the 12C isotope.**

It is very important to note that the mole of a substance always contain the same number of entities, no matter what the substance may be.

This number of entities in 1 mol is given a separate name and symbol. It is known as **'Avogadro constant'**, denoted by $\mathbf{N_A}$ in honour of Amedeo Avogadro.

**The mass of one mole of a substance in grams is called its molar mass.**

The molar mass is numerically equal to atomic/molecular/ formula mass in u but expressed in grams in place of u.

1 amu = $1.66056\times10^{-24}$ g.

Mass of an atom of hydrogen = $1.6736\times10^{-24}$ g.

Thus, in terms of amu, the mass of hydrogen atom

$1.6736\times10^{-24}$g/$1.66056\times10^{-24}$g

= 1.0078 amu
= 1.0080 amu

Today, **'amu'** has been replaced by **'u'** which is known as **unified mass**.

**Q. Ca**lculate molecular mass of glucose ($C_6H_{12}O_6$) molecule.

**Formula Mass---**In crystalline substances e.g. sodium chloride do not contain discrete molecules as their constituent units. In such compounds, positive (sodium) and negative (chloride) entities are arranged in a three-dimensional structure, so for ease of calculations, simple ratio of these entities taken as formula unit and its mass known as formula mass.

E.g:

Thus, formula mass of sodium chloride = atomic mass of sodium + atomic mass of chlorine
= 23.0 u + 35.5 u = 58.5 u

**PERCENTAGE COMPOSITION**

This determination is important to check the purity of a given sample. Let us consider the example of water ($H_2O$). Water contains hydrogen and oxygen, the percentage composition of both these elements can be calculated as:

Mass % of an element =

$$\frac{\text{Mass of that element in the compound}}{\text{molar mass of the compound}} \times 100$$

**Empirical Formula for Molecular Formula**—

An **empirical formula** represents the simplest whole number ratio of various atoms present in a compound. E.g. CH is the empirical formula of benzene.

The **molecular formula** shows the exact number of different types of atoms present in a molecule of a compound. E.g. $C_6H_6$ is the molecular formula of benzene.

Determination of the **Empirical Formula and Molecular Formula---**With the help of mass per cent of various elements present in a compound, its empirical formula can be determined. Molecular formula can further be obtained if the molar mass is known.

**STOICHIOMETRY AND STOICHIOMETRIC CALCULATIONS**

We know chemical equation is maximum informative, when it is written in the form of balanced chemical equation. It gives quantitative relationship between the various reactants and products in terms of moles, masses, molecules and volumes. This is called stoichiometry. (The word 'stoichiometry' is derived from two Greek words - *stoicheion* (meaning *element*) and *metron* (meaning *measure*) i.e. measurement of an element.). The coefficients of the balanced chemical equation are known as stoichiometric coefficients.

**E.g.:**

Molecular mass of water=18.02u

And

Molar mass of water =18.02g (mass of 1- water molecule) = (mass of $6.02 \times 10^{23}$ - water molecules)

Molar mass of water = 18.02 g

**E.g:**

Mass % of hydrogen =

$$\frac{2 \times 1.008 \times 100}{18.02}$$

= 11.18

Mass % of oxygen =

$$\frac{16.00 \times 100}{18.02}$$

= 88.79

**Balancing a chemical equation--**According to the law of conservation of mass, a balanced chemical equation has the *same number of atoms of each element on both sides* of the equation.

**Limiting Reagent:** the reactant which gets consumed first or limits the amount of product formed is known as **limiting reagent**.

**Reactions in Solutions:** A majority of reactions in the laboratories are carried out in solutions. The concentration of a solution or the amount of substance present in its given volume can be expressed in any of the following ways.

1. Mass per cent or weight per cent (w/w %)
2. Mole fraction
3. Molarity
4. Molality

**1. Mass percent:**

It is obtained by using the following relation

Mass per cent (w/w %) =

Mass of solute/Mass of solution x 100

**2. Mole Fraction (X):**

It is the ratio of number of moles of a particular component to the total number of moles of the Solution. If a substance 'A' dissolves in substance 'B' and their number of moles are *n*A and *n*B respectively; then the mole fractions of A and B are given as

$$\text{Mole fraction of A } (X_A) = \frac{\text{no. of moles of A}}{\text{No of moles of solution}} = \frac{nA}{nA+nB}$$

Similarly we can calculate the mole fraction of B ($X_B$).

**3. Molarity (M) --** It is defined as the number of moles of the solute in 1 litre of the solution. Thus,

$$\text{Molarity (M)} = \frac{\text{No. of moles of solute}}{\text{Volume of solution in litres}}$$

Molarity on dilution can be calculated by using the general formula $M_1V_1 = M_2V_2$

**4. Molality (m) --** It is defined as the number of moles of solute present in 1 kg of solvent.

$$\text{Molality (m)} = \frac{\text{No. of moles of solute}}{\text{Mass of solvent in kg}}$$