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UNIT - I

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1 CHAPTER

Units & Measurement

Measurement of any physical quantity involves comparison with a certain basic, arbitrarily chosen, internationally accepted reference standard called unit. The result of a measurement of a physical quantity is expressed by a number or (numerical measure) accompanied by a unit. The units for the fundamental or base quantities are called fundamental or base units. The units of all other physical quantities can be expressed as combinations of the base units. Such units obtained for the derived quantities are called derived units. A complete set of these units, both the base units and derived units, is known as the system of units.

Physical Quantities

Physical quantities are quantities that can be measured. In physical quantities include velocity, acceleration, force, area, volume, pressure, and so on.

Types of Physical Quantities

Physical quantities are classified into two types:

1. **Fundamental Physical Quantities:** Fundamental physical quantities are those that do not depend on or are independent of other quantities.
   - There are seven of them: **length, mass, time, thermodynamic temperature, electric current, luminous intensity, and substance amount.**
2. **Derived Physical Quantities:** Physical quantities that are derived from fundamental physical quantities are referred to as derived physical quantities.
   - For example, velocity is a derived physical quantity because it is derived from the fundamental quantities' length and time.

Units

A physical quantity is measured by comparing it to a standard quantity. This standard quantity is referred to as the quantity's unit.

- To measure the length of a desk, it is compared to the standard quantity known as **'Metre'**.
- For example, the length of a race, which is a physical quantity, can be expressed in metre (for sprinters) or Kilometers (for long distance runners).
- Without standardized units, it would be extremely difficult for scientists to express and compare measured values in a meaningful way.

Types of Units

Units are classified into two types:

1. **Fundamental Units:** Fundamental units are those that cannot be deduced from any other unit and cannot be resolved into any other basic or fundamental unit.
   - Fundamental units are also the units of fundamental physical quantities. The table below depicts the seven fundamental units of the **S.I. System**.
2. **Derived Units:** A derived unit is any unit that can be created by combining one or more fundamental units. **Area, Speed, Density, Volume, Momentum, Acceleration, Force,** and so on are some examples of the Derived Units.
   - Till now, the scientists of different countries adopted different systems of units for measurement and widely accepted among them were three such systems, i.e. the **CGS**, the **FPS** (or British) system and the **MKS** system.
   - In **CGS** system they were Centimetre, Gram and Second respectively.
   - In **FPS** system they were Foot, Pound and Second respectively.
   - In **MKS** system they were Metre, Kilogram and Second respectively.

- Here, in all these systems, the first unit is for length, second for weight and third for time.
- Now, the system of units which is internationally accepted for measurement is the **International System of Units** (French) shortly known as **SI**.
- The present SI, with standard scheme of symbols, units and abbreviations, was developed by **General Conference on Weights and Measures in 1960** for international usage in scientific, technical, industrial and commercial work.

Supplementary Units of SI System

1. **Radian (rad):** The radian is the plane angle formed by two radii of a circle intersecting on the circumference to form an arc of length equal to the radius.
2. **Steradian (sr):** The steradian is a solid angle with its vertex at the centre of a sphere that cuts off an area of the sphere's surface equal to that of a square with sides the length of the sphere's radius.

2

CHAPTER

Motion

Most motions are complex. Some objects may move in a straight line, others may take a circular path. Some may rotate and a few others may vibrate. There may be situations involving a combination of these. In this chapter, we shall first learn to describe the motion of objects along a straight line and circular path. We shall also learn to express such motions through simple equations and laws.

Motion and Dimension

Motion is change in position of an object with time in respect to its surroundings. When a body does not change its position with respect to time, then it is said to be at rest; while motion is the change of position of an object with respect to time.

- To study the motion of the object, one has to study the change in position (x,y,z coordinates) of the object with respect to the surroundings.
- These positions change even due to the change in one, two or all the three coordinates of the position of the objects with respect to time.
- No force is required to keep an object in uniform motion.
- When an object has uniform motion along a straight line in a given direction, the magnitude of displacement is equal to actual distance covered.

Thus, motion can be classified into three types:

1. **Motion in One Dimension:** It is defined as a motion in which a particle moves along a straight line.

   In other words, motion of an object is said to be one dimensional, if only one of the three coordinates specifying the position of the object changes with respect to time.

   For instance an ant moving in a straight line, running athlete, etc. It is also called **Rectilinear or Translatory motion.**
2. **Motion in Two Dimensions:** A motion wherein a particle rotates about a fixed axis.

   In this, the motion is represented by any two of the three coordinates. Example: a body moving in a plane. It is also called Rotational motion.
3. **Motion in Three Dimensions:** Motion of a body is said to be three dimensional, if all the three coordinates of the position of the body change with respect to time.
   - In other words, it is a motion in which a particle moves to and fro or back and forth about a fixed point. It is also called Vibratory or Oscillatory motion.
   - **Examples:** Motion of a flying bird, motion of a kite in the sky, motion of a molecule, etc.

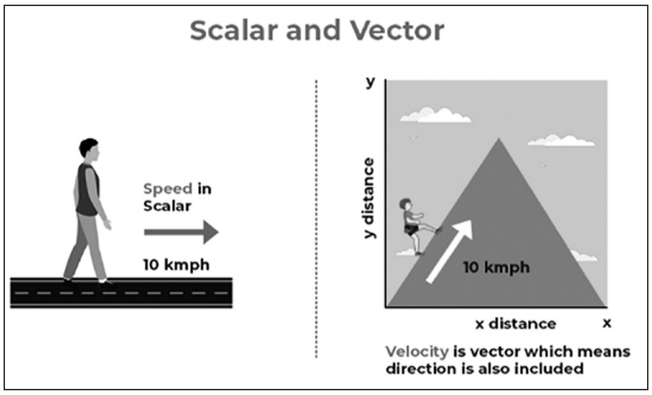
Particle or Point Mass

- The smallest part of matter with zero dimensions which can be described by its mass and position is defined as a particle.
- If the size of a body is negligible in comparison to its range of motion then that body is known as a particle.
- A body (Group of particles) to be known as a particle depends upon types of motion. For example in a planetary motion around the sun the different planets can be presumed to be the particles.
- In above consideration when we treat body as particle, all parts of the body undergo same displacement and have same velocity and acceleration.

Scalars and Vectors

Scalars: These are quantities completely specified by a single number and a proper unit and therefore have magnitudes only.

- Scalars can be added, subtracted, multiplied and divided just as ordinary numbers. Scalar product is Commutative. Mass, Speed, Distance, Temperature, Length, Time, Density, Energy, Electric potential etc. are scalar quantities.
- **Vectors:** Quantities possessing both magnitude and directions are known as vectors.
- Some of the examples of the vectors quantities are displacement, velocity, acceleration, momentum, force, etc.



3 CHAPTER

Work, Energy and Power

The terms 'work', 'energy' and 'power' are frequently used in everyday language. We shall find that there is at best a loose correlation between the physical definitions and the physiological pictures these terms generate in our minds. The aim of this chapter is to develop an understanding of these three physical quantities.

Primitive man used muscular energy to do work. Later, animal energy was harnessed to help people do various kinds of tasks. With the invention of various kinds of machines, the ability to do work increased greatly.

- Progress of our civilization now critically depends on the availability of usable energy. Energy and work are, therefore, closely linked.
- The rate of doing work improved with newer modes, i.e. as we shifted from
- Humans → Animals → Machines to provide necessary force. The rate of doing work is known as power.

Work

The scientific definition of work differs in some ways from its everyday meaning of hard work or carrying heavy load.

- The scientific definition of work has its relationship to energy—whenever work is done, energy is transferred.
- For work to be done a force must be exerted and there must be motion or displacement in the direction of the force, therefore Work is considered done when a force produces some kind of motion.
- For example, when a man climbs a mountain, work is done because while climbing a mountain he is moving against the force of gravity.

Factors Affecting Work

- The **magnitude of the force** forms the formula of work done. It is evident that the higher the magnitude of force, the higher the work gets done and vice-versa.
- The **magnitude of the displacement** form the formula of work done.
- It is evident that the higher the magnitude of the displacement, the higher the work gets done and vice-versa.
- The **direction between the force and the displacement,** If the angle between the force and the displacement is θ, then the value of cosθ is obtained to get the magnitude of work done. So, work done depends on the value of cosθ.
- The work done by a force is defined to be the product of the component of the force in the direction of the displacement and the magnitude of this displacement.

$$\mathbf{W = F \cos\theta = \vec{F}\vec{d}}$$

- Work (W) = FS Cos θ (angle between the displacement and force)
- Where W is the work done, F is the force, d is the displacement, θ is the angle between force and displacement and F cosθ is the component of force in the direction of displacement.
  - It is a scalar quantity as it is a dot product of Force and Displacement (Dot product is always a scalar quantity)
  - It has only magnitude not direction.
  - The SI unit of work is Joule (J) or Newton-metre (N.m)
  - Its dimension is $[ML^2T^{-2}]$ where (M= mass, L= length, T = time) and SI base unit is $kg.m^2/s^2$.

Alternative Units of Work and Energy in Joule

erg	10^{-7}J
electron volt (eV)	1.6×10^{-19}J
calorie (cal)	4.186J
kilowatt hour (kWh)	3.6×10^{6}J

No work is done if

- The **displacement** is **zero**. A weightlifter holding a 150 kg mass steadily on his shoulder for 30s does no work on the load during this time.
- The **force** is **zero**. A block moving on a smooth horizontal table is not acted upon by a Horizontal force (since there is no friction), but may undergo a large displacement.
- The force and displacement are mutually **perpendicular**.
  - For example, a man tries to move a wall but the wall does not move, hence the work done by the man is zero as there is no displacement produced.
  - But he does lose energy because in his attempt to push the wall he stretches his muscles and thus feels tired.

4 CHAPTER

Gravitation

From our early childhood days we have become aware that the tendency of all material objects to be attracted towards the earth. Anything thrown up falls down towards the earth, going uphill is lot more tiring than going downhill, raindrops from the clouds above fall towards the earth and there are many other such phenomena. In this chapter we are going to learn about Gravitation and its nature in a brief manner.

The force of attraction between any two bodies in the universe is called **gravitation**. In other words, gravitation is a natural phenomenon by which all physical bodies attract each other. Gravitation is also known as gravity and denoted by **g**.

- All the objects in the universe attract each other with a certain amount of force, but in most of the cases, the force is too weak to be observed due to the very large distance of separation.
- Besides, gravity's range is infinite, but the effect becomes weaker as objects move away.

History of Gravitational Theory

Ptolemy proposed the **Geocentric model** which failed in understanding planetary motions. It led to the development of the heliocentric model by **Nicholas Copernicus** whose idea is based on the rotation of a test mass around the source mass in circular orbits.

- Although the model correctly predicts the position of planets and their motions but has failed in explaining many aspects like the occurrence of seasons which led the construction of a model based on **Kepler's laws of planetary motion.**
- This force of attraction was first observed by **Sir Isaac Newton** and was presented as Newton's law of gravitation in the year 1680.
- The works of John Kepler, Isaac Newton and Albert Einstein contributed a lot in the development of gravitational theory.
- However, gravitation can generally exist in two main instances.
  - Gravitation may be the **attraction of objects by the earth**. **Example:** If a object (ball) is thrown upwards, it reaches a certain height and falls downwards because of the gravity of the earth.
  - Gravitation may be the **attraction of objects in outer space**. **Example:** Force of attraction between the other planets and the sun.

Kepler's Laws of Planetary Motion

- **Kepler** derived these laws from the observations of **Tycho Brahe** on planetary motion.
- **Kepler's First Law (The Law of Ellipses):** Each planet's orbit about the Sun is an ellipse.
  - The Sun's center is always located at one focus of the orbital ellipse.
  - The Sun is at one focus.
  - The planet follows the ellipse in its orbit, meaning that the planet to Sun distance is constantly changing as the planet goes around its orbit.
- **Kepler's Second Law (The Law of Equal Areas):** The imaginary line joining a planet and the Sun sweeps equal areas of space during equal time intervals as the planet orbits.
- Basically, that planets do not move with constant speed along their orbits.
- Rather, their speed varies so that the line joining the centers of the Sun and the planet sweeps out equal parts of an area in equal times.
  - The point of nearest approach of the planet to the Sun is termed perihelion.
  - The point of greatest separation is aphelion, hence by Kepler's Second Law, a planet is moving fastest when it is at perihelion and slowest at aphelion.
- **Kepler's Third Law (The Law of Harmonies):** The squares of the orbital periods of the planets are directly proportional to the cubes of the semi-major axes of their orbits.
  - Kepler's Third Law implies that the period for a planet to orbit the Sun increases rapidly with the radius of its orbit.
  - Thus, we find that Mercury, the innermost planet, takes only 88 days to orbit the Sun. The earth takes 365 days, while Saturn requires 10,759 days to do the same.

5 CHAPTER

Mechanical Properties of Solids and Fluids

Solids and liquids have much lower compressibility as compared to gases. Shear stress can change the shape of a solid keeping its volume fixed. The key property of fluids is that they offer very little resistance to shear stress; their shape changes by application of very small shear stress. The shearing stress of fluids is about million times smaller than that of solids.

Mechanics of Solids

A rigid body generally means a hard solid object having a definite shape and size. But in reality, bodies can be stretched, compressed and bent. Even the appreciably rigid steel bar can be deformed when a sufficiently large external force is applied on it. This means that solid bodies are not perfectly rigid.

- Solid is one of the four fundamental states of matter including liquid, gas and plasma.
- Solid is generally rigid in normal conditions and resists its change. However, it has elastic property in case of a force occurred on it.
- Due to stronger intermolecular force of attraction, solid has definite shape and size.
- All solids have rigid structures that tend to resist any external forces applied to them.
- Solids also are known to have a fixed, definite shape (unlike liquids and gases, which assume the shape of the container they are placed in).
- Furthermore, solids are also known to have a fixed, definite volume (unlike gaseous substances which expand to occupy the entire volume of the container they are placed in).
- Forces acting between the atoms due to electrostatic interaction between the charges of the atoms are called **interatomic forces**.
- A force which produces a change in configuration of the object on applying it is called a deforming force.
- In solid, the atoms and molecules are free to vibrate about their mean positions.
- If this vibration increases substantially, molecules shake apart and start vibrating in random directions.
- At this stage, the shape of the material is no longer fixed and converts into liquid state.
- The intermolecular force in liquid is respectively weaker; hence, it has no definite shape but has fix volume.
- In gases, the intermolecular force is minimum, so they don't have definite shape, size and volume. Solids do not have the ability to flow as liquids and gases do.
- Another dissimilarity between solids and gases is that gases can be compressed when some external pressure is applied to them, but solids are virtually incompressible.
- In the plasma state, matter exists in **ionised state**. Plasma state is common in stars.
- The atoms of a solid can be bound together in either a regular or an irregular manner. The manner in which the atoms of the solid are arranged in three-dimensional space determines the type of the solid.

Categories of Solids

(i) **Crystalline Solid-** Having regular pattern of constituent particles in three dimensional spaces, they have a definite external geometrical shape and a sharp melting point.

They are anisotropic i.e. their physical properties have different value in different directions. Examples- rice, sugar and diamond.

(ii) **Amorphous or Glassy Solids-** They have irregular arrangements of particles; hence, they don't have a definite external geometrical shape and sharp melting point.

They are isotropic i.e. their physical properties have same value in all directions. Examples- Glass, Cement, Rubber and Plastic, etc.

Major Classes of Solids Include

- **Minerals:** Minerals are natural solids formed by geological processes.
- A mineral has a uniform structure. Examples include diamond, salts, and mica.
- **Metals:** Solid metals include elements (e.g., silver) and alloys (e.g., steel). Metals are typically hard, ductile, malleable, and excellent conductors of heat and electricity.

6 CHAPTER

Thermodynamics

Thermodynamics is a branch of physics which deals with the energy and work of a system. It deals only with the large scale response of a system which we can observe and measure in experiments. Small scale gas interactions are described by the kinetic theory of gases. The methods complement each other; some principles are more easily understood in terms of thermodynamics and some principles are more easily explained by kinetic theory.

Let's split the term "Thermodynamics" into its two components, "Thermo" and "Dynamics." The term "Thermo" refers to heat, whereas the term "Dynamics" refers to a mechanical motion that requires "work." The field of physics that studies the relationship between heat and other types of energy is called thermodynamics.

Thermodynamics

Thermodynamics is the branch of physics concerned with heat and temperature and their relation to energy and work.

- Heat is a form of energy called thermal energy. Heat is referred to energy that is transferred from one body to another as a result of difference in temperature.
- The transfer of energy always takes place from the region of the higher temperature to the region of the lower temperature. Heat is the energy in flow due to the difference in temperature.

Branches of Thermodynamics

- The study of Thermodynamics is classified into several branches listed below:
- **Classical Thermodynamics:** The behavior of matter is examined using a macroscopic perspective in classical thermodynamics.
  - In order to determine the characteristics and predict the characteristics of the matter conducting the process, individuals take into account units like temperature and pressure.
- **Statistical Thermodynamics:** The development of atomic and molecular theories in the late 19^{th} and early 20^{th} centuries gave rise to statistical mechanics, also known as statistical thermodynamics, which added an interpretation of the microscopic interactions between individual particles or quantum-mechanical states to classical thermodynamics.
  - This field explains classical thermodynamics as a natural consequence of statistics, classical mechanics, and quantum theory at the microscopic level.
- **Chemical Thermodynamics:** Chemical thermodynamics is the study of how energy interacts with chemical processes or state changes in accordance with the laws of thermodynamics.
  - Determining the spontaneity of a certain transition is the main goal of chemical thermodynamics.
- **Equilibrium Thermodynamics:** Equilibrium thermodynamics is the study of matter and energy transfers in systems or substances that can be moved from one state of thermodynamic equilibrium to another by agents in their environment.
  - The phrase "thermodynamic equilibrium" refers to a condition of equilibrium in which all macroscopic flows are zero.
- **Non-equilibrium Thermodynamics:** Systems that are not in thermodynamic equilibrium are the focus of the field of thermodynamics known as non-equilibrium thermodynamics.
  - The majority of systems in nature are not in thermodynamic equilibrium because they are not in stationary states and are subject to fluxes of matter and energy to and from other systems on a continual and irregular basis.

Thermodynamic Systems

- A collection of an extremely large number of atoms or molecules confined within certain boundaries such that it has certain values of pressure (P), volume (V) and temperature (T) is called a thermodynamic system.
- Anything outside the thermodynamic system to which energy or matter is exchanged is called its surroundings. Taking into consideration the interaction between a system and its surroundings, a system may be divided into three classes-

1. **Open System:** A system is said to be an open system if it can exchange energy and matter with its surroundings. See figure 1(A).
2. **Closed System:** A system is said to be a closed system if it can exchange only energy (not matter) with its surroundings. See figure 1(B).

7 CHAPTER

Oscillation

In your childhood you must have enjoyed rocking in a cradle or swinging on a swing. Both these motions are repetitive in nature. Here, the object moves to and fro about a mean position. Such a motion is termed as oscillatory motion. In this chapter we will study about oscillation.

Oscillation is a motion that repeats itself in a regular cycle or interval such as a wave or swinging pendulum. In other words, oscillation is the process of returning a system to its equilibrium position, the stable position of the system where the net force acting on it is zero.

- Periodic motion can be defined as repetition in motion of an object at a regular interval of time i.e. motion of planets around the Sun, motion of hands of a clock, etc.
- Dropping a stone into a still lake causes ripples to spread out to the edges; plucking a sitar string making vibrations in the wire of sitar, etc.
- The oscillation of a physical system is caused by elasticity and inertia. The total energy of an oscillating particle is equal to the sum of its kinetic energy and potential energy if conservative force acts on it.

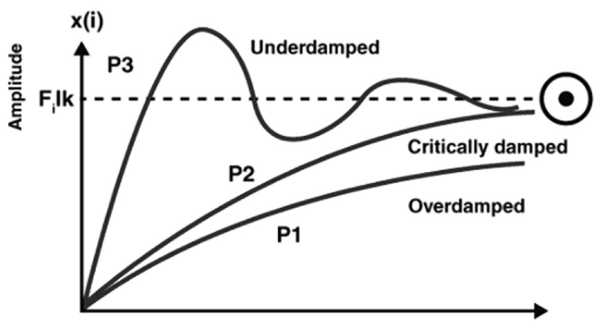
Variables of Oscillation

- **Amplitude** is the maximum displacement from the equilibrium point.
  - If a pendulum swings one centimeter from the equilibrium point before beginning its return journey, the amplitude of oscillation is one centimeter.
- **Period** is the time it takes for a complete round trip by the object, returning to its initial position.
  - If a pendulum starts on the right and takes one second to travel all the way to the left and another second to return to the right, its period is two seconds. Period is usually measured in seconds.
- **Frequency** is the number of cycles per unit of time.
  - Frequency equals one divided by the period. Frequency is measured in Hertz, or cycles per second.

Types of Oscillation

Oscillation can be classified into the following types which are as follows-

- **Free Oscillation:** When the body, in an oscillating movement, vibrates with a frequency of its own, the oscillation is known as free oscillation.
  - It has a constant amplitude and period to set the oscillation without any external force. Examples of free oscillation include the vibrations caused by a tuning fork.
- **Damped Oscillation:** The type of oscillation that is decreased with time is known as damped oscillation.
  - The damping is caused due to external factors which include friction or air resistance which further reduces the amplitude of the oscillation with time and these results in the loss of energy in the system.
  - Examples of damped oscillation include decaying oscillations of a pendulum.
- **Forced Oscillation:** When an external period force influences something to oscillate it is known as forced oscillation.
  - In this case, the amplitude experiences damping but due to external energy supplied to it, it remains constant. Examples of forced oscillation include feet moved by a child in order to move the swing.
- **Resonance:** When the frequency of external force (driver) is equal to the natural frequency of the oscillator (driven), then this state of driven is known as the state of resonance. In the state of resonance there occurs maximum transfer of energy from driven to the driver. Hence the amplitude of motion becomes maximum.



- **Coupled Oscillation:** A system of two or more oscillations linked together in such a way that there is a mutual exchange of energy between them is called a coupled system. The oscillations of such a system are called coupled oscillations.

UNIT - II

CHEMISTRY

- Nature and Scope of Chemistry
- Atoms
- Matter
- Periodic Properties of Elements
- Chemical Bonding
- Radioactivity
- Chemical Reaction
- Catalysis
- Metals, Metallurgy and Non-Metal
- Electrochemistry
- Soil Chemistry
- Food Chemistry
- Environmental Chemistry
- Scientific Laws, Instruments & Inventions
- Glossary

1 CHAPTER

Nature and Scope of Chemistry

Chemistry has influenced our life so much that we do not even realise that we come across chemicals at every moment; that we ourselves are beautiful chemical creations and all our activities are controlled by chemicals. In this chapter, we shall study the nature and scope of Chemistry as a subject.

Chemistry is the study of matter : what it consists of, what its properties are, and how it changes. Being able to describe the ingredients in a cake and how they change when the cake is baked is called chemistry.

- Matter is anything that has **mass** and takes up **space-** that is, anything that is **physically real.**

Scope of Chemistry

Chemistry is one branch of science. Science is the process by which we learn about the natural universe by observing, testing, and then generating models that explain our observations. Because the physical universe is so vast, there are many different branches of science.

- Thus, chemistry is the **study of matter**, biology is the study of **living things**, and geology is the study of **rocks and the earth.**
- Mathematics is the language of science, and we will use it to communicate some of the ideas of chemistry.
- According to **Roald Hoffmann**, "***Chemistry is the science of molecules and their transformations***." Sometimes, Chemistry is known as the central science because it links other natural sciences like physics, geology and biology.

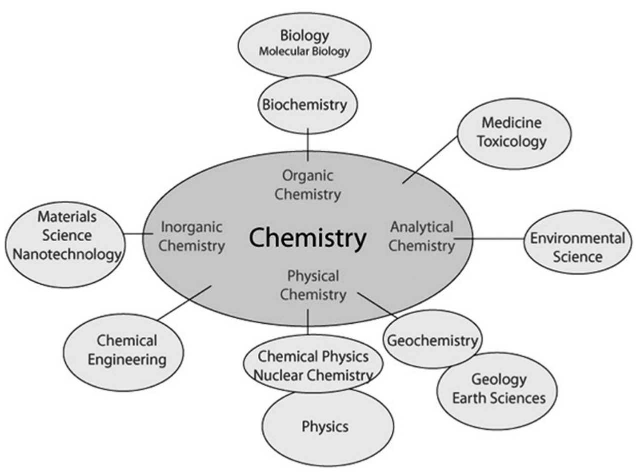


Figure: The Relationships between Some of the Major Branches of Science. Chemistry lies more or less in the middle, which emphasizes its importance to many branches of science.

Main Branches of Chemistry

Traditionally, chemistry is broken into five main branches. There are also more specialized fields, such as **food chemistry, environmental chemistry** and **nuclear chemistry,** but this section focuses on chemistry's five major sub-disciplines.

1. **Analytical Chemistry:** It involves the analysis of chemicals, and includes qualitative methods like looking at color changes, as well as quantitative methods like examining the exact wavelength (s) of light that a chemical absorbed to result in that color change.
   - These methods enable scientists to characterize many different properties of chemicals, and can benefit society in a number of ways.
   - For example, analytical chemistry helps food companies **make tastier frozen dinners by detecting how chemicals in food change** when they are frozen over time.
   - Analytical chemistry is also used to **monitor the health of the environment** by measuring chemicals in water or soil, for example.
2. **Bio-chemistry**: It uses chemistry techniques to understand how biological systems work at a chemical level.
   - Thanks to biochemistry, researchers have been able to **map out the human genome**, understand what different proteins do in the body and develop cures for many diseases.
3. **Inorganic Chemistry:** Inorganic chemistry studies the chemical compounds in inorganic, or non-living things such as minerals and metals.
   - Traditionally, inorganic chemistry considers compounds that do *not* contain carbon (which are covered by organic chemistry), but this definition is not completely accurate.
   - Some compounds studied in inorganic chemistry, like **"organometallic compounds,"** contain metals, which are metals that are attached to carbon.
   - The main element that's studied in organic chemistry. As such, compounds such as these are considered part of both fields.

2 CHAPTER

Atoms

By the nineteenth century, enough evidence had accumulated in favour of atomic hypothesis of matter. In this chapter we are going to study Atomic Molecular Theories and some major discoveries in Chemistry in a brief manner.

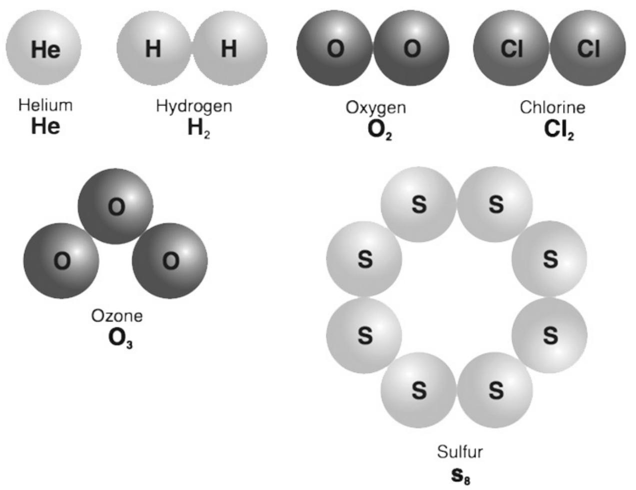
All the matter is made up of atoms. The atom is the one of the smallest part of the element that retains the chemical characteristics of the element itself. Atoms don't exist independently, instead, they form ions and molecules which further combine in large numbers to form matter that we see, feel and touch.

- Atoms are much too small to be seen; hence experiments to find out their structure and behavior have to be conducted with large numbers of them.
- From the results of these experiments we may attempt to construct a hypothetical model of an atom that behaves like the true atom.

Size of an Atom

- An atom is exceedingly small, much smaller than our imagination allows us to imagine.
- When more than millions of atoms are packed together, a layer of an atom the thickness of a thin sheet of paper is created.
- Because it's difficult to detect the positions of electrons surrounding the nucleus, measuring the size of an isolated atom is impossible.
- However, assuming that the distance between neighbouring atoms is equal to half the radius of an atom, the size of an atom can be approximated. The radius of an atom is usually measured in nanometers (10^{-9} m).

- An atom is composed of sub-atomic particles and these cannot be made or destroyed.
- All atoms of the same element are identical and different elements have different types of atoms. Chemical reactions occur when atoms are rearranged.
- Some elements are **monatomic**, meaning they are made of a single (*mon-*) atom (*-atomic*) in their molecular form. Helium (He) is an example of a monatomic element.
- Other elements contain two or more atoms in their molecular form. Hydrogen (H_2), oxygen (O_2), and chlorine (Cl_2) molecules, for example, each contains two atoms.
- Another form of oxygen, ozone (O_3), has three atoms, and sulfur (S_8) has eight atoms. All elemental molecules are made of atoms of a single element.



Structure of an Atom

Atoms are composed of protons, neutrons and electrons. Neutrons and protons have approximately the same mass and in contrast to this the mass of an electron is negligible.

- A proton carries a positive charge, a neutron has no charge and an electron is negatively charged.
  - **Proton** (p^+), which is positively (+ve) charged;
  - **Electron** (e^-), which is negatively (–ve) charged; and
  - **Neutron** (n^0), which has no charge, it is neutral (0).
- An atom contains equal numbers of protons and electrons and therefore overall an atom has no charge.
- The nucleus of an atom contains protons and neutrons only, and therefore is positively charged. The electrons occupy the region of space around the nucleus.
- Therefore, most of the mass is concentrated within the nucleus.
- Electrons (having negative charge) at the orbit in an atom are bound to the atom by the electromagnetic force, while the protons (having positive charge) and neutrons (with no charge) in the nucleus are bound to each other by the nuclear force.

3 CHAPTER

Matter

In this chapter, we will learn more about solid, liquid and gaseous physical states of matter, particularly liquid and gaseous states. To begin with, it is necessary to understand the nature of intermolecular forces, molecular interactions and effect of thermal energy on the motion of particles because a balance between these determines the state of a substance.

Everything around us is composed of matter. The matter is defined as anything that has mass and occupies space (i.e., has a volume). The matter possesses mass, offers resistance and can be felt through one or more of our senses.

- Till very recently, it was assumed that matter can neither be created nor destroyed. Scientists have established that there are two fundamental entities in the universe: Matter and Energy.
- They have also come to the conclusion that the total quantity of matter and of energy in the universe is constant.
- After the discovery of radioactivity, and work done by scientists like Einstein, it was realized that matter and energy are inter-convertible.
- It is this convertibility of matter into energy that is responsible for construction of atom bombs and nuclear reactors.

Characteristics of Particles of Matter

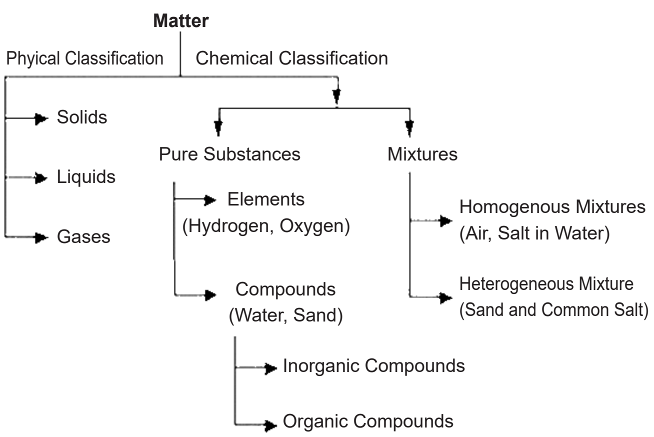
The important characteristics of particles of matter are the following:

- **The particles of matter are very, very small:** The very, very small size of particles of matter can be shown by performing the following experiment by using potassium permanganate and water.
  - Take 2-3 crystals of potassium permanganate and dissolve them in 100 ml of water in a beaker.
  - We will get a deep purple colored solution of potassium permanganate in water.
  - So we conclude that there must be millions of tiny particles in just one crystal of potassium permanganate, which keep on dividing themselves into smaller and smaller particles.
- **Particles in matter are in a state of continuous motion**: The particles present in matter are not stationary, but have a tendency to acquire motion.
- In fact they are in a state of continuous motion. The rate of movement of the particles is directly proportional to the thermal energy of the particles.
- **Particles in matter attract one another**: The particles in matter attract one another. This attraction is inversely proportional to the distance between the particles. However, the magnitude of these inter-particle forces differs from one substance to another.
- **Particles in matter have spaces between them**: Empty spaces called voids, separate the particles from one another. The distance between them ranges from 10^{-8} cm to 10^{-5} cm. Due to these voids matter is able to disperse into one another bringing about diffusion.

States of Matter

Matter exists in three physical states such as **solid, liquid** and **gas.** Every material substance is characterized by properties such as shape, texture, colour, mass, melting point, boiling point and so on.

- Matter can be classified as **solid**, **liquid** and **gas** on the basis of inter-particle forces and the arrangement of particles.
- These three forms of matter are interconvertible by increasing or decreasing pressure and temperature. For example, ice can be converted from solid to a liquid by increasing the temperature.



Solid

- Something is usually described as a solid if it can hold its own shape and is hard to compress (squash). The **molecules** in a solid are **closely packed together** – they have a high density.

4

CHAPTER

Periodic Properties of Elements

In this chapter, we will study the historical development of the Periodic Table as it stands today and the Modern Periodic Law. We will also learn how the periodic classification follows as a logical consequence of the electronic configuration of atoms. Finally, we shall examine some of the periodic trends in the physical and chemical properties of the elements.

Periodic Table is a graphical representation of certain data in a systematic way i.e. elements are vertically and horizontally arranged that show some gradation and periodic connection between them.

- After the discovery of some elements, periodic table was developed, amid the need arise, to organise them.
- At present **118 elements** are known as against only 31 till 1800.

Mendeleev's Periodic Table

Mendeleev in **1869** stated that ***"properties of elements are a periodic function of their atomic weights"*** i.e. if elements are arranged in the order of their atomic weights, similar elements are repeated at regular periods or intervals.

- Mendeleev arranged the elements in the order of their ascending atomic weights (mass) in the form of a table called **Mendeleev's periodic table** i.e. the first real periodic table. The table includes:
  - The nine vertical columns are called **Groups** numbered **from I to VII and 0**.
  - Group I to VII are subdivided into subgroups **A & B,** ***group*** *VIII* is the group of **transition elements** and *group* '0' is the group of noble gases.
  - The seven horizontal rows are called ***Periods*** numbered from 1 to 7.

Merits of Mendeleev's Periodic Table

A. Study of Elements - First time all known elements were classified in groups according to their **similar properties**. So study of the properties becomes easier of elements.

B. Prediction of New Elements - It gave encouragement to the discovery of new elements as some gaps were left in it. **Sc (Scandium), Ga (Gallium), Ge (Germanium), Tc (Technetium)** were the elements for whom position and properties were defined by Mendeleev even before their discoveries and he left the blank spaces for them. e.g.

For Example

- Blank space at atomic weight 72 in silicon group was called **Eka Silicon** (means properties like silicon) and element discovered later was named Germanium. Similarly, other elements discovered after Mendeleev periodic table were.
  - **Eka Aluminium-** Gallium (Ga); Eka Boron - Scandium (Sc)
  - **Eka Silicon –** Germanium (Ge); Eka Manganese - Technetium (Tc)

C. Correction of doubtful atomic weights - Correction was done in atomic weight of some elements.

Atomic Weight = Valency × Equivalent weight

- Initially, it was found that equivalent weight of Be is 4.5 and it is trivalent (V=3), so the weight of Be was 13.5 and there is no space in Mendeleev's table for this element.
- So, after correction, it was found that Be is actually divalent (V= 2).
- So, the weight of Be became 2 × 4.5 = 9 and there was a space between 'Li' and 'B' for this element in Mendeleev's table.
  - Corrections were done in atomic weight of elements are – U, Be, In, Au, Pt.

Demerits of Mendeleev's Periodic Table

A. Position of Hydrogen - Hydrogen resembles both, the alkali metals (IA) and the halogens (VIIA) in properties so Mendeleev could not decide where to place it.

B. Position of Isotopes - As atomic weight of isotopes differs, they should have placed in different position in Mendeleev's periodic table. But there were no such places for isotopes in Mendeleev's table.

C. Anomalous Pairs of Elements - There were some pair of elements which did not follow the increasing order of atomic wts.eg. Ar and Co were placed before K and Ni respectively in the periodic table, but having higher atomic weights.

D. Like elements were placed in different groups. There were some elements like Platinum (Pt) and Gold (Au) which have similar properties but were placed in different groups in Mendeleev's table.

5 CHAPTER

Chemical Bonding

Why do atoms combine? Why are only certain combinations possible? Why do some atoms combine while certain others do not? Why do molecules possess definite shapes? In this chapter we will find answer to such questions.

Chemical bonding is an important part of Inorganic Chemistry though some part of chemical bonding is also studied under physical chemistry. Under normal conditions, only Noble gases remains independent while most of the elements are found in compound or in mixture form.

- **Chemical bonds** are defined as the forces that hold the atoms of different elements together.
  - In other words, **the strong force of binding or combining between two or many atoms is referred to as a Chemical Bond** that forms a stable compound with properties of its own.
  - Chemical bonding, any of the interactions that account for the association of atoms into molecules, ions, crystals, and other stable species that make up the familiar substances of the everyday world.
- **Molecules form bonds** through **sharing electrons.** Atoms or molecules can share one, two, or three pairs of electrons, forming single, double, and triple bonds, respectively.

Octet Rule

Kössel and Lewis Theory

- **Kössel and Lewis** in **1916** developed an important theory of chemical combination between atoms known as electronic theory of chemical bonding.
- The outermost or valence electrons (extra electrons) of an atom are involved in chemical bonds. **Molecules of elements have tendency to attain octet configuration by formation of compounds, and that tendency is called the octet rule.**
- According to this, atoms can combine either by transfer of valence electrons from one atom to another (gaining or losing) or by sharing of valence electrons in order to have an octet in their valence shells.

Valency

- Valency is the number of atoms of a particular element that is combined with one atom of another element to form a molecule.
- Valency is also known as molecular weight. Valency is a measure of the **combining power of an atom**. The valency of an element is determined by the number of electrons in its outermost shell. The valency of an element can be increased either by gaining or losing electrons.
- Introduced in 1868, the term is used for the expression of both the possibility of combination of an element in general and the numerical value of the power of combination.
- Thus valence meaning is the number of electrons as most of the bonds are formed by the exchange of the valence electrons.
- When an atom donates one, two or three electrons from its valence or outermost shell to another able atom, it is known as **electrovalency**.

Importance of Valency

- The higher the valency, the stronger the bond. This is why elements with a high valency are often used in chemical reactions - they form strong bonds with other atoms.
- By understanding valency, we can better predict how chemicals will react with each other.

Applications of Valency

1. **Medicine:** Valency is used to determine the efficacy of a drug. Valency predicts **how much drug will be needed in order to treat a patient.**
   - Valency also determines how easily a drug can penetrate biological membranes such as the placenta (for pregnant women), blood-brain barrier.
2. **In Industrial Chemistry:** It is used to predict the properties of compounds and their suitability for particular applications.
3. **Genetics:** It results **from the binding of two alleles at a single loci,** where each allele may have a different valence depending on its own gene product and that of another allele present at the same locus.
4. **Properties of the Compound-** Valency helps in predicting the physical and chemical properties of the compound.

6

CHAPTER

Radioactivity

We shall discuss various properties of nuclei such as their size, mass and stability, and also associated nuclear phenomena such as radioactivity, fission and fusion in this chapter.

As its name implies, *radioactivity* is the act of **emitting radiation spontaneously.** This is done by an atomic nucleus that, for some reason, is unstable; it give up some energy in order to shift to a more stable configuration.

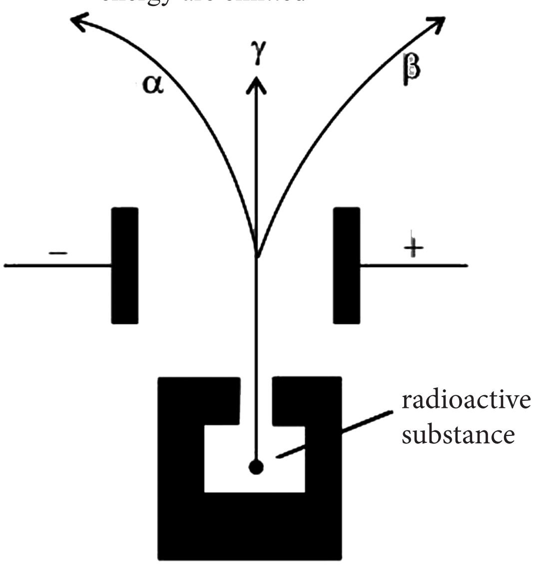
- Atoms become unstable due to **large neutron to proton ratio** and such unstable nucleus emits some radiations and then converts itself into some other stable nucleus, and the phenomenon is called Radioactivity.
- Like uranium, all other elements/compounds that emit highly penetrating radiations are called radioactive elements.
- The chance of encountering instability increases as the size of the nucleus increases because the mass of the nucleus becomes a lot when concentrated. That's the reason why atoms of **Plutonium, Uranium are extremely unstable and undergo the phenomenon of radioactivity.**
- Following Henri Becquerel's work, **in 1898 Pierre and Marie Curie** isolated polonium and radium, unknown radioactive elements present in uranium ore.

Discovery of Radioactivity

Henry Becquerel discovered radioactivity by accident in 1896. A **Uranium** compound was placed in a drawer containing photographic plates, wrapped in a black paper.

- He thought that the uranium salts, after being excited by light, emitted these X-rays. Imagine his surprise when, in Paris in **March 1896**, he discovered that **photographic film** had been exposed without exposure to sunlight.
- He concluded that uranium emitted invisible radiation, different from X-rays, spontaneously and inexhaustibly. The phenomenon he discovered was named **radioactivity** (from the **Latin radius**, meaning **ray**).
- When the plates were examined later, it was found that they were exposed. This exposure gave rise to the concept of **Radioactive decay**.
- In **1899, Ernest Rutherford**, a British physicist, analysed the Becquerel rays emitted by radioactive elements. He established the existence of two distinct components: α-particles and β-rays.

- The existence of third radiation – **gamma rays** – was established by **P. Villard.**
- Radioactivity can be seen in such forms –
  - **Alpha Decay** : Emission consists of Helium nucleus
  - **Beta Decay** : Emission consists of Electrons
  - **Gamma Decay** : Photons having high energy are emitted



Emission of α, β and γ Raditions

- Too many neutrons in a nucleus lead it to emit a **negative *beta*** particle, which changes one of the neutrons into a proton.
- Too many protons in a nucleus lead it to emit a **positron** (positively charged electron), changing a proton into a neutron.
- Too much energy leads a nucleus to **emit a *gamma*** ray, which discards great energy without changing any of the particles in the nucleus.
- Too much mass leads a nucleus to emit an *alpha* particle, discarding four heavy particles (two protons and two neutrons).

α-particles

Alpha particles are **helium nuclei ($^4He_2$)** and consist of two protons and two neutrons. Detailed studies of these particles revealed the following properties:

7 CHAPTER

Chemical Reactions

Chemical reactions are all around us. From the metabolism of food in our body to how we get the light from the sun is the result of chemical reactions. Before beginning with chemical reactions, it is important to know about physical and chemical changes. In this chapter we are going to discuss these concepts.

Chemical Reaction is a process that leads to the transformation of one set of chemical substances to another. The new substances produced in a chemical reaction have chemical properties different from those of the reactants. Generally, four basic types of chemical reactions occur:

Type of Chemical Reaction

i. **Displacement or Replacement Reaction:** This reaction takes place when a single uncombined element replaces another in a compound.
   - **E.g.** when magnesium replaces hydrogen in water to make magnesium hydroxide and hydrogen gas, $Mg+2H_2O \longrightarrow Mg(OH)_2+H_2$

ii. **Double Displacement Reactions:** This type of reactions occurs when the anions and cations of two compounds switch places and form two entirely different compounds.
   - **E.g.** When lead nitrate with potassium iodide to form lead iodide and potassium nitrate: $Pb(NO_3)_2+2Kl \longrightarrow PbI_2+2KNO_3$

iii. **Synthesis Reaction:** In this reaction, two or more simple substances combine to form a more complex substance or compound. **E.g.** $\mathbf{6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2}$

iv. **Decomposition Reaction:** Unlike synthesis reaction, this reaction takes place when a more complex substance breaks down into its more simple parts.

   E.g. $2H_2O$ ==> $2H_2+O_2$

Chemical Kinetics

Chemical Change: This is the phenomena in which new substances are formed, though cannot be reversed into the previous compound or substances.

- These chemical changes take place at a particular rate and this rate tells us how fast a reaction occurs.

Average reaction rate = Total change in concentration/ Time taken for the change

- The branch of chemistry which deals with the rate of chemical reactions or chemical change is called as **Chemical Kinetics**.

Major factors that affect the rate of a chemical reaction:

a. **Temperature:** Most of the chemical reactions take place at higher temperature.
   - Temperature increases the kinetic energy of the molecules increases, which increases the number of collisions between the molecules.

b. **Light:** Some reactions only take place in the presence of light.
   - **E.g.** photosynthesis in green plants or reaction between H2 and Cl2 to form HCl.

c. **Electricity:** Some reactions occur with the help of electric current. **E.g.**
   - $2H_2O \xrightarrow{Electricity} 2H_2 + O_2$
   - $PbBr_2 \xrightarrow{Electricity} Pb + Br_2$

d. **Pressure:** Some reactions require very high pressure to take place.
   - **E.g.**, in the manufacture of ammonia (NH_3) from nitrogen and hydrogen (Haber's process), a pressure of over 200 atmosphere is required in the presence of the catalyst iron and a temperature of 450°C to 500°C.

e. **Surface Area:** In case of reactions involving solid reactants and heterogeneous reactions, surface area of the reactant play an important role.
   - More number of molecules at the surface will be exposed to the reaction conditions, the rate of the reaction increases accordingly.

f. **Catalysts:** It is a substance that increases the rate of chemical reaction without undergoing any change itself.
   - The addition of catalyst generally increases the rate of the reaction at a given temperature.

Evidence of a Chemical Reaction/Change: Following events indicate that a chemical reactions has taken place-

a. Change of Colour. e.g. Black copper oxide on reaction with hydrogen converts to red coloured copper.

   $CuO + H_2 \rightarrow Cu + H_2O$

b. Formation of Gas

c. Change in Temperature or Energy

d. Formation of Precipitate

8 CHAPTER

Catalysis

The science of catalysis is of great significance in our daily life. Catalyst is a substance which enhances the rate of reaction. In this chapter we will study importance of catalysis, acids and bases.

There exists a wide variation in the rates of chemical reactions. Some are fast and some are slow. **Catalysis** is defined as increasing the rate of a chemical reaction by introducing a **catalyst**.

Catalyst

A catalyst, in turn, is a substance that is not consumed by the chemical reaction, but acts to lower its activation energy. In other words, a catalyst is both a reactant and product of a chemical reaction. Typically, only a very small quantity of catalyst is required in order to catalyze a reaction.

- The **SI unit** for catalysis is the **katal**.
- This is a derived unit which is **moles per second**.
- When enzymes catalyze a reaction, the preferred unit is the enzyme unit.
- The effectiveness of a catalyst may be expressed using the **Turnover Number (TON)** or **Turnover Frequency (TOF)**, which is TON per unit time.
- Catalysis is a vital process in the chemical industry. It is estimated that 90% of commercially-produced chemicals are synthesized via catalytic process.
- Sometimes the term "catalysis" is used to refer to a reaction in which a substance is consumed (e.g., base-catalyzed ester hydrolysis).
- According to the IUPAC, this is an incorrect usage of the term. In this situation, the substance added to the reaction should be called an activator rather than a catalyst.
  - **E.g. Hydrogen peroxide** normally decomposes slowly into oxygen and water, but in the presence of **platinum (pt)**, the decomposition becomes violent or explosive.
  - Likewise the rate of decomposition of potassium chloride speeds up in the presence of **manganese dioxide**.

$$2H_2O_2 \xrightarrow{Pt} 2H_2O + O_2$$

$$2KClO_3 \xrightarrow{MnO_2} 2KCl + 3O_2$$

  - Here, **platinum and manganese dioxide are called Catalysts.**

- Thus, **Catalyst** is a substance which increases or decreases the rate of a chemical reaction, without being consumed in the process.
- Furthermore, some substances considerably **enhance the activity of a catalyst**, and are known as ***promoters***. Substances which inhibit catalytic activity are called ***poisons***.

Types of Catalysts

- The two main categories of catalysts are **heterogeneous** catalysts and **homogeneous** catalysts. Enzymes or biocatalysts may be viewed as a separate group or as belonging to one of the two main groups.

(i) Heterogeneous Catalysis: Heterogeneous catalysts are those which exist in a different phase from the reaction being catalyzed. For example, solid catalysts catalyze a reaction in a mixture of liquids or gases are heterogeneous catalysts.

- Surface area is critical to the functioning of this type of catalyst. E.g. formation of ammonia from nitrogen and hydrogen under the catalytic influence of Iron Oxide.

$$N_2(g) + 3H_2(g) \xrightarrow{Fe_2O_3(S)} 2NH_3(g)$$

(ii) Homogeneous Catalysis: In homogeneous catalysis, the catalyst is in the same phase as the reactant (s).

- The number of collisions between reactants and catalyst is at a maximum because the catalyst is uniformly dispersed throughout the reaction mixture.
- Many homogeneous catalysts in industry are transition metal compounds. As an added barrier to their widespread commercial use, many homogeneous catalysts can be used only at relatively low temperatures, and even then they tend to decompose slowly in solution.
- Despite these problems, a number of commercially viable processes have been developed in recent years. **High-density polyethylene** and **polypropylene** are produced by homogeneous catalysis.

UNIT - III

BIOLOGY

- Introduction to Biology
- Cell Biology
- Genetics
- Evolution
- Diversity in the Living World
- Plant Kingdom
- Morphology of Flowering Plants
- Anatomy of Flowering Plants
- Plant Physiology
- Reproduction in Plants
- Animal Kingdom
- Skeletal System
- Animal Tissue
- Digestive System
- Sensory Organs
- Nervous System
- Endocrine System
- Immune System
- Circulatory System
- Respiratory System
- Excretory System
- Reproductive System
- Health and Nutrition
- Disease and Diagnosis
- Biotechnology
- Microbiology

1

CHAPTER

Introduction to Biology

Biology is the study of life in its entirety. The word 'biology' is derived from the Greek word 'bios' meaning life and 'logos' meaning study. Biology can also be described as the study of living organisms, divided into many specialized fields that cover their morphology, physiology, anatomy, behaviour, origin, and distribution.

Biology is the science of life and living organisms. It is a stream of natural science that uses scientific principles to study the living world. Today, the knowledge of biology is used in the study of **agriculture, medicine, sericulture, pisciculture, selective breeding of animals, etc.**

- Biology, as a branch of human knowledge started with observations made by the ancient Greek Philosopher **Aristotle** (384-322 BC). Thus, he is known as the "**Father of Biology**".
- **Andreas Vesalius (1514-1564)**, often referred to as the founder of **modern human anatomy**, was the first to challenge the teachings of Aristotle.
- The term 'Biology' was, however, first used by the French naturalist **Jean Lamarck and Gottfried Reinhold Treviranus in 1800**.

Classification of Biology

Classification of biology refers to the process of grouping organisms according to certain similarities. **Carl Linnaeus** proposed the two kingdoms of classification; He called organisms in the animal kingdom as **Animalia** and in the plant kingdom as **Plantae.** Thus biology is broadly classified into:

(a) Botany (b) Zoology

- **Botany:** It is the branch of Biology, which deals with the study of plant life including their structure, properties and biochemical processes. It also includes plant classification, study of plant diseases, their genetics and breeding.
- Botany also helps us to understand basic ecology of plants that is relationship between plant and its environment.
- The principles and findings of botany have provided the base for such applied sciences **as agriculture, horticulture, and forestry.**
  - **Theophrastus** is known as the **Father of Botany**.
  - So far, scientists have discovered more than 3, 40,000 species of plants.
- **Zoology:** It is the branch of Biology, which deals with the study of animal kingdom including the structure, **Embryology, Evolution, Classification, Habitats,** and Distribution of all animals, both living and extinct.
- It is an interdisciplinary field, drawing on knowledge from Genetics, Biochemistry, Ecology and Physiology. Zoologists observe animals in their natural habitat and also classify them. Classification is based on their similarities and differences.
  - **Aristotle is known as the Father of Zoology.**
  - Out of all the known species (approximately 1.5 million) till now more then 95% are boneless and remaining **5% are animals with bone**. Animals could be **unicellular** like amoeba, paramecium, etc. or **multi-cellular** like Birds, Fishes, Snake, Rabbit, Human beings, etc.
  - In addition, animals exist in a great variety of forms, shapes and sizes. **For example**: The Blue Whale is the largest living animal of the world as it's over 30.5 meters long and 150 tons heavy whereas the smallest animal is not more than 0.001 mm in length on the scale of microscope.

Nature and Scope of Biology

- Biology creates an awareness of vast array of forms of life which normally goes unseen. Biology offers a large scope and provides a large field for study. Some of the most familiar aspects where biology helps us in various ways are:-
- **Helps us to Understand Ourselves Better:** It unfolds different queries of life along with its cultural, social, philosophical and economical aspect.
- **Biology and Inter-relationship of Living Beings:** Study of biology helps us in understanding the wonderful phenomenon and laws of nature which finally tell us to predict the behaviour of different living beings under changed conditions.
- **Biology and Resources:** Biology helps us to know how to tap and conserve the resources available to us e.g. fishes, birds, forests etc.
- **Study of Nature is a Rewarding Experience:** Many plants like Narcissus, Dahlia, Gloriosa, Roses, Marigold, Aster, etc. are used for ornamental purposes.

2

CHAPTER

Cell Biology

Cells are considered as the basic building blocks of all the organisms. All our tissues and organs are made up of billions of different types of cells such as blood cells, muscle cells, skin cells or nerve cells etc. Studying the basic structure of the cell and its different components has played a magnificent role in understanding plant and human anatomy.

Cell is the basic structural and functional unit of living organisms. All living organisms on the Earth are composed of cells and they are often called the **"building blocks of life"**. Each cell has a specific function but works in tandem with other types of cells to perform the enormous number of tasks needed to sustain life. Most body cells have similar basic structure.

- **Size:** Cell size depends shape and size of living organism. Such as Mycoplasma is smallest cell (size 0.34um) while bacteria could be 3 to 5 um. The Largest cell is egg of on ostrich and narve cell are some of the longest cells.
- **Shape:** Shape of a cell varies according to the role or function, cells have to perform as part of tissue or organ system. They may be **spherical, oval, rectangular, polygonal, spindle-shaped, rod-shaped or star shaped.**
- **Anton Von Leeuwenhoek** first saw and described a live cell. **Robert Brown** later discovered the nucleus.

Cell Theory

In 1838 **M.J. Schleiden** and **Theodore Schwann** formulated the "cell theory." Later in 1855 , **Rudolf Virchow** explained that cells are divided and new cells are formed from pre-existing cells and thus with few modifications he gave cell theory final shape.

- Cell theory is a widely accepted hypothesis of **how life operates** on the Earth. Understanding how cells form, grow, and die enables us to comprehend how all living beings function.
- With this knowledge, we may better understand how life first emerges, why organisms adopt particular forms, how cancer spreads, how to treat various diseases, and more.
- Cell theory has **three basic principles** as:
    - All living organisms are composed of cells and product of cells.
    - A cell is the basic structural and functional unit of living organisms.
    - All cells arise from pre-existing cells.
- This theory is one of the foundation stones of modern biology. However, viruses, fungi, etc. are exceptions to the rule that the cell is the basic unit of life.

Characteristics of Cell

- Cells help in building the structure of an organism.
- Inside each cell is a dense membrane bound structure called **nucleus**. This nucleus contains the chromosomes which in turn contain the **genetic material, RNA and DNA**. Cells that have membrane bound nuclei are called **eukaryotic** whereas cells that lack a membrane bound nucleus are **prokaryotic**
- In both prokaryotic and eukaryotic cells, a semi-fluid matrix called **cytoplasm** occupies the volume of the cell. The cytoplasm is the main arena of cellular activities in both the plant and animal cells.
- Besides the nucleus, the eukaryotic cells have other membrane bound distinct structures called organelles like the **Endoplasmic reticulum (ER), Golgi complex, Lysosomes, Mitochondria, Microbodies and Vacuoles**. The prokaryotic cells lack such membrane bound organelles.
- **Ribosomes** are non-membrane bound organelles found in all cells – both eukaryotic as well as prokaryotic. Within the cell, ribosomes are found not only in the cytoplasm but also within the two organelles – **chloroplasts (in plants) and mitochondria and on rough ER.**
- Animal cells contain another non-membrane bound organelle called **centrosome** which helps in cell division.
- **Lysosomes** is a type of cell organelle which helps in cellular digestion.

Cell Structure

The cell structure includes individual parts with explicit capabilities fundamental for complete life's cycles. These parts incorporate the **Cell Membrane, Cell Wall, Protoplasm, Cytoplasm, Nucleus Core, and Cell Organelles.**

Cell Membrane

- The cell membrane, also called the plasma membrane, is found in all cells and separates the interior of the cell from the outside environment. The cell membrane consists of a **lipid bilayer** that is **semipermeable**. The cell membrane regulates the transport of materials entering and exiting the cell.

3 CHAPTER Genetics

Genetics can be stated as the exploration of the working and major codes of variation and heredity. The groundwork on which heredity stands is known as inheritance. It is defined as the procedure by which characteristics are handed down from one generation to the other. In this chapter, we will study the important concepts related to genetics.

Genetics is the scientific study of genes and heredity; of **how certain qualities or traits are passed** from parents to offspring as a result of changes in DNA sequence. Gene is the basic physical and functional unit of heredity. These are made up of DNA. Some genes act as instruction of proteins for mation some gene do not code for protein.

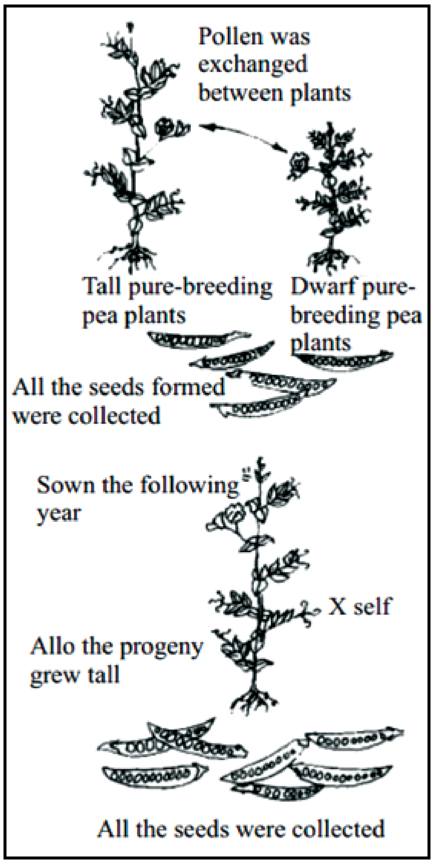
- In humans genes very in size from a few hundred DNA bases to more than 2 million basis. DNA is shaped like a corkscrew-twisted ladder, called a **double helix**.
- The two ladder rails are called backbones, and the rungs are pairs of four building blocks **(adenine, thymine, guanine, and cytosine)** called bases. The sequences of these bases provide the instructions for building molecules, most of which are proteins. Researchers estimate that humans have about **20,000 genes**.
- All of an organism's genetic material, including its genes and other elements that control the activity of those genes, is its genome.
- An organism's entire genome is found in nearly all of its cells. In human, plant, and animal cells, the genome is housed in a structure called the nucleus.
- The human genome is mostly the same in all people with just small variations.
- **Gregor Mendel** in 1866 in a journal "**Proceedings of Brunn Society for Natural History**" highlighted the theory of genetics. However, the term genetics was first coined by **Bateson in 1906.**
- **William Bateson**, who applied Mendel law on animals, is regarded as **Father of Animal Genetics**.
- **Gregor Johann Mendel is the Father of Genetics.**
- The process of transmission of characters from parents to offspring (progeny) is called **heredity**. The characters so transmitted are called **hereditary characters**.
- Due to these hereditary characters we resemble our parents and this consistency is maintained generation after generation.
- Besides the similarities, some differences are expressed by members of a species and also by the offspring of the some parents these differences are known as variation.

Thus, Genetics = Heredity + Variation.

Mendel's Experiments and Heredity

Gregor Johann Mendel was a German-speaking Moravian scientist and Augustinian friar who gained posthumous fame as the **Founder of the Modern Science of Genetics**.

- Though farmers had known for centuries that crossbreeding of animals and plants could favor certain desirable traits.
- Mendel's experiments established many of the rules of heredity, now referred to as the **laws of Mendelian inheritance.**



Prelude to Mendel's Experiments and Heredity: Genetics is the study of heredity.

- Johann Gregor Mendel set the framework for genetics long before chromosomes or genes had been identified, at a time when meiosis was not well understood.
- Mendel selected a simple biological system and conducted methodical, quantitative analyses using large sample sizes. Because of Mendel's work, the fundamental principles of heredity were revealed.

- We now know that genes, carried on chromosomes, are the basic functional units of heredity with the capability to be replicated, expressed, or mutated. Today, the postulates put forth by Mendel form the basis of classical, or Mendelian, genetics. Not all genes are transmitted from parents to offspring according to Mendelian genetics, but Mendel's experiments serve as an excellent starting point for thinking about inheritance.

Mendel's Experiment: In 1865, Mendel presented the results of his experiments with nearly 30,000 pea plants to the local **Natural History Society**.

- He demonstrated that traits are transmitted faithfully from parents to offspring independently of other traits and in dominant and recessive patterns.
- Mendel selected **garden pea (Pisum Sativum)** as his experimental material because
- Pea has many distinct contrasting characters.
- Life span of a pea plant is short.
- Flowers show self-pollination, reproductive whorls being enclosed by corolla.
- It is easy to artificially cross-pollinate the pea flowers. The hybrids thus produced were fertile.
- Mendel studies the inheritance of seven pairs of contrasting characters in Pisum Sativum:

Characters	Dominant	Recessive
1. Stem Height	Tall	Dwarf
2. Flower position	Axial	Terminal
3. Flower colour	Violet	White
4. Pod shape	Inflated	Constricted
5. Pod colour	Green	Yellow
6. Seed shape	Round	Wrinkled
7. Seed colour	Yellow	Green

Mendel conducted 2 main experiments to determine the laws of inheritance. These experiments were:

1. **Monohybrid Cross:** It refers to study of single characteristic or trait by mating two individuals that only differ in one trait of interest.
   - **For example**: Cross between plants one with green color flower and one with yellow color flower.
2. **Dihybrid Cross:** It refers to the study of two characteristics or traits by mating two individuals that differ in two traits of interest. **For example**: Cross between plants one with green color, round seed, and one with **yellow color, wrinkled seed**.

- The difference between monohybrid and dihybrid crosses is about the number of traits that are being studied.
- A monohybrid cross is when we're focusing on one particular trait, while a dihybrid cross involves looking at two different traits simultaneously.
- This variation can affect the chances of certain traits appearing in future generations, and can be used **to predict how genes are passed down** in various living things.
- It's important to grasp the difference between monohybrid and dihybrid crosses in order to understand the fundamentals of genetics and how traits are inherited.

Mendel's Laws of Inheritance

There are **three laws** which together form Mendel's Laws of Inheritance.

1. Law of Dominance
2. Law of Segregation
3. Law of Independent Assortment

Law of Dominance

- Mendel discovered that by crossing true-breeding white flower and true-breeding purple flower plants, the result was a hybrid offspring.
- Rather than being a mix of the two colors, the offspring was purple flowered.
- He then conceived the idea of heredity units, which he called "factors", one of which is a recessive characteristic and the other dominant.
- Thus the law of dominance states that when parents with pure, contrasting traits are crossed together, only one form of the trait appears in the next generation. The trait which appears in the next generation is known as a **dominant trait**. The trait that do not express is called a **recessive trait.**
- This is also known as **Mendel's first law of inheritance.**

Law of Segregation

- Individuals possess two alleles (alternative form of the gene) and a parent passes only one allele to his/her offspring. One allele is given by the female parent and the other is given by the male parent.
- The two factors may or may not contain the same information. If the two alleles are identical, the individual is called **homozygous** for the trait. If the two alleles are different, the individual is called **heterozygous.**
- This is also known as **Mendel's third law of inheritance.**
- The Law of segregation was formulated based on the monohybrid cross.

Law of Independent Assortment

- It states the inheritance of one pair of factors (genes) is independent of the inheritance of the other pair.
- This is also known as **Mendel's second law of Inheritance.**
- The law of independent assortment was formulated based on the dihybrid cross.

CHAPTER 4

Evolution

To understand the changes in flora and fauna that have occurred over millions of years on earth, we must have an understanding of the context of origin of life, i.e., evolution of earth, of stars and indeed of the universe itself. In this chapter, we will study the origin of life and evolution of life forms or biodiversity on planet earth in the context of evolution of earth and against the background of evolution of universe itself.

The origin of life is considered a unique event in the history of universe. The universe is vast. Relatively speaking the earth itself is almost only a speck. The universe is very old – almost **20 billion years old**. Huge clusters of galaxies comprise the universe. Galaxies contain stars and clouds of gas and dust. Considering the size of universe, earth is indeed a speck.

- **The Big Bang theory** attempts to explain to us the origin of universe. It talks of a singular huge explosion unimaginable in physical terms.
- The universe expanded and hence, the temperature came down. Hydrogen and Helium formed sometimes later. The gases condensed under gravitation and formed the galaxies of the present day universe.
- In the solar system of the **Milky Way Galaxy**, earth was supposed to have been formed about **4.5 billion years** back. There was **no atmosphere on early earth**. Water vapor, methane, carbon dioxide and ammonia released from molten mass covered the surface.
- The UV rays from the sun broke up water into Hydrogen and Oxygen and the lighter H2 escaped. Oxygen combined with ammonia and methane to form water, CO2 and others.
- The ozone layer was formed. As it cooled, the water vapor fell as rain, to fill all the depressions and form oceans. Life appeared 500 million years after the formation of earth, i.e., almost four billion years back

Theories of Origin of Life

The Earth formed roughly **4.5 billion years ago** and life probably began between **3.5 to 3.9 billion years** ago. There have been different theories of origin of life given at different points of time:

- **Theory of Special Creation:** Based upon religious mythologies of evolution given by **Father Saurez**, this theory states that all living organisms were created by God and first man called Adam was created by God.
- **Theory of Spontaneous Creation:** Propounded by **Aristotle and Epicurus**, this theory said that living things originated spontaneously from inanimate objects.
    - (a) In 1652, **Von Helmont** further added that "Mice could be produced from wheat grains when put in dark room with moist cloth."
    - (b) He further said that insects arose from dew and fly maggots evolved from meat. It is also called **abiogenesis or biopoiesis**.
- **Theory of Biogenesis:** Living things come from other living things through sexual or asexual reproduction. This theory was given by **Francisco Redi** and **Louis Pasteur**. They both demonstrated that life cannot be spontaneously created as given by Theory of Spontaneous creation
- **Cosmozoic Origin Theory:** According to this theory, life has reached on Earth from other heavenly bodies such as **meteorites, other planets or stars** in the form of **spores** which grew and evolved into different organisms. This theory too clearly lacks the scientific evidence.
- **Biological Origin Theory:** According to this theory, origin of life on earth is the result of a slow and gradual process of chemical evolution that probably occurred about 3.8 billion years ago. Propounded by **A.I. Oparin** and **J.B.S Haldane**, this theory is described in following **three stages**:
    - **(a) Chemogeny:** When temperature of earth crust became less than 10,000°C, the simple molecules like NH_3, CH_4, H_2O etc. combined to form saturated and unsaturated hydrocarbons that further combined to form **bio-molecules** such as Glucose, Amino acids, DNA, RNA, Starch, Cellulose, Carbohydrates etc.
    - **(b) Biogeny:** This theory refers to formation of life or self reproducing biological units. In this, bio-molecules aggregate in various combinations to form large colloidal particles called **coacervates** and these coacervates binding by limiting membrane helped in evolving bacteria and amoeba.

5 CHAPTER

Diversity in the Living World

If you look around you will see a large variety of living organisms, be it potted plants, insects, birds, your pets or other animals and plants. There are also several organisms that you cannot see with your naked eye but they are all around you. Each different kind of plant, animal or organism that you see, represents a species. The number of species that are known and described ranges between 1.7-1.8 million. This refers to biodiversity or the number and types of organisms present on earth.

There are millions of plants and animals in the world; we know the plants and animals in our own area by their local names. These local names would vary from place to place, even within a country. Probably you would recognize the confusion that would be created if we did not find ways and means to talk to each other, to refer to organisms we are talking about. Hence, there is a need to standardize the naming of living organisms such that a particular organism is known by the same name all over the world.

- This process is called **nomenclature**. Obviously, nomenclature or naming is only possible when the organism is described correctly and we know to what organism the name is attached to. This is **identification.**
- Biologists follow universally accepted principles to provide scientific names to known organisms. Each name has two components – the **Generic name and the specific epithet**.
- This system of providing a name with two components is called **Binomial Nomenclature**.
- **For Example** The scientific name of mango is written as **Mangifera Indica**. In this name Mangifera represents the **genus** while indica, is a particular **species**, or a specific epithet.
- This naming system given by **Carolus Linnaeus** is being practiced by biologists all over the world.
- This naming system using a two word format was found convenient. Name of the author appears after the specific epithet. I.e., at the end ofthe biological name and is written in an abbreviated form, e.g. **Mangifera Indica Linn**. It indicates that this species was first described by Linnaeus.

Taxonomy

Since it is nearly impossible to study all the living organisms, it is necessary to devise some means to make this possible. This process is **classification.**

- Classification is the process by which anything is **grouped into convenient categories based on some easily observable characters**. For example, we easily recognize groups such as plants or animals or dogs, cats or insects.
- The moment we use any of these terms, we associate certain characters with the organism in that group. The scientific term for these categories is **taxa**.
- Hence Taxonomy is the science of naming, describing and classifying organisms and includes all plants, animals and microorganisms of the world.
- Using morphological, behavioural, genetic and biochemical observations, taxonomists identify, describe and arrange species into classifications, including those that are new to science.
- Organisms classification when takes place in the form of a taxonomic system is often referred to as Linnean Classification.

Importance of Taxonomy

- Global biodiversity is being lost at an unprecedented rate as a result of human activities, and decisions must be taken now to combat this trend.
- Taxonomy provides basic understanding about the **components of biodiversity** which is necessary for effective decision-making about conservation and sustainable use.
- It also helps in deciding where to establish the protected areas based on what needs to be protected.
- It helps to differentiate invasive alien species (IAS) from native species, followed by finding methods to protect from the threats emanating from these species.
- It makes possible to execute the international efforts such as Convention on Biodiversity (CBD) , protection of endangered species etc.

Taxonomic Categories

- Classification is not a single step process but involves hierarchy of steps in which each step represents a rank or category.