## INTRODUCTION

As we Know that word science comes from latin word “Scientia” which means knowledge, This knowledge is based on hypothesis observation and experiments of universal science. In this universal sciences chemistry purely deals with the matter which have mass and occupy space. Even from the table salt we use in cooking to electro chemical interaction of our human brain show the differences of substance because of the composition, structure, properties and interaction of matter.

The matter is undergoing changes continuously in nature as rusting of iron, evaporation of spirit and burning of coal are examples of reaction in which new substance are formed and energy is absorbed or released. All of these things are different due to the presence of different substances. Which are different by means of composition, properties, interaction , structure of matter.

The chemists use chemistry to explain occurrence and description of things. They investigate material, their interactions and propose theories to illuminate our understanding from a particle to galaxies.

## 1.1 HISTORICAL BACKGROUND OF CHEMISTRY:

Table 1.1 Time Chronology of Chemistry

| Period /Timeline | Name of Scientists | Contribution/invention | Origin of scientist |
|---|---|---|---|
| 384 - 322 B.C | Aristotle | Proposed idea of a substance as a combination of *matter* and *form*. Described theory of the Four Elements, i.e. fire, water, earth, air | Greek |
| 347 - 428 B.C | Plato | Proposed term ‘elements’ as composition of organic and inorganic bodies with particular shape. | Greek |
| 357 - 460 B.C | Democritus | Proposed the idea of atom, an indivisible particle of matter. | Greek |
| 721 - 803 A.D | Jabir Ibne-Hayan | Invented experimental methods of nitric acid, hydrochloric acid and white lead.<br><br>Extraction of metals from their ores and dyeing clothes. | Muslim |

| | | | |
|---|---|---|---|
| 862-930 A.D | Al-Razi | Prepared ethyl alcohol by fermentation process. | Muslim |
| 973-1048 A.D | Al-Beruni | Determined densities of different substances. | Muslim |
| 980-1037 A.D | Ibne –Sina | Contributed in medicines, philosophy and astronomy. | Muslim |
| 1627-1691 A.D | Robert Boyle | Put forward idea of chemistry as systematic investigation of nature. Discovered the gaseous law. | English |
| 1728-1799 A.D | J. Black | Discovered carbon dioxide | Scottish |
| 1733-1804 A.D | J.Priesly | Discovered oxygen,sulphur dioxide and hydrogen chloride. | English |
| 1742-1786 A.D | Scheele | Discovered chlorine | German |
| 1731-1810 A.D | Cavendish | Discovered hydrogen | British |
| 1743-1794 A.D | Lavoisier | Discovered that oxygen is one fifth of air | French |
| 1766-1844 A.D | John Dalton | Proposed atomic theory of matter | English |
| 1778-1850 A.D | Gay-Lussac | Discovered that water is composed of two parts hydrogen and one part oxygen by volume. Discovered several chemical and physical properties of air and other gases, | French |
| 1776-1856 A.D | Avogadro | Proposed Avogadro's law that equal volumes of gases under constant temperature and pressure contain equal number of molecules. | Italian |

| | | | |
|---|---|---|---|
| 1746-1823 A.D | Jacques Charles | Described the gaseous law. | French |
| 1741-1820 A.D | Petit | Determined the classical expression for the molar specific [heat capacity] of certain chemical elements. | French |
| 1779-1848 A.D | J.J.Berzellius | Introduced symbols, formula and chemical equation to make study more systematic | Swedish |
| 1824-1907 A.D | Mendeleve | Discovered periodic arrangement of elements. | Russian |
| 1859-1927 A.D | Arrhenius | Proposed acid base theoryand ions dissociation. | Swedish |
| 1791-1867 A.D | M.Faraday | Contributed to the study of electromagnetism and electrochemistry. | British |
| 1856-1940 A.D | J.J.Thomson | Discovered the electron by experiments. | British |
| 1885-1962 A.D | Neil Bohr | Proposed a theory for the hydrogen atom based on quantum theory | British |
| 1871-1937 A.D | Rutherford | Postulated the nuclear structure of the atom.<br><br>Discovered alpha and beta rays, and proposed the laws of radioactive decay. | Scottish |
| 1887 - 1961 A.D | Schrodinger | Proposed Quantum mechanical model of atom | Australian |

| | | | |
|---|---|---|---|
| 1892 - 1987 A.D | De Broglie | Proposed hypothesis about wave particle duality nature of electron. | French |
| 1894 - 1974 A.D | Stendra Nath Bose | Proposed fourth state of matter | Indian |
| 1879 - 1955 A.D | Elbert Eienstein | Proposed fourth state of matter | German |
| 1961 - Alive | Eric Cornell | Synthesized the first Bose Einstein Condensate. | American |
| 1951 - Alive | Carl weiman | Produced first bose Einstein Condensate | American |

### 1.1.1 Definition of Chemistry:

Chemistry is the branch of science which deals with the properties, composition and structure of matter. Chemistry also deals with the changes involved in the matter .

### 1.1.2 Importance of Chemistry in daily life

Our planet earth has only life in the all planet of universe, due to existence of water ($H_2O$). The water is basic need of human, animals and plants. The chemical reactions take place in human, animals and plants. Disorder in these reactions may cause different diseases. Which may be over come with the help of chemistry.
The role of chemistry in daily life is unavoidable fact.

- Cooking, eating and digestion of food are purely chamical processes.
- Construction, cleaning and washing of our homes are dependable on chemistry.
- The production of fertilizers, glass, plastic synthetic fiber, polymer, ceramics, petroleum products, soaps, and detergents are based on chemistry.
- The diseases transmitted through impure drinking water as cholera, typhoid, dysentery, skin and eye infections can be controlled with the help of chlorine treatment to kill the pathogenic organism to obtain pure water.
- The chlorine is most important chemical which is used commercially to produce more than one thousand compounds which are used in chemical industry as bleaching agent, disinfectants, solvents, pesticides, refrigerates, PVC and drugs all are miracles of chemistry.

**Test Yourself**

- Identify and list down the chemistry related products in your home?
- How you can relate living things with chemistry?

## Do You Know?


## 1.2 BRANCHES OF CHEMISTRY

As we know that chemistry is serving humanity everywhere in our environment. Due to its wide scope Chemistry is divided into following main branches:

### 1.2.1 Physical Chemistry

Physical chemistry is the branch of chemistry which deals with relationship between composition and physical properties of matter with the changes in them. It also deals with the laws and principles governing the combination of atoms and molecules in chemical reactions.

### 1.2.2 Organic Chemistry

Organic chemistry is the branch of chemistry which deals with hydrocarbons and their derivatives. Organic chemistry is the study of structure, properties, composition, reactions, and preparation of carbon-containing compounds, which include hydrocarbons except oxides, carbonates, bicarbonates and cynites. The gasoline, plastics, detergents, dyes, food additives, natural gas, and medicines are studied in the organic chemistry.

### 1.2.3 Inorganic Chemistry

Inorganic chemistry is the branch of Chemistry which deals with the study of all elements and their compounds except hydrocarbons. These compounds are generally obtained from nonliving things. It is applicable in all areas of chemical industry. Such as glass, cement, ceramics and metallurgy.

### 1.2.4 Biochemistry

Biochemistry is the branch of Chemistry which deals with the compounds of living organisms (plants and animals) their metabolism and synthesis in the living body such as carbohydrates, proteins and fats. Biochemistry helps us to understand how living things obtain energy from food. It tells that how disorder or deficiency of these biomolecules causes diseases. This branch is useful in medicine, agriculture and food science.

### 1.2.5 Industrial Chemistry

The branch of Chemistry which deals with the study of chemical processes involved in the chemical industries for the manufacture of synthetic products like fertilizers, glass, cement and medicines is called as industrial chemistry.

### 1.2.6 Nuclear Chemistry

Nuclear chemistry is the branch of Chemistry which deals with the radioactivity, nuclear processes and properties of radioactive substances. Radioactive elements are widely used in medicine as diagnostic tools and as a means of treatment, especially for cancer, preservation of food and generation of electric power through nuclear power reactors.

### 1.2.7 Environmental Chemistry

It is the branch of Chemistry which deals with the study of the interaction of chemical materials and their effect on the environment of animals and plants. Personal hygiene, pollution, health hazards are the important areas of environmental chemistry.

### 1.2.8 Analytical Chemistry

Analytical chemistry is the branch of chemistry which deals with separation and analysis of kind, quality and quantity of various components in given substance. It used in chromatography, electrophoresis and spectroscopy.

### 1.2.9 Medicinal Chemistry

The branch of Chemistry which deals with synthetic organic chemistry, pharmacology and various biological specialties. The medicinal chemistry is used in synthesis of chemicals, bioactive molecules (Drugs) and pharmaceutical agents.

### 1.2.10 Quantum Chemistry

The branch of Chemistry which deals with application, mechanics and experiments of physical models in chemical system. It is also called molecular quantum mechanics.

### 1.2.11 Green Chemistry

The branch of chemistry which deals with study of processes and designing products, which are composed of less hazardous substances. It is also known as sustainable chemistry.

Safer chemical (polyphenylsulfon), less hazardous chemical (poly carbons) and safer solvents are examples of green chemistry. The main purpose of this branch is to use waste material efficiently and improvement of energy efficiency in chemical industry.

### Test Yourself

- In which branch of chemistry analysis of quality and quantity of compounds studied?
- What happens due to deficiency of biomolecules?
- Identify and list down examples of green chemistry in our environment?
- Differentiate among Medicinal chemistry and Biochemistry?

## 1.3 BASIC DEFINITIONS

### 1.3.1 Matter

Matter is all around us i.e. The air we are breathing, book we are reading and the stuff we touch and see. Matter is simply defined as anything that has mass and occupies space. It is found in three common states solid, liquid and gas. The plasma is also considered as fourth state of matter. The different states of matter are due to difference of energy in increasing order.

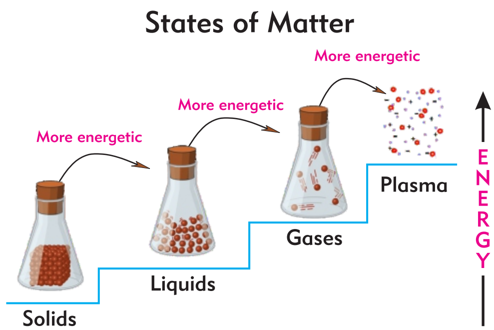
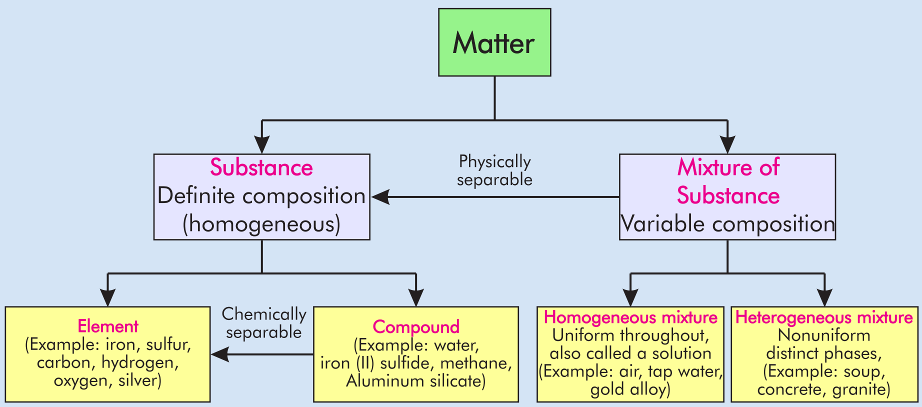



Fig 1.1 States of matter from solid to liquid, liquid to gases and gases to plasma due to increase in energy levels of the particles.

### Do You Know?



## 1.3.2 Atom

Matter is made up of smallest particles which are known as atom. Atoms are the basic units of matter and define structure of elements. Now it is discovered that atoms are made up of three particles: protons, neutrons and electrons. Atoms are composed of even smaller particle as shown in figure 1.2. Where neutron and proton are situated in nucleus and electrons are revolving around the nucleus

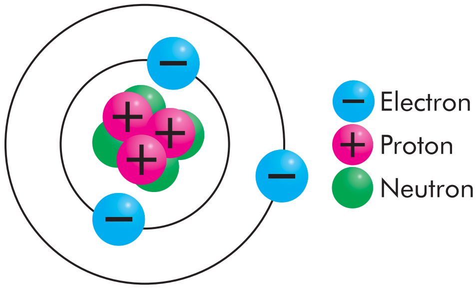
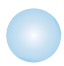
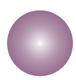
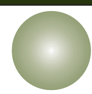
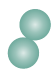
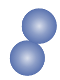
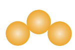
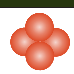
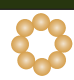



Fig 1.2 Particles of atom

## 1.3.3 Molecules

A molecule is the smallest particle in a chemical element or Compound that has the chemical properties of that element or Compound. Molecules are made up of atoms that are held together by chemical bonds. These bonds form as a result of the Sharing or exchange of electrons among atoms. Molecules are Mono, di and poly atomic molecules. Examples of mono,di and Poly atomic molecules are as follows.

Table 1.2 Examples of mono, di and poly atomic molecules

| Monatomic elements | | | | | |
|---|---|---|---|---|---|
| |  |  |  |  |  |
| Name | helium | argon | krypton | xenon | radon |
| Symbol | He | Ar | Kr | Xe | Rn |
| **Diatomic molecules** | | | | | |
| |  |  |  |  |  |
| Name | nitrogen | oxygen | chlorine | bromine | iodine |
| Molecular formula | $N_2$ | $O_2$ | $Cl_2$ | $Br_2$ | $I_2$ |
| **Polyatomic molecules** | | | | | |
| |  | |  | |  |
| Name | ozone | | phosphorus | | sulphur |
| Molecular formula | $O_3$ | | $P_4$ | | $S_8$ |

## 1.3.4 Substance

A piece of matter in pure form is termed as a substance. Every substance has a fixed composition and specific properties. Every substance has physical and chemical properties. Examples of pure substances include tin, sulfur, diamond, water, pure sugar (sucrose), table salt (sodium chloride) and baking soda (sodium bicarbonate). Substances are elements and compounds.

Salt

Diamond

Sulphur

Fig 1.3 Examples of pure substance

## 1.3.5 Element

An Element is a substance made up of same type of atoms, Having same atomic number and cannot be decomposed into Simple substances by ordinary chemical reaction. Elements occur in nature in free or combined form in solid, Liquid and gaseous states. Till now 118 elements have been discovered. Majority of elements are solids as copper, gold, zinc etc. Very few elements are liquid as mercury and bromine. Few elements are gases as hydrogen, oxygen nitrogen etc. Elements are divided in to metals, nonmetals and metalloids on the basis of their properties.

### Do you know?

Metal: solid material which is typically hard, shiny, malleable, fusible, and ductile, with good electrical and thermal conductivity (e.g. iron, gold, silver, aluminium, and alloys such as steel).

Nonmetal: is an element that doesn't have the characteristics of metal including: ability to conduct heat or electricity, luster, or flexibility. An example of a nonmetal element is carbon.

Metalloid: an element (e.g. arsenic, antimony, or tin) whose properties are intermediate between those of metals and non-metals i.e. semi conductor.

## 1.3.6 How to write Symbol?

Symbol is an abbreviation to represent the name of elements. A symbol is taken from the name of elements from English , Latin, Greek and German languages.

- Symbols are usually one or two letter long.
- Every symbol starts with capital letter as carbon with C or sulphur as S.
- If symbol is two letter then start with capital and second will be in small letter as He for helium, Cr for chromium.


Fig 1.4 Symbols of elements

The symbols of 30 elements in English derived from Latin, Greek and German are given in table 1.3

Table 1.3 Symbols of first 30 Elements

| S. No | Names of Elements in English | Derived from Latin and Greek | Symbol |
|---|---|---|---|
| 01 | Hydrogen | Greek (root genes) | H |
| 02 | Hellim | Greek (Helios) | He |
| 03 | Lithium | Greek (lithos) | Li |
| 04 | Beryllium | Greek (beryllos) | Be |
| 05 | Boron | Latin (Busaq) | B |
| 06 | Carbon | Latin (Carbone) | C |
| 07 | Nitrogen | Greek (nitrumgenes) | N |
| 08 | Oxygen | Greek (oxygeinomes) | O |
| 09 | Flourine | Latin (fluor) | F |
| 10 | Neon | Greek (neos) | Ne |
| 11 | Sodium | Latin (Natrium) | Na |
| 12 | Magnesium | Greek (magnesium) | Mg |
| 13 | Aluminium | Latin (alumen) | Al |
| 14 | Silicon | Latin (silen) | Si |
| 15 | Phosphorous | Greek (Phoros) | P |
| 16 | Sulphur | Latin (sulohur) | S |
| 17 | Chlorine | Greek (Chloros) | Cl |
| 18 | Argon | Greek (argon) | Ar |
| 19 | Potassium | Latin (Kalium) | K |
| 20 | Calcium | Greek (Claix) | Ca |
| 21 | Scandium | Latin (scandia) | Sc |
| 22 | Titanium | Greek (titan) | Ti |
| 23 | Vanidium | Greek (vanadis) | V |
| 24 | Chromium | Greek (Chroma) | Cr |
| 25 | Mangnese | Greek (Magnesia) | Mn |
| 26 | Iron | Latin (Ferrum) | Fe |
| 27 | Cobalt | German (Kobold) | Co |
| 28 | Nichel | German (kupanickel) | Ni |
| 29 | Copper | Latin (Cuprum) | Cu |
| 30 | Zinc | German (zink) | Zn |

### 1.3.7 What is valency?

The Combining power of an element with other element is called valency. The valency depends upon the number of electrons in the outermost shell. Valency is the number of electrons of an atom of an element can gain, lose or share. Some elements with their symbol and common valencies are given below in table 1.4

| S. No | Elements | Symbol | Atomic Number | Valency |
|---|---|---|---|---|
| 1 | Hydrogen | H | 1 | 1 |
| 2 | Helium | He | 2 | 0 |
| 3 | Lithium | Li | 3 | 1 |
| 4 | Beryllium | Be | 4 | 2 |
| 5 | Boron | B | 5 | 3 |
| 6 | Carbon | C | 6 | 4<br>2 |
| 7 | Nitrogen | N | 7 | 3 |
| 8 | Oxygen | O | 8 | 2 |
| 9 | Flourine | F | 9 | 1 |
| 10 | Neon | Ne | 10 | 0 |
| 11 | Sodium | Na | 11 | 1 |
| 12 | Magnesium | Mg | 12 | 2 |
| 13 | Aluminium | Al | 13 | 3 |
| 14 | Silicon | Si | 14 | 4 |
| 15 | Phosphorus | P | 15 | 3 |
| 16 | Sulphur | S | 16 | 2 |
| 17 | Chlorine | Cl | 17 | 1 |
| 18 | Argon | Ar | 18 | 0 |
| 19 | Potassium | K | 19 | 1 |
| 20 | Calcium | Ca | 20 | 2 |
| 21 | Scanidium | Sc | 21 | 3 |
| 22 | Titanium | Ti | 22 | 2<br>3 |
| 23 | Vanidium | V | 23 | 5, 4 |
| 24 | Chromium | Cr | 24 | 3 |
| 25 | Manganese | Mn | 25 | 2, 4, 7 |

| | | | | |
|---|---|---|---|---|
| 26 | Iron | Fe | 26 | 2<br>3 |
| 27 | Cobalt | Co | 27 | 2 , 3 |
| 28 | Nickle | Ni | 28 | 1<br>2 |
| 29 | Copper | Cu | 29 | 1, 2 |
| 30 | Zinc | Zn | 30 | 2 |

## 1.3.8 What is Chemical formula?

The chemical formula represents the symbol of elements and ratios of elements to one another in a compound.

Chemical formula tells us number of atoms of each element in a compound with symbols.

For Example: Chemical formula of water is $H_2O$ which indicates that 2 atoms of hydrogen combines with 1 atom of oxygen, or Chemical formula of ammonia $NH_3$ shows that one nitrogen atom combines with 3 atoms of hydrogen.

## 1.3.9 Compounds:

The Compound is a substance formed when two or more elements are chemically bonded together in a fixed ratio by mass, As a result a new entirely different properties possessing substance is formed.

The type of bonds holding elements may be ionic bond or covalent bond.

For Example: NaCl, $CuSO_4$, KBr are ionic compounds and $H_2O$, $CH_4$, $H_2SO_4$ are covalent compounds.

**Table 1.5 Some Common Compounds with their Formula**

| Compounds | Chemical Formula |
|---|---|
| Water | $H_2O$ |
| Silicon dioxide(sand) | $SiO_2$ |
| Sodium hydroxide (caustic soda) | NaOH |
| Sodium chloride(common salt) | NaCl |
| Sodium carbonate(washing soda) | $Na_2CO_3.10H_2O$ |
| Calcium carbonate(lime stone) | $CaCO_3$ |
| Sugar | $C_{12}H_{22}O_{11}$ |
| Ammonia | $NH_3$ |
| Sulphuric acid | $H_2SO_4$ |
| Calcium oxide | CaO |

## 1.3.10 Mixture

When two or more than two elements or compounds physically combined without any fixed ratio is known as Mixture. The component substances retain their chemical properties. Mixtures can be separated again by physical methods, as Filtration, Evaporation, Distillation and Crystallization. There are two main types of mixtures, which are shown in figure 1.5, Homogeneous mixture and Heterogeneous mixture. In a homogenous mixture all the substances are evenly distributed throughout the mixture (Salt water, air, blood). In a heterogeneous mixture the substances are not evenly distributed (chocolate chip cookies, pizza, rocks)

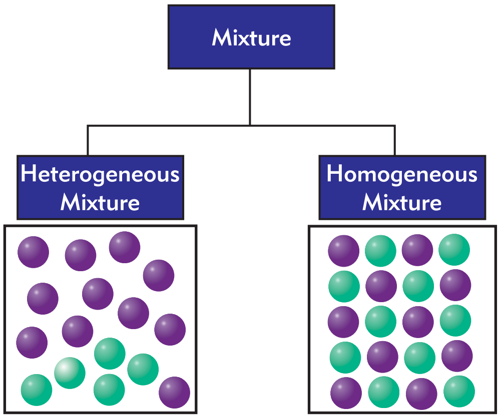



Fig 1.5 Types of Mixture

Table 1.6 Difference between Element, Compound, Mixture

| Element | Compound | Mixture |
|---|---|---|
| Element is a substance made up of same atoms, and discovered naturally. | Compound is formed by a chemical combination of atoms of the elements. | Mixture formed by the simple mixing of the substances. |
| Element shows unique properties due to similarity of atoms. | Constituent of compound lose their identity and form a new substance with new properties. | Constituents of mixture retain their properties in mixture. |
| Atoms of elements have same atomic number. | Compounds have fixed composition by mass. | Mixtures have no fixed composition by mass. |
| Element cannot be decomposed in to simple substances by ordinary means. | Components cannot be separated by physical means. | The components can be separated by physical means. |

| | | |
|---|---|---|
| Element represented by symbols, which are abbreviations for the names of elements. | Every compound represented by chemical formula. | It consists of two or more components and does not show any chemical formula. |
| Elements are homogenous | Compounds have homogenous composition. | Mixtures have homogenous as well as heterogeneous composition. |
| As the atomic number increases in elements melting points increases. | Compounds have sharp and fixed melting points | Mixtures do not have sharp and fixed melting points. |

**Test Yourself**

- How you can differentiate between matter and substance?
- Which elements do the following compounds contains?
  Washing soda, sugar, sand, caustic soda
- Identify mixture, element or compound from the following?
  Table salt, ice cream, blood, silicon, coca cola, tin, zinc, water, sulphur

## 1.3.11 Relative Atomic Mass and Atomic Mass Unit

### Relative Atomic mass:

The Relative atomic mass of an atom is the average mass of naturally occurring isotopes, compared with $^{1}/_{12}{}^{th}$ mass of one atom of carbon (C-12)

$$A_r = \frac{\text{Average mass of one atom of the element}}{\frac{1}{12} \times \text{the mass of one atom of carbon} - 12}$$

The unit of relative atomic mass is atomic mass unit, with symbol a.m.u .

$$1\text{a.m.u} = 1.66 \times 10^{-24}\ \text{gram}$$

## 1.3.12 Empirical Formula and Molecular Formula

The compounds are represented by Chemical Formula as elements are represented by symbols. Chemical formula are of two types Empirical Formula and Molecular Formula.

## Empirical Formula

The formula showing minimum relative numbers of each type of atoms in a molecule is called Empirical Formula.

- Empirical Formula shows simplest ratio of each atoms present in a molecule.
- Empirical Formula does not show the actual number of atoms in the molecule.
- Empirical Formula tells us the type of element present in it.

For Example:

( 1) Benzene has molecular formula $C_6H_6$. The simplest ratio of hydrogen and carbon is 1:1, so the empirical formula becomes CH.

(2) Glucose has molecular formula $C_6H_{12}O_6$. It shows the ratio as follows

$$C_6H_{12}O_6$$
$$6:12:6$$
$$1:\ 2:\ 1$$
$$C:\ H_2:\ O$$

So the empirical formula of glucose is $CH_2O$ and has simple ratio 1:2:1 of atoms in molecule of glucose.

## Molecular Formula

The Molecular formula is the formula which shows actual number of atoms of each element present in a molecule.

- Molecular formula is derived from empirical formula.
- Molecular formula Mass calculated by adding atomic masses of its atoms.
- Molecular formula of a compound may be same or multiple of empirical formula.

For Example: Molecular Formula of benzene is $C_6H_6$, which have six carbon and six Hydrogen, molecular formula is an integral multiple (1,2,3 etc.) of the empirical Formula.

Molecular Formula = (Empirical Formula)n where n=1,2,3,etc

Table 1.7 Some Compounds with their Empirical and Molecular Formula

| Compound | Empirical Formula | Molecular Formula |
|---|---|---|
| Carbon dioxide | $CO_2$ | $CO_2$ |
| Glucose | $CH_2O$ | $C_6H_{12}O_6$ |
| Hydrogen peroxide | HO | $H_2O_2$ |
| Benzene | CH | $C_6H_6$ |
| Acetic Acid | $CH_2O$ | $CH_3COOH$ |

## 1.3.13 Atomic Number and Atomic Mass

The Atomic Number is number of protons present in the nucleus of atom of any Element. It is represented by symbol Z. All atoms of an element have same atomic number due to the presence of same number of protons. For example all oxygen ($O_8$) atoms have 8 number of protons due to this atomic number is 8 (Z=8).

The Atomic Mass is sum of number of protons and neutrons present in the nucleus of atom of any element. It is represented by symbol A and calculated by A=Z+n where n is number of neutrons. For example nitrogen atom have 7 number of protons and 7 number of electrons then Atomic mass of nitrogen is 14 (A=7+7=14).

**Example 1.1: If any element have number of protons 11 and number of neutrons 12, find out its atomic number and atomic mass?**

Data:

Number of protons = 11

Number of neutrons = 12

Z =?

A =?

As we know atomic number Z is number of protons due to this

Atomic number Z = 11

Atomic mass is A = Z+n

A = 11+12

A =23

**Example 1.2: How many number of protons and neutrons are there in an atom having A= 40 and Z= 20?**

Data:

A = 40

Z = 20

Number of protons?

Number of neutrons?

As Number of protons is Z = 20

Number of neutrons = A - Z

= 40 - 20

= 20

## 1.3.14 Molecular Mass and Formula Mass

### Molecular Mass:

The Molecular Mass is the sum of atomic masses of all the atoms present in one molecule of a substance. For example molecular mass of $CO_2$ is 44 a.m.u and $H_2O$ is 18 a.m.u .

**Example 1.3: Calculate the molecular mass of $HNO_3$**

**Solution**

| | |
|---|---|
| Atomic mass of H | = 1 a.m.u |
| Atomic mass of N | = 14 a.m.u |
| Atomic mass of O | = 16 a.m.u |
| Molecular mass | = 1(At. Mass of H) +1(At. Mass of N) +3(At. Mass of O) |
| | = 1 + 14 +3(16) |
| | = 1 + 14 + 48 |
| | = 63 a.m.u |

### Formula Mass:

The ionic compounds which form three dimensional solid crystals are represented by their formula units. In such cases formula mass calculated by sum of atomic masses of all atoms in formula unit is called Formula Mass of that substance. For example formula mass of sodium chloride is 58.5 a.m.u

**Example 1.4: Calculate the Formula mass of $Al_2(SO_4)_3$**

**Solution**

| | |
|---|---|
| Atomic mass of Al | = 26.98 a.m.u |
| Atomic mass of S | = 32 a.m.u |
| Atomic mass of O | = 16 a.m.u |
| Formula unit | = $Al_2(SO_4)_3$ |
| Formula mass of $Al_2(SO_4)_3$ | = 2(26.98) + 3(32) +12(16) |
| | = 53.96 + 96 + 192 |
| | = 341.96 a.m.u |

**Test Yourself**

- How you can differentiate empirical formula and molecular formula?
- Why formula mass and molecular mass calculated separately while process of calculation is same?

## 1.4 CHEMICAL SPECIES:

If one molecule is identical to another we can say they are the same chemical species. Chemical species is a chemical entity, such as particular atom, ion or molecule.

### 1.4.1 Ions (anions, cations), Molecular ions and Free Radicals

Ions (anions, cations): ion is an atom or group of atoms having a charge on it. The charge may be positive or negative. There are two types of ions, cations and anions. The cations are formed when an atom loses electrons form its outer most shells.

For example: $Na^+$, $K^+$ are cations. The following equation shows formation of cations.

$$Na \longrightarrow Na^+ + 1e^-$$

An atom or group of atom that has a negative charge on it is called anion. Anion is formed by the gain or addition of electrons to an atom. For example: $Cl^-$ and $O^{2-}$, following examples shows formation of an anion by addition of electrons to an atom.

$$Cl + 1e^- \longrightarrow Cl^-$$

Molecular ions: when a molecule loses or gains electrons the species formed called molecular ions. Molecular ions also possess positive or negative charge like any ion. If it has negative charge known as anionic molecular ion, if they have positive charge known as cationic molecular ions. For example $CH_4^+$, $So_4^{2-}$ etc.

Free Radicals: Free radicals are atoms and group of atoms having number of unpaired electrons. It is represented by putting a dot over the symbol of an element.

For example: $H^\circ$, $Cl^\circ$, $H_3C^\circ$

Free radicals are formed when homolytic breakage of bond between two atoms takes place by the absorption of heat or light energy. Free radical is very reactive chemical species.

With the above mentioned definitions of ions, molecular ions and free Radicals. Question arises that what is difference between Atom and Ions, Molecule and Molecular ion. Even what is difference between ion and free Radical? Let's discuss it one by one.

Table 1.8 Difference between Atom and Ions

| Atom | Ion |
|---|---|
| Atom is the smallest particle of an element. | Ion is the smallest unit of ionic compound |
| Atom can or can not exist independently and take part in chemical reaction. | Ion can not exist independently and surrounded by oppositely charged ions. |
| Atom is electrically neutral. | Ion has negative or positive charge. |

Table 1.9 Difference between Molecule and Molecular ion

| Molecule | Molecular Ion |
|---|---|
| Molecule is the smallest particle in a chemical element or compound that has chemical properties of that element or compound. | Molecular ion formed by gain and lose of electrons by a molecule. |
| Molecule is always neutral. | Molecular ion have positive or negative charge. |
| Molecule is stable unit. | Molecular ion is reactive species. |
| Molecule is formed by the combination of atoms. | Molecular ion formed by the ionization of a molecule. |

Table 1.10 Difference between ion and Free Radicals

| Ion | Free Radicals |
|---|---|
| Ions are atoms which have positive or negative charge. | Free Radicals are atoms with odd number of unpaired electrons. |
| Ions exist in crystals and solutions. | Free Radicals exist in air and solutions. |
| Ion are not affected by the presence of light. | Free Radicals are affected by the presence of light. |

## 1.4.2 Molecule and Types of Molecules:

**Molecule:**
**Molecule is chemical combination of atoms**
**Molecule is smallest unit of a substance.**
**Molecule shows properties of substance.**
**Molecule can exist independently.**

| (1) Mono atomic Molecule | (2) Di atomic Molecule | (3) Tri atomic Molecule | (4) Poly atomic Molecule | (5) Homo atomic Molecule | (6) Hetero Molecule |
|---|---|---|---|---|---|
| Molecule consists of one atom.e.g. helium (He), neon(Ne), argon(Ar) | Molecule consists of two atoms. e.g Hydrogen ($H_2$) Oxygen ($O_2$), Chlorine ($Cl_2$) | Molecule consists of three atoms.e.g. $H_2O$, $CO_2$ | Molecule consists of many atoms.e.g. $CH_4$,$H_2SO_4$ ,$C_6H_{12}O_6$ | Molecule consists of same type of atoms.e.g $H_2$,$O_3$,$P_4$,$S_8$ | Molecule consists of different type of atoms.e.g $CO_2$, $H_2O$, $NH_3$ |

**Test Yourself**

- Identify the cations, anions, free Radical, molecular ion, molecule from the following.

  $O_2$ , $H^-$, $N_2$ , $Cl_2$ ,$CO_3^{2-}$, $H_2O$ , $Br^-$ , $H_2$ , $H_3C^\circ$ $Na^+$
- Justify the classification of molecules?

## 1.5 CHEMICAL EQUATION AND BALANCING CHEMICAL EQUATION

### 1.5.1 Chemical Equation:

Chemical equation is short hand method of describing the chemical reaction in terms of symbols and formulae of substances.

- The starting substances are known as reactants and always written on the left hand side of arrow,
- The substances which are formed due to reactions of reactants are known as products and written on the right side of arrow.
- The reactants and products are separated from one another by using ($\rightarrow$) single arrow or ($\rightleftharpoons$) double arrow depending on type of reaction.
- The number written in front of formula is called coefficient which shows number of molecules of that reactant or product.
- The expression (s),(g) and(l) shows the state i.e. solid ,gaseous and liquid of reactants and products.
- The expression (aq) expresses that substance is in the form of solution.

  Similarly if a catalyst is used then this catalyst is shown over the arrow.

For example : when two molecules of hydrogen and one molecule of oxygen react then two molecules of water are formed instead of writing the full names of reactants and products, chemists show this reaction as follows in form of equation.

Reactants　　　　Product

$$2H_{2(g)} + O_{2(g)} \longrightarrow 2H_2O_{(L)}$$

Coefficients　　Gaseous State　　Liquid

### 1.5.2 Balancing of Chemical equation

The chemical equation must be balanced in order to fulfill Law of conservation of mass. Mostly chemical equations can be balanced by inspection method (trial and error method). We can balance the equation by following steps.

1.Write the correct formula of all reactants on the left side and products on the Right side of an arrow.

2.Balance the number of atoms on each side.

3.If the number of atoms may appears more or less than other side, balance the equation by inspection method. Multiply the coefficient with formula to make the number of atoms same on the both (reactants and products) sides of equation.

4. The covalent molecules of hyderogen, nitrogen and chlorine exist as diatomic molecules. e.g $H_2$, $O_2$, $N_2$ and $Cl_2$. We must write them as diatomic molecule rather than isolated atoms in chemical equation.

5. Finally check the equation to be sure that number and kind of atom are same on the reactant and product side. If yes now equation is balanced.

For Example: Let us consider, in laboratory oxygen ($O_2$) gas is prepared by heating potassium chlorate ($KClO_3$). The products are potassium chloride (KCl) and oxygen ($O_2$) gas.

Now balance the equation step wise.

**Step no1: Write correct formula of all reactants on left side and product on right side of an equation.**

$$KClO_{3\,(s)} \longrightarrow KCl_{(s)} + O_{2\,(g)}$$

**Step no2: Balance the number of atoms on each side.**

Reactants → Products

K (1) → K (1)

Cl (1) → Cl (1)

O (3) → O (2)

We see that K and Cl elements have same number of atoms on both sides of equation but O is not balance because three atoms on reactant side and two atoms on product side.

**Step no3: Now multiply the formula ($KClO_3$) with co efficient 2 on reactant side and 3 in front of oxygen on product side to balance the oxygen atoms.**

$$2KClO_{3\,(s)} \qquad KCl_{(s)} + 3O_{2\,(g)}$$

Reactants → Products

K (2) → K (1)

Cl (2) → Cl (1)

O (6) → O (6)

**Step no4: Now again check and balance the equation by placing 2 in front of KCl on product side.**

$$2KClO_{3\,(s)} \longrightarrow 2KCl_{(s)} + 3O_{2\,(g)}$$

| Reactants | | Products |
|---|---|---|
| K (2) | $\longrightarrow$ | K (2) |
| Cl (2) | $\longrightarrow$ | Cl (2) |
| O (6) | $\longrightarrow$ | O (6) |

Now this chemical equation is balanced.

**Test Yourself**

- Balance the following equation with coefficient 4 in front of $KClO_3$ on reactant side and 4 in front of KCl on product side.

  $KClO_{3\,(S)} \longrightarrow KCl_{(S)} + O_{2(g)}$

- Balance the following equation.

  $CaCO_3 + HCl \longrightarrow CaCl_2 + H_2O + CO_2$

## 1.6 MOLE AND AVOGADRO'S NUMBER

### 1.6.1 Gram Atomic Mass, Gram Molecular Mass, Gram Formula Mass

As we have discussed before that all substances are made up of atoms, molecules or formula units.

The mass of atom is atomic mass, mass of molecule is molecular mass and mass of formula unit is formula mass. All of these masses are expressed in a.m.u. When these masses are expressed in Gram they are termed as Gram atomic mass, Gram molecular mass and Gram formula mass.

**Gram Atomic Mass:** The atomic mass of an element expressed in gram is called gram atomic mass. It is also called 1 mole.

1 gram atomic mass of oxygen = 16.00g = 1 mole of oxygen atom

1 gram atomic mass of carbon = 12.00g = 1 mole of carbon atom

1 gram atomic mass of nitrogen = 14.00g = 1 mole of nitrogen atom

Its means 1 gram atomic mass of different elements has different masses.

**Gram Molecular Mass:** The molecular mass of an element or a compound expressed in gram is called gram molecular mass. It is also called 1 mole.

1 gram molecular mass of oxygen ($O_2$) = 32.00g = 1 mole of oxygen molecule

1 gram molecular mass of water ($H_20$) = 18.00g = 1 mole of water

1 gram molecular mass of ethanol $C_2H_5OH$ = 46.00g = 1 mole of ethanol

**Gram Formula Mass:** The formula mass of an ionic compound expressed in grams is called gram formula mass. It is also called 1 mole.

1 gram formula of NaCl = 58.5g = 1 mole of sodium chloride

1 gram formula mass of $CaCO_3$ = 100g = 1 mole of calcium carbonate

## 1.6.2 Mole:

The atomic mass, molecular mass and formula mass of a substance expressed in grams is known as mole. A mole is defined as "amount of substance containing particles equal to the avogadro's number $6.02 \times 10^{23}$.

Gram atomic mass and a.m.u

Gram atomic mass of carbon atom = 12g

Atomic mass of one atom of C=12a.m.u

Thus

Gram Atomic mass of carbon is 12gram = 1 mole of carbon atom

Gram Molecular mass of $H_2SO_4$ is 98gram = 1mole of $H_2SO_4$

The relationship between mole and mass can be expressed as

$$\text{Number of moles} = \frac{\text{Given mass of a substance}}{\text{Molar mass of the substance}}$$

Or

$$\text{Mass of substance ( gm)} = \text{Number of moles} \times \text{Molar mass}$$

**Example 1.5: Calculate the number of moles in 40g of Na.**

**Solution**

Given mass of Na =40g

Molecular mass of Na =23 a.m.u

Number of moles =?

$$\text{Number of moles} = \frac{\text{Given mass of a substance}}{\text{Molar mass of the substance}}$$

$$\text{Number of moles of Na} = \frac{40}{23} = 1.73 \text{ moles of Na}$$

Example 1.6: What is the mass of 4 moles of $CO_2$?

Solution

Number of moles of $CO_2$ = 4 moles

Formula mass of $CO_2$ = 44 a.m.u

mass of $CO_2$ = ?

Mass of $CO_2$ = number of moles of $CO_2$ × formula mass of $CO_2$

= 4 x 44 = 176 gm

### 1.6.3 Avogadro's Number

Avogadro an Italian scientist, calculated the number of atoms, molecules or ions present in one mole. The value is found to be $6.02 \times 10^{23}$. This value is represented by $N_A$ and is called as Avogadro's number.

For example: 1 mole of $O_2$ molecule = 32 g

So 32gm of $O_2$ will contain $6.02 \times 10^{23}$ molecules

Similarly 1 mole of NaCl =(23+35.5)= 58.5g of NaCl

$= 6.02 \times 10^{23} Na^{+} + 6.02 \times 10^{23} Cl^{-}$

**Example 1.7: Calculate the number of atoms present in 9.2gm of Calcium (Ca).**

**Solution:**

Atomic mass of Calcium (Ca) = 40

1g atomic weight of Calcium = 40gm

40g of Calcium contains = $6.02 \times 10^{23}$ atoms of Calcium

By using the formula

$$\text{Number of atoms} = \frac{N_A \times \text{Given Mass in g}}{\text{Atomic mass}}$$

$$\text{Number of atoms} = \frac{6.02 \times 10^{23} \times 9.2}{40}$$

$$= 1.384 \times 10^{23} \text{ atoms of Ca}$$

**Example 1.8: Calculate the number of moles, number of molecules present in 8g of $C_6H_{12}O_6$?**

Solution

Molecular weight of glucose ( $C_6H_{12}O_6$ ) = (6x12) + (12x1) + (6x16) = 180

Given Mass of $C_6H_{12}O_6$ = 8gm

$$\text{Number of moles} = \frac{8}{180} = 0.04 \text{ mole}$$

$$\text{Number of molecules} = \text{Number of moles} \times N_A$$

$$= 0.04 \times 6.02 \times 10^{23}$$

$$= 0.240 \times 10^{23}$$

$$= 2.40 \times 10^{22} \text{ molecules of glucose}$$

**Test Yourself**

- Prove that Avogadro's number is related to mole of any substance.
- Calculate the number of moles in 30gm of $H_3PO_4$.

## 1.7 CHEMICAL CALCULATIONS

In all type of chemical calculations we calculate number of moles and number of particles of a substance. These calculations are based on mole. In the sequence of calculation first moles are calculated then number of particles.

### 1.7.1 Mole-Mass Calculation

In this calculation we calculate number of moles of a substance with the help of following equation.

$$\text{Number of Moles} = \frac{\text{Given mass of substance}}{\text{Molar mass of substance}}$$

We can calculate mass of a substance with the given moles of substance with following equation.

$$\text{Mass of substance} = \text{Number of moles} \times \text{Molar Mass}$$

**Example 1.9: A coin of silver (Ag) having 8.5 gm weight. Calculate the number of moles of silver in coin?**

Solution

The mass is converted to number of moles by the following equation:

$$\text{Number of Moles} = \frac{\text{Given mass of substance}}{\text{Molar mass of substance}}$$

$$= \frac{8.5}{107}$$

$$= 0.07 \text{ moles of silver in 8.5 gm silver coin}$$

## 1.7.2 Mole-Particle Calculation

In this calculation we calculate number of moles of a substance in the given number of Particles (atom, molecules or formula unit).

$$\text{Number of Moles} = \frac{\text{Given number of particles}}{\text{Avogadro's number}} = \frac{\text{Given number of particles}}{6.02\text{x}10^{23}}$$

We can calculate number of particles as

$$\text{Number of particles} = \text{Number of moles x } 6.02\text{x}10^{23}$$

**Example 1.10: Calculate the number of moles and number of molecules present in 10gm of $H_2SO_4$?**

Solution

The given mass of $H_2SO_4$ = 10gm

Molar mass of $H_2SO_4$ = 98.0gm

$$\text{Number of Moles of } H_2SO_4 = \frac{\text{Given mass of substance}}{\text{Molar mass of substance}} = \frac{10}{98} = 0.10 \text{ mole}$$

$$\text{Number Of molecules} = \text{Number of moles x Avogadro's number}$$

$$= 0.10 \text{ x } 6.02\text{x}10^{23}$$

$$= 0.602 \text{ x}10^{23}$$

$$= 6.02 \text{ x}10^{22} \text{ molecules of } H_2SO_4 \text{ in 10g.}$$

## 1.7.3 Mole Volume Calculation

The mole quantities of gases can be expressed in terms of volume, According to Avogadro, one gram mole of any gas at STP occupies volume of 22.4dm$^3$ (where standard temperature is O$^{\circ}$C and standard pressures is 1 atm)

**Example 1.11: How many liters of carbon dioxide would be produced if 0.450 mole of carbon monoxide reacts with excess oxygen at STP.**

**Solution:**

The equation for the reaction is

$2CO\,(g) + O_2\,(g) \longrightarrow 2CO_2(g)$

$x_1 = 0.450$ moles　　　　$x_2$ liters = ?

2 moles of CO　　　　2 moles of $Co_2$

So,

Step 1　$\frac{0.450}{2} = \frac{x_2}{2} \longrightarrow x_2 = \frac{0.450 \times 2}{2} = \frac{0.450}{\text{moles}}$

1 mole of gas at STP means 0°C temperature, 1 atm pressure and occupied volume $22.4dm^3$.

Step 2　Volume in litre/$dm^3$ = moles × $22.4dm^3$

$= 0.45 \times 22.4 = 10.08$ litre of $CO_2$

So 10.08 liter of $CO_2$ would be produced when 0.450 mole of carbon monoxide reacts with excess oxygen at STP.

## Summary

- Chemistry is the branch of science which deals with the properties, composition and Structure of matter. Chemistry also deals with the changes involved in the matter.
- Chemistry is everywhere in our environment and serving the humanity day and night. Due to its wide scope Chemistry is divided into physical chemistry, organic chemistry, inorganic chemistry, biochemistry, industrial chemistry, nuclear chemistry, environmental chemistry, analytical chemistry, medicinal chemistry, quantum chemistry, green chemistry.
- Matter is simply defined as anything that has mass and occupies Space.it is found in three common states solid, liquid and gas. The plasma is also considered as fourth state of matter. The different states of matter are due to difference of energy in increasing order.
- Matter is made up of smallest particles which are known as Atom. Atoms are the basic units of matter and define Structure of elements. Now it discovered that atoms are made up of three particles: protons, neutrons and electrons.
- A molecule is the smallest particle in a chemical element or Compound that has the chemical properties of that element or Compound. Molecules are made up of atoms that are held together by chemical bonds. These bonds form as a result of the Sharing or exchange of electrons among atoms. Molecules are Mono, di and poly atomic molecules.

- A piece of matter in pure form is termed as a substance. Every substance has a fixed composition and specific properties. Every substance has physical and chemical properties.
- An Element is a substance made up of same type of atoms having same atomic number and cannot be decomposed into Simple substances by ordinary chemical reaction.
- Elements occur in nature in free or combined form in solid, Liquid and gases states.

  Now 118 elements have been discovered.
- Symbol formula is an abbreviation to represent the name of element. A symbol is taken from the name of that element in English, Latin and Greek. If it is one letter, it will be capital as H for Hydrogen, C for carbon, S for Sulphur and N for Nitrogen etc. in case of two letters symbol, only first letter is capital as Na for sodium, Cr for Chromium, He for Helium and Zn for Zinc.
- When two or more than two elements or compounds physically combined without any fixed ratio is known as Mixture. The component substances retain their chemical properties. Mixtures can be separated again by physical methods, as Filtration, Evaporation, Distillation and crystallization.
- The Atomic Number is number of protons present in the nucleus of atom of any Element. It is represented by symbol Z. All atoms of an element have same atomic number due to the presence of same number of protons.
- The Atomic Mass is sum of number of protons and neutrons present in the nucleus of atom of any element.it represented by symbol A and calculated by $A=Z+n$ where n is number of neutrons.
- The atomic mass of an element expressed in gram is called gram atomic mass. It is also called 1 mole.
- The molecular mass of an element or a compound expressed in gram is called gram molecular mass. It is also called 1 mole.
- The formula mass of an ionic compound expressed in grams is called gram formula mass. It is also called 1 mole.
- The atomic mass, molecular mass and formula mass of a substance expressed in grams is known as mole.
- Avogadro an Italian scientist, calculated the number of atoms, molecules or ions present in one mole. The value is found to be $6.02\text{x}10^{23}$ . This value is represented by $N_A$ and is called as Avogadro's number.

# Exercise

## SECTION- A: MULTIPLE CHOICE QUESTIONS

**Tick Mark (✓) the correct answer**

1. The branch of Chemistry which deals with hydrocarbons:
   - (a) Industrial chemistry
   - (b) Inorganic chemistry
   - (c) Organic chemistry
   - (d) Physical chemistry

2. The atomic mass of an element expressed in gram is:
   - (a) Gram molecular mass
   - (b) Gram atomic mass
   - (c) Gram formula mass
   - (d) Mole

3. Which of the following can be separated by physical means?
   - (a) Mixture
   - (b) Element
   - (c) Compound
   - (d) Substance

4 The molar mass of $H_2SO_4$ is:
   - (a) 98 a.m.u
   - (b) 9.8gm
   - (c) 98gm
   - (d) 9.8 a.m.u

5. The Molecule consist of two atoms is :
   - (a) Monoatomic molecule
   - (b) Polyatomic molecule
   - (c) Hetero atomic molecule
   - (d) Di atomic molecule

6. A formula that indicates actual number and type of atoms in a molecule is called:
   - (a) Chemical formula
   - (b) Empirical formula
   - (c) Molecular formula
   - (d) Formula mass

7. Ethyl alcohol was prepared by:
   - (a) Ibne-Sina
   - (b) Al-Razi
   - (c) Al-Beruni
   - (d) Jaber bin-Hayan

8. which of the following is a homo atomic molecule:
   - (a) $H_2$
   - (b) $NH_3$
   - (c) $H_2O$
   - (d) $CO_2$

9. The Empirical formula of hydrogen peroxide ($H_2O_2$) is:
   (a) $H_2O_2$ (b) HO
   (c) $OH_2$ (d) $O_2H_2$
10. A piece of matter in pure form is termed as:
   (a) Redical (b) Mixture
   (c) Compound (d) substance

## SECTION- B: SHORT QUESTIONS:

1. Differentiate between the physical and analytical chemistry?
2. Write down the classification of molecule?
3. Identify the differences among the following:
   (a) Atom and Ion
   (b) Molecule and Molecular ion
   (c) Compound and Mixture
4. Define the following terms:
   (a) Gram atomic mass
   (b) Gram molecular mass
   (c) Gram formula mass
5. Write down the empirical and molecular formula of the following?
   Sulphuric acid, Carbon dioxide, Glucose, Benzene
6. What is Free Radical?
7. Describe relationship between empirical and molecular formula? Explain with examples.
8. Explain why hydrogen and oxygen are considered as element whereas water is compound?

## SECTION- C: DETAILED QUESTIONS:

1. What do you mean chemical species, explain ion, molecular ion and free radical?
2. Write down the applications of chemistry in daily life?
3. Explain in detail empirical and molecular formula?
4. Explain the steps for balancing the equation?
5. Name the branches of chemistry and discuss any five branches?

## SECTION- D: Numerical

.(1) Balance the following equations by inspection method:

(a) $NH_3 + O_2 \longrightarrow NO + H_2O$

(b) $KNO_3 \longrightarrow KNO_2 + O_2$

(c) $Ca + H_2O \longrightarrow Ca(OH)_2 + H_2$

(d) $NaHCO_3 \longrightarrow Na_2CO_3 + H_2O + CO_2$

(e) $CO + O_2 \longrightarrow CO_2$

(2) Calculate the formula mass (a.m.u) of the following?

$Al_2O_3$ , $MgCl_2$ , $NaCl$ , $KNO_3$

(3) Calculate the molecular mass (a.m.u) of the following?

$C_2H_5OH$, $H_2O$, $NH_3$, $CO_2$

(4) How many moles are present in 40 gm of $H_2SO_4$?

(5) Calculate the number of moles and number of molecules present in the following?

(a) 16 g of $H_2CO_3$ (b) 20g of $C_6H_{12}O_6$

# Chapter 2 ATOMIC STRUCTURE

**Time Allocation**

| | |
|---|---|
| Teaching periods | = 14 |
| Assessment period | = 4 |
| Weightage | = 14 |

## Major Concepts

2.1 Discovery of Sub Atomic Particles, electron, proton and neutron.

2.2 Theories and Experiments Related to Atomic Structure.

2.3 Modern Theories of Atomic Structure.

2.4 Electronic Configuration.

2.5 Isotopes and their common application.

## STUDENTS LEARNING OUT COMES (SLO'S)

**Students will be able to:**

- Describe the discovery of electron, proton and neutron.
- Define Atomic Number (Z) and Mass Number (A) in term of number of proton and/or neutron.
- Describe the contributions Rutherford made to the development of the atomic theory.
- Explain how Bohr's atomic model is different.
- Define Modern theories of Atomic Structure( De Broglie Hypothesis & Schrodinger atomic model)
- Describe the presence of sub shells in a shell.
- Distinguish between Shells and Sub shells.
- Write Electronic Configuration of the first 18 Elements in the Periodic Table.
- Define and compare isotopes of an Atom.
- Discuss the properties of the isotopes of the H, C, Cl and U.
- Draw the structure of different isotopes from mass number and atomic number.
- State the importance and uses of the isotopes in various fields of life.

## Introduction

The word atom is derived from a Greek word ATOMOS means indivisible, which was first describe by Greek philosopher Democritus. Democritus beleived that all matter consist of very small indivisible particles which are known as atoms. Johan Dalton an English school teacher and chemist suggested the fundamental atomic theory, which explains that all elements are made up of tiny indivisible particles called atoms. Dalton assumed that no particles smaller than atom exist, but by the passage of time new experiments showed that atom is composed of even smaller particles which are known as sub-atomic particles. After that these sub-atomic particles were discovered and named as electron, proton and neutron. We will discuss all these discoveries in this chapter.

Fig 2.1 Democritus

## 2.1 Discovery of Sub Atomic Particles (Electron, Proton, Neutron) of an Atom

Dalton's atomic theory explains the chemical nature of matter and existence of indivisible atoms, but at the end of $19^{th}$ century sub-atomic particles were discovered by different scientists. First sub-atomic particle Electron was discovered by M. Farady, William Crooks and J.J. Thomson, second sub-atomic particle Proton was identified by Goldstein and Ernest Rutherford, while third sub-atomic particle Neutron was revealed by Chadwick. All of these findings were milestone in the knowledge of atomic structure which we have now.

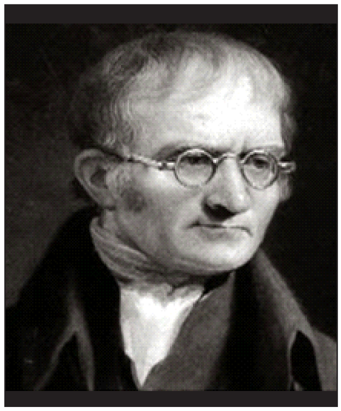


Fig 2.2 john Dalton

### 2.1.1 Discovery of Electrons

Electron is the lightest particle carrying negative charge in an atom discovered by J.J.Thomson and William crooks.

Fig 2.3 Chadwick

Fig 2.4 J.J.Thomson

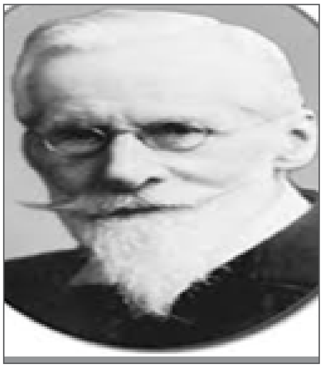


Fig 2.5 William Crooks

Fig 2.6 M.Faraday

The apparatus used for this type of experiment is called discharge tube which consists of glass tube fitted with two metal electrodes connected to a high voltage source and a vacuum pump. Discharge tube inside is evacuated, and electrodes are connected with high voltage source at very low pressure(1mm of Hg), when the high voltage current start passing between electrodes then a streak of bluish light originate and travel in straight line from cathode (-ve electrode) to anode(+ve electrode), Which cause glow at the wall of opposite end. These rays are called cathode rays.

## Discovery of Electrons

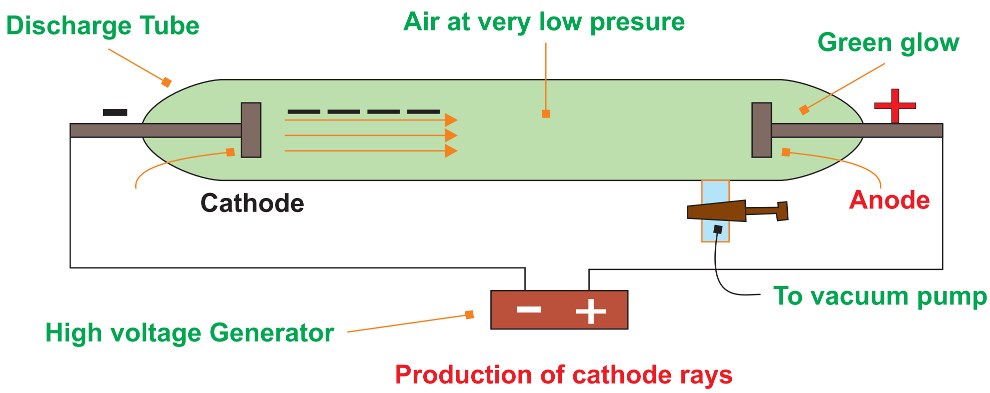



Fig 2.7 William Crooks Discharge Tube

J.J.Thomson justified that these rays were deflected towards positive plate in electric and magnetic field which shows that these rays possess negative charge due to this negative charge, particle was named Electron .These electrons were obtained from the cathode and when cathode material was changed the same phenomenon was observed which proves that electrons are constituent of all matter.

## Properties of Cathode Rays (Electrons)

1. They travel in straight line from cathode towards Anode.
2. They produce sharp shadow of an opaque object placed in their path.
3. They have negative charge and bend towards positive plate in electric and magnetic field.
4. These rays when strike with glass or other material and cause the material to glow.
5. The charge to mass ratio (e/m) of cathode particles is $1.7588 \times 10^{8}$ coulomb per gram. This is same for all electrons, regardless of any gas in discharge tube.
6. They can produce mechanical pressure indicating they possess kinetic energy (K.E).

## 2.1.2 Discovery of Protons

The Proton is positively charged particle discovered by Goldstein in 1886. J.J.Thomson investigated properties of proton in 1897.

Protons were observed in same apparatus of cathode rays tube but with perforated cathode. Goldstein discovered that not only negatively charged cathode rays but positively charged rays are moving in opposite direction through perforated cathode. These positive rays passes through the holes of cathode, where they strike with walls of tube and cause the glow of tube. These rays were named as Canal rays (protons).

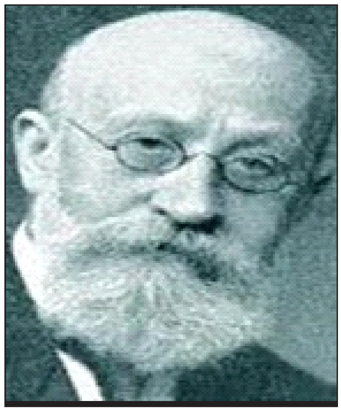


Fig 2.8 Goldstein

### Discovery of Protons

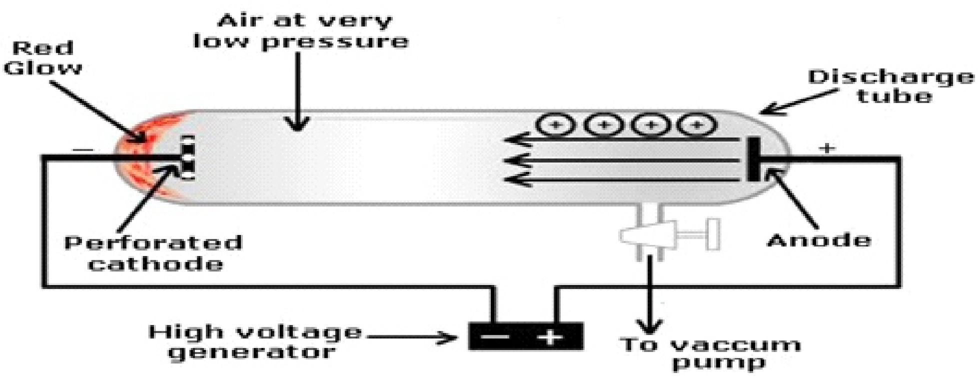



Fig 2.9 Gold Stein Discharge Tube

Remember that canal rays are not emitted by anode, but they are result of striking of electron with residual gas molecules in discharge tube. Electrons ionize the gas molecules as follows.

$$M + e^- \longrightarrow M^{+1} + 2\,e^-$$

Goldstein justified that atoms are electrically neutral, while electrons carry negative charge. It mean for each electron there must be one equivalent positive charge to neutralize that electron. This particle is called proton and it is a fundamental particle of all Atoms.

## Properties of Canal Rays (Protons)

1. They travel in straight line towards Cathode.
2. They produce sharp shadow of object placed in their path.
3. They have positive charge and bend towards negative plate in electric and magnetic field.
4. The charge to mass ratio (e/m) of positive particles is much smaller than electron. It varies according to nature of gas present in tube.
5. The mass of proton is 1836 times more than electron.

## 2.1.3 Discovery of Neutrons

In 1920 Rutherford predicted that atom must possess another neutral particle with equivalent mass of proton. Different scientists started working on this neutral particle. later on, in 1932 Chadwick successfully discovered Neutron. Chadwick found that when alpha ($\alpha$)particles bombarded on Beryllium plate some penetrating radiations were given out. Chadwick suggested that these radiations were due to material particle with mass comparable to hydrogen atom but have no charge. These radiations (particle) are called Neutron. It can be expressed in equation as follows.

$${}^{9}_{4}Be + {}^{4}_{2}He \longrightarrow {}^{12}_{6}C + {}_{0}n^{1}$$

The neutron is fundamental part of an Atom, present inside nucleus with proton and is included in atomic mass.

## Properties of Neutrons

1. The Neutrons are neutral particles.
2. They have no charge.
3. The mass of neutron is almost equal to that of proton.
4. These particles are most penetrating in matter.

## 2.1.4 How Atomic Number (Z) and Mass Number (A) are related with number of proton and neutron

As we discussed in discovery of fundamental particles of an atom, that Atom consist of three particles Electron, Proton and Neutron. But if all atoms have same fundamental particles then why the atoms of one element are different from the atoms of another element?

For example: How does an atom of Carbon (C) is different from an atom of Nitrogen (N)?Because all atoms can be identified by their number of protons they contain. Therefore no two elements have the same number of protons.

### Atomic Number (Z)

The number of protons inside the nucleus of an atom is called Atomic Number. Atomic number is represented by Z. The elements are identified by their atomic number. Different elements have different atomic numbers because of different number of protons. In neutral atoms number of protons are equal to number of electrons, so the atomic number also indicate total number of electrons outside the nucleus. For example atomic number of Carbon(C) is 6. It mean that each carbon atom has 6 protons and 6 electrons in it.

Atomic number= Z = Number of proton in nucleus = Total number of electron around nucleus

Atomic number (Z) is written as subscript on the left hand side of the chemical symbol e.g ${}_{6}C$. Some other examples are as follows.

$${}_{3}Li, \quad {}_{8}O, \quad {}_{1}H$$

### Mass Number (A)

The total sum of protons and neutrons in the nucleus of an atom is called Mass Number. It is also known as "Nucleon number"Mass number represented by A. For example, the sodium (Na) atom has atomic number 11 and mass number 23. It indicates that sodium atom has 11 protons and 12 neutrons. The mass number (A) is written as superscript on left hand side of chemical symbol. e.g ${}^{23}_{11}Na$

Mass number = A = Number of protons (Z) + Number of neutrons (N) OR

Mass number $A = Z + N$

And number of neutron $N = A - Z$

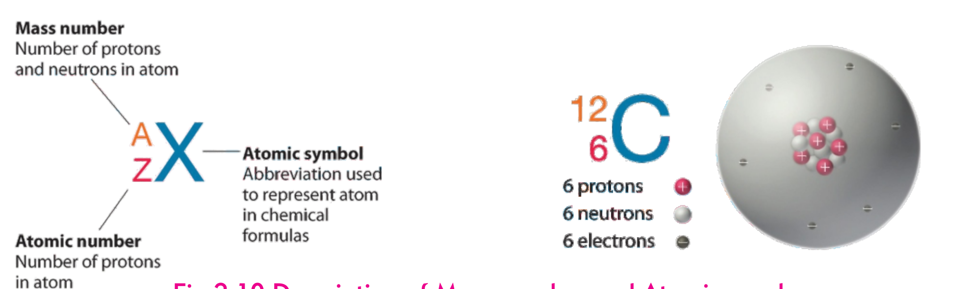



Fig 2.10 Description of Mass number and Atomic number

### Test Yourself

a. What is atomic number of an oxygen atom which have 8 Neutrons and 8 protons?

b. Find out mass number of chlorine which have 17 protons and 18 neutrons?

c. How many electrons, protons and neutrons are present in Co ?

d. Do you know any element which have no neutron in its atom?

## 2.2 Theories and Experiments Related to Atomic Structure

### 2.2.1 Rutherford Atomic Model

Lord Rutherford in 1911, carried out series of experiments and proposed a new model for the atom.

#### EXPERIMENT

Rutherford took a thin sheet of gold foil and bombarded it with alpha ($\alpha$) particles obtained from a radioactive element (Like Polonium). These rays were scattered after passing through the foil and examined on a zinc sulphide (ZnS) screen.

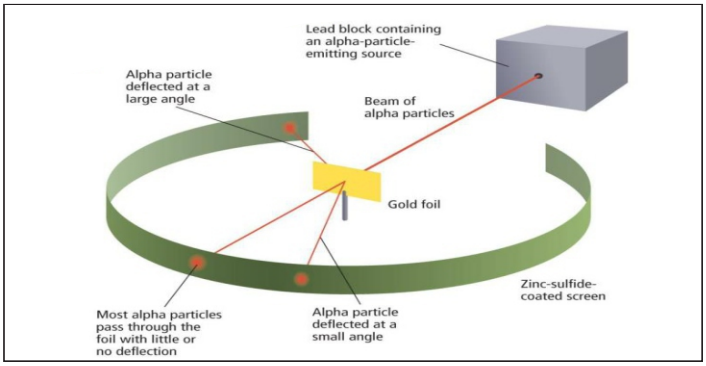



Fig 2.11 Gold Foil experiment

### Do you know?

Radioactive element are unstable isotopes that release subatomic particles or energy as they decay.

For example:

Uranium, Radium and Polonium

## Observations

1. Most of the particles passed straight and un deflected through the sheet and produced illumination on the zinc sulphide screen.
2. Very few alpha ($\alpha$) particles undergo small and strong deflection after passing through gold sheet.
3. A very few alpha ($\alpha$) particles (one out of 8000) retraced their path.

### Do you know?

Illumination:

It is the action of supplying or brightening with light The luminous flux per unit area on an intercepting surface at any given point called illumination

## Conclusion

1. According to Rutherford an atom consist of two parts nucleus and extra nuclear part.
2. Majority of the alpha particles passed straight line and un-deflected, shows that most volume occupied by atom is empty.
3. Alpha particles are positively charged and their deflection indicates that the centre of atom has a positive charge, which is named as nucleus.
4. The mass is concentrated in the nucleus and the electrons are distributed outside the positively charged nucleus.
5. The electrons are revolving around the nucleus in extra nuclear part called orbits.

### Conclusion of Ruther Ford "Gold Foil" experiment

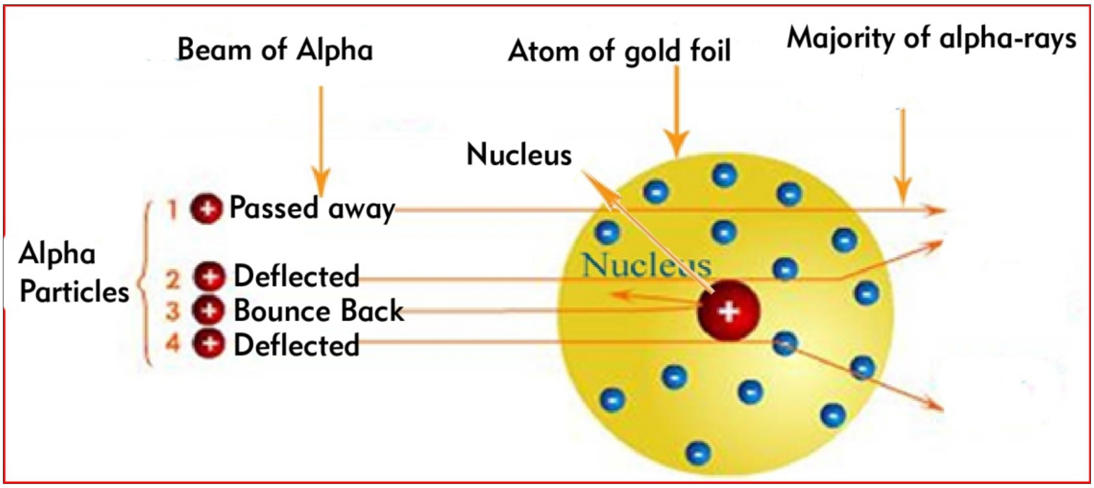



Fig 2.12 Pictorial description of bombardment of alpha particles on gold foil

## Rutherford postulates

- An atom consists of positively charged, dense and very small nucleus containing protons and neutrons. The entire mass is concentrated in the nucleus of an atom.
- The nucleus is surrounded by large empty space which is called extra nuclear part where probability of finding electron is maximum.

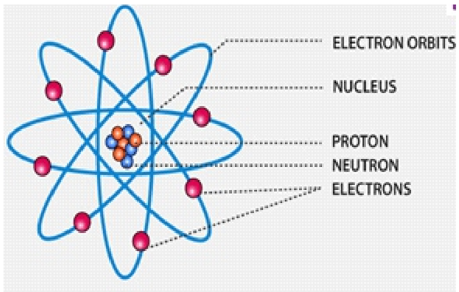


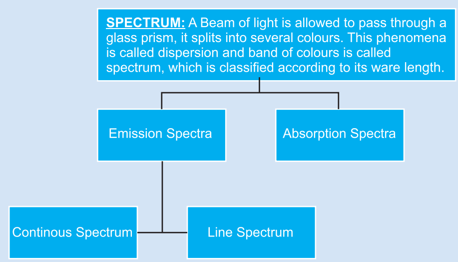

Fig 2.13 Rutherford Atomic Model

- The electrons are revolving around the nucleus in circular paths with high speed (Velocity).
- These circular paths are known as orbits (Shells).
- An atom is electrically neutral because it has equal number of protons and electrons.
- The size of the nucleus is very small as compared to the size of its original atom.

## Defects of Rutherford atomic model

1. Rutherford did not explain the stability of an atom.
2. In Rutherford atomic model the negatively charged electrons revolve around the nucleus in circular path and emits energy continuously. Due to continuous loss of energy ultimately it must fall into the nucleus.
3. If the revolving electron emits energy, continuously then there would be a continuous spectrum but in contrast to it we get line spectrum from the atoms of elements.

**Do you know?**




## 2.2.2 Neil Bohr's Atomic Model

In 1913 Neil Bohr proposed another atomic model. This atomic model was different in this manner that it showed two folds, first removed the Rutherford atomic model and second explained the line spectrum of Hydrogen atom based on quantum theory of Max Planck.

**Do you know?**

**What is quantum?**

A discrete quantity of energy proportion which can exist independently.

## Postulates of Neil Bohr's Atomic Model

Neil Bohr proposed the following postulates for atomic structure.

1. The atom has fixed orbits in which negatively charged electrons are revolving around the positively charged nucleus.
2. These orbits possess certain amount of energy which are called shells and named as K, L, M, N shells.
3. The energy levels are represented by an integer (n= 1, 2, 3....) known as quantum number, this quantum range starts from nucleus side, where n=1 is lowest energy level.
4. Electrons are revolving in particular orbits (ground state) continuously, but they do not emit energy.
5. When electron absorbs energy, it jumps from lower energy level ($E_1$) to higher energy level ($E_2$) (excited state).
6. When electrons jumps back from higher energy level ($E_2$) to lower energy level ($E_1$), it emits energy.
7. The emission or absorption is discontinuous in the form of energy packet called Quantum or Photon.
8. The $\Delta E$ difference in energy of higher ($E_2$) and lower ($E_1$) energy level.

   $\Delta E = E_2 - E_1$

   $\Delta E = h\nu = 1$ photon

Here h is planks constant, its value is $6.63 \times 10^{-34}$ Js and $\nu$ is a frequency of light.

9. Stationary state were present in those orbits in which angular moment of electron would be integral multiple of $h/2\pi$

   $mvr = nh/2\pi$ (where n = no: of orbits) h=(planks constant) m= (mass of electron)

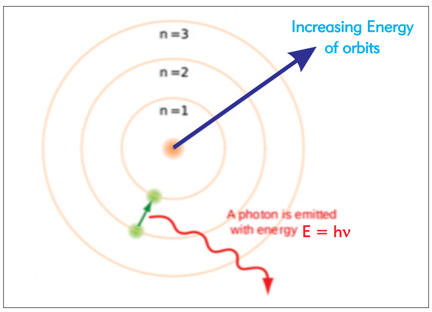



Fig 2.14 Neil Bohr's Atomic model

## Limitations of Bohr's Atomic Model :

- Bohr's model of an atom failed to explain the Zeeman Effect (effect of magnetic field on the spectra of atoms).
- It also failed to explain the Stark effect (effect of electric field on the spectra of atoms).
- It deviates the Heisenberg Uncertainty Principle.
- It could not explain the spectra obtained from larger atoms.
- It only explain the monoelectronic species like $He^{+}$, $Li^{+2}$, $Be^{3+}$.

### Test Yourself

- Which particles shows mass of an atom?
- Prove Rutherford atomic model based on classical theory and Bohr atomic model based on quantum theory?
- How you can relate living things with chemistry?

## 2.3 Modern Theories of Atomic Structure

In the year of 1900 Max Planck proposed quantum nature of radiations and energy in a photon wave $E=h\nu$ as quantum theory. This quantum theory accepted by Albert Einstein in 1905 and proposed relationship between mass and energy to explain photoelectric effect by wave particle duality as $E = mc^2$. In 1913 Neil Bohr continue to use quantization of radiation with angular momentum of electrons. Bohr predicted and explained the line spectrum of Hydrogen atom

### 2.3.1 de Broglie Hypothesis

In 1923 Lois de Broglie extended the wave particle duality to electron, and proposed a hypothesis that all matter has particle as well as wave nature at the submicroscopic level.

De Broglie combined the Einstein and Planck equations and argued that if

$E=h\nu$ where E = energy, h = plank 'constant, $\nu$ = frequency of light

And $E = mc^2$ where E = energy, m = mass, c = speed of light

**Then**

$$h\nu = mc^2$$

$$\frac{hc}{\lambda} = mc^2 \qquad \left(\nu = \frac{c}{\lambda}\right)$$

or $$\lambda = \frac{h}{mc} \qquad (P = mc)$$

or $$\boxed{\lambda = \frac{h}{P}} \qquad \text{or } P = m\nu$$

The wave nature of a particle is quantified by De Broglie wavelength defined as $\lambda = h/p$ where p is the momentum of the particle.

According to De-Broglie a light, or any other electromagnetic wave, can also exhibit the properties of a particle, similarly a particle should also exhibit the properties of a wave, and those two nature are interchangeable.

DeBroglie wave particles duality hypothesis

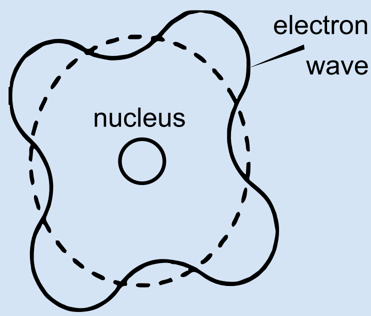



Fig 2.15 De Broglie wave duality hypothesis

## 2.3.2 Schrodinger Atomic Model

In 1926 Erwin Schrödinger, an Austrian physicist, took the Bohr's atomic model one step forward. Schrödinger used mathematical equations to describe the likelihood of finding an electron in a certain position. This atomic model is known as the quantum mechanical model of the atom.

Schrodinger model is just an improvement of Bohr's atomic model. He took an atom of hydrogen because it has one proton and one electron. He proved mathematically that electron can be find in different position around the nucleus and determined by probability.

- The quantum mechanical model determines that electron can be find in various location around the nucleus. He found electrons are in orbit as an electron cloud.
- Each subshell in an orbit have different shapes which determine the presence of electron.
- Different subshells of orbitals are named as s, p, d and f with different shapes as 's' is spherical and 'p' is dumbbell shaped.
- The numbers and kind of atomic orbitals depends on the energy of shell.

According to quantum mechanical model probability of finding an electron within certain volume of space surrounding the nucleus can be represented as a fuzzy cloud. If the cloud is denser the probability of finding electron is high which are called atomic orbitals. Detail and mathematical derivation will be discussed in next classes.

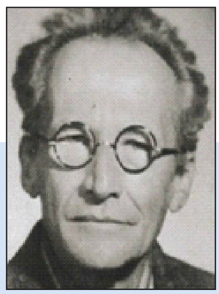


Fig 2.16 Schrodinger

## 2.4 Electronic Configuration

Before discussing electronic configuration we must understand the concept of shells and subshell.

As we know that nucleus is present in the centre of an atom and around the nucleus electrons are revolving. Now we have to understand how these electrons are revolving around the nucleus. These electrons are revolving around nucleus in different levels according to their potential energy.

### 2.4.1 Concept of Shell ( K, L, M, N,O, P & Q)

The Energy levels or Shell or Orbit are all possible paths on which electrons are revolving around nucleus. Which is shown by 'n'. These shells are named as K, L, M, N, O, P & Q with quantum numbers n= 1, 2, 3, 4, 5, 6 and 7 respectively. These shells have definite amount of energy by means of increasing order as they become away from nucleus.

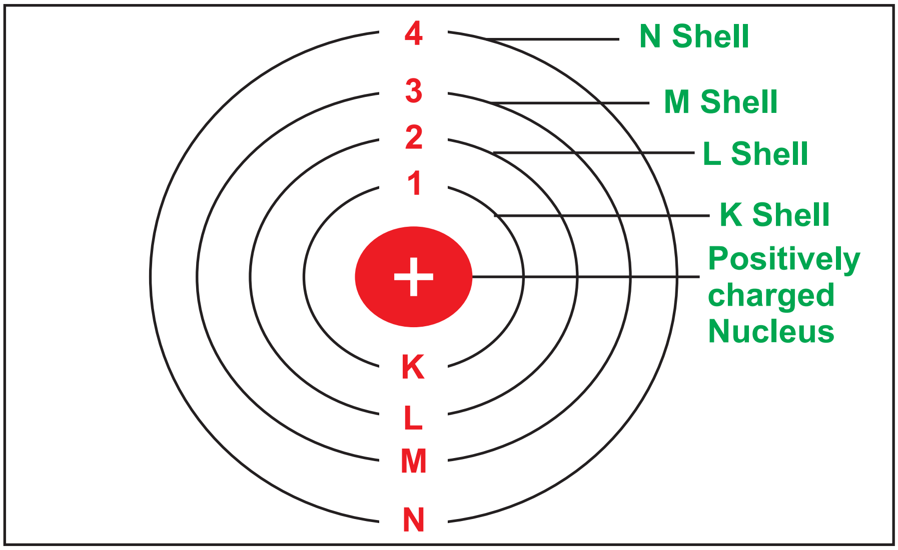



Fig 2.17 Shell (Energy level)

First energy level is K shell and has less energy.

Second energy level is L shell and has more energy than K shell.

Third energy level is M shell and has more energy than K and L shells.

Fourth energy level is N shell and has more energy than K, L and M shells.

Fifth energy level is O shell and has more energy than K, L, M and N shells.

## 2.4.2 Concept of Sub Shell (s,p,d & f)

When atomic spectra of substances were observed in a high powered spectroscope, it was found that they consist of two or more lines closely packed with each other as discussed in zemen and stark effects. These lines means that electrons in the same shell may differ in energy by small amount. Thus main energy level are divided in to sub energy levels and known as sub shells. When electrons are many in numbers in a shell they show repulsion and main shell splits into subshell which are named as s, p, d and f subshells.

The number of subshells in a shell is according to value of that shell, which are given in table 2.1

Table 2.1 Values of shell and sub shell

| Value of 'n' | Shell | Sub shell |
|---|---|---|
| **1** | K | Only s |
| **2** | L | s, p |
| **3** | M | s. p,d |
| **4** | N | s,p, d, f |

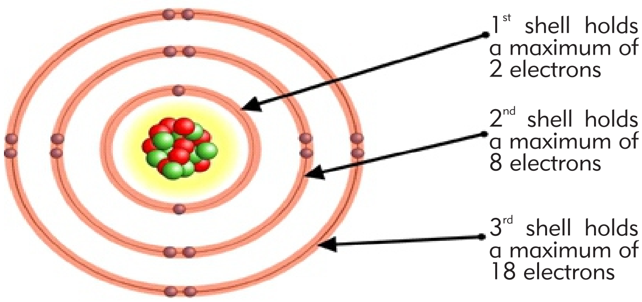
**Do you know?**

The atomic spectrum of substance consists of spectral lines. These lines differ in energy by small amount. Energy levels are divided into subshells/ subenergy levels due to repulsion. The shell or orbit split into subshell which are named as s, p, d, and f.

## 2.4.3 Electronic Configuration of First 18 Elements

Now we can understand that 'the distribution of electrons among the different orbits/shells and subshells according to some rules is known as the electronic configuration of an atom'. Generally, the most stable electronic configuration is represented when an atom is at the ground state with less energy level. Electrons filled in increasing order from lower to higher energy levels as

Each shell has a maximum number of electrons that it can hold. Electrons will fill the shells nearest the nucleus first.




This electron arrangement is written as 2,8,8.

Fig 2.18 Filling of energy level

The maximum number of electrons that can be accommodated in a shell is represented by the formula $2n^2$, where 'n' is the shell number. The distribution of electrons in different orbits are as follows:

**K-shell/ $1^{st}$ orbit (n=1) = $2(1)^2$ = 2**
**L-shell/ $2^{nd}$ orbit (n=2) = $2(2)^2$ = 8**
**M-shell/ $3^{rd}$ orbit (n=3) = $2(3)^2$ =18**
**N-shell/$4^{th}$ orbit (n=4) =$2(4)^2$ =32 and so on**

There is slight difference in Energy of subshells, the subshell "s" filled first then subshell 'p' and onward. The distribution of maximum electrons in subshells is as follows.

**2 electrons in's' subshell**

**6 electrons in 'p' subshell**

**10 electrons in 'd' subshell**

**14 electrons in 'f' subshell**

Whenever we write electronic configuration always remember following points.

1. Number of Electrons in an Atom.
2. Arrangement of shells and subshells according to energy levels.
3. Maximum number of electrons for shells and subshells.

### Example 2.1: write down electronic configuration of an element which has 8 electrons.

For this element first of all electrons will be filled in K shell which have maximum capacity of 2 electrons, than remaining electrons will be filled in L shell which has maximum capacity of 8 electrons. Now arrangement of electrons will be as:

K L M

2, 6, 0

The above element is Oxygen which has 8 electrons. In writing electronic configuration first two electrons will go into '1s' subshell of K shell which hold two electrons. The next two electrons for oxygen go in the 2s subshell of L shell and remaining four electrons will go into 2p subshell of L shell. Now electronic configuration of oxygen is $1s^2\ 2s^2\ 2p^4$

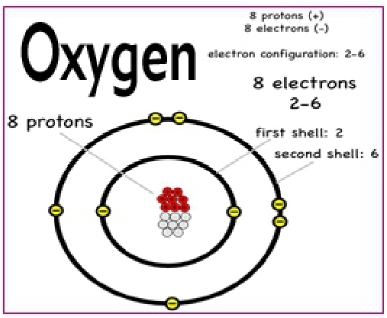



Fig 2.19
Electronic Configuration of Oxygen

The electronic configuration of different subshell of atom is written as $1s^2$, $2s^2$, $2p^6$, $3s^2$, as shown in figure 2.20.

Where coefficient shows number of shell, s,p are subshells and superscript is number of electrons in subshells. The electronic configuration of first 18 elements is given in table 2.2

### Order of Filling of Electrons in Subshells

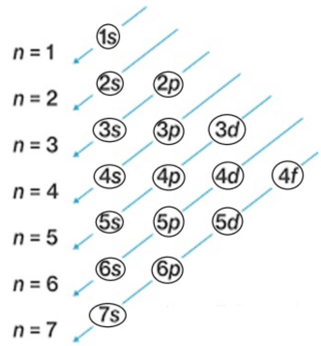



Fig 2.20 Order of filling of electrons in sub shells

Table 2.2 Electronic arrangement of the first 18 elements of the periodic table

| Elements | Symbol | Atomic Number (number of electrons) | Electronic Configuration |
|---|---|---|---|
| Hydrogen | H | 1 | $1s^1$ |
| Helium | He | 2 | $1s^2$ |
| Lithium | Li | 3 | $1s^2$, $2s^1$ |
| Beryllium | Be | 4 | $1s^2$, $2s^2$ |
| Boron | B | 5 | $1s^2$, $2s^2$, $2p^1$ |
| Carbon | C | 6 | $1s^2$, $2s^2$, $2p^2$ |
| Nitrogen | N | 7 | $1s^2$, $2s^2$, $2p^3$ |
| Oxygen | O | 8 | $1s^2$, $2s^2$, $2p^4$ |
| Fluorine | F | 9 | $1s^2$, $2s^2$, $2p^5$ |
| Neon | Ne | 10 | $1s^2$, $2s^2$, $2p^6$ |
| Sodium | Na | 11 | $1s^2$, $2s^2$, $2p^6$,$3s^1$ |
| *Magnesium* | Mg | 12 | $1s^2$, $2s^2$, $2p^6$,$3s^2$ |
| Aluminum | Al | 13 | $1s^2$, $2s^2$, $2p^6$,$3s^2$,$3p^1$ |
| Silicon | Si | 14 | $1s^2$, $2s^2$, $2p^6$ $3s^2$,$3p^2$ |
| *Phosphorus* | P | 15 | $1s^2$, $2s^2$, $2p^6$,$3s^2$,$3p^3$ |
| Sulphur | S | 16 | $1s^2$, $2s^2$, $2p^6$,$3s^2$,$3p^4$ |
| Chlorine | Cl | 17 | $1s^2$, $2s^2$, $2p^6$,$3s^2$,$3p^5$ |
| Argon | Ar | 18 | $1s^2$, $2s^2$, $2p^6$,$3s^2$,$3p^6$ |

### Test Yourself

- What is maximum number of electrons that can be accommodate in's' subshell?
- How many electrons will be in L shell of an atom having atomic number 11?
- In the distribution of electrons of an atom, which shell filled first and why?
- If both K and L shells of an atom are completely filled, what is the total number of electrons are present in them?

## 2.5 ISOTOPES AND THEIR COMMON APPLICATION

As we know that atom is composed of three particles electrons, protons and neutrons. In all the atoms of an element number of electrons, protons and number of neutron are same, due to this their atomic number and mass number are same but in few elements some atoms have different atomic number and mass number.

### 2.5.1 What are Isotopes?

Atoms of the same elements having same atomic number but different Mass number are called isotopes. They have same number of electrons and protons but different number of neutrons. These elements have same chemical properties due to same electronic configuration but different physical properties due to difference in mass number.

### 2.5.2 Examples of Isotopes

#### (1) Isotopes of Hydrogen

There are three isotopes of Hydrogen. These are known as Protium, deuterium and tritium as shown in fig 2.21

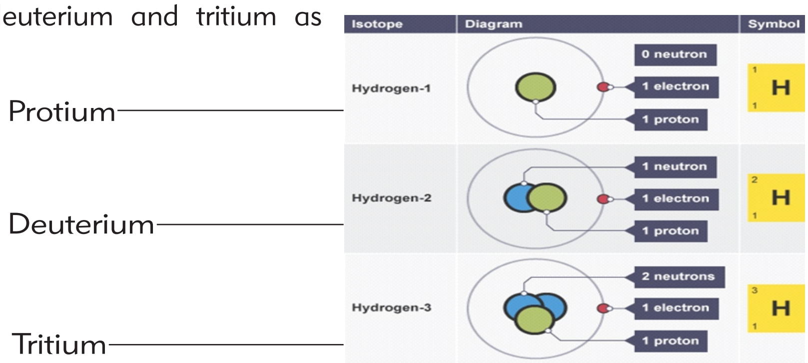



Fig 2.21 Isotopes of Hydrogen

### (2) Isotopes of Uranium

There are three common isotopes of uranium with atomic number 92 and mass number 234,235 and 238 respectively, as shown in fig 2.22. The uranium $^{238}_{92}U$ is found 99% in nature.

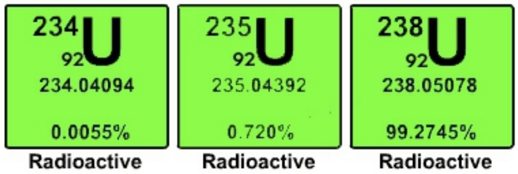



Fig 2.22 Isotopes of Uranium

### (3) Isotopes of Carbon

There are two stable isotopes and one radioactive isotope of carbon. Which are shown in fig 2.23.

The carbon 12 contain 6 proton and 6 neutron, Carbon 13 possess 6 proton and 7 neutron, carbon 14 contain 6 proton and 8 neutron. Carbon 12 is the most abundant (98.89%) isotope.

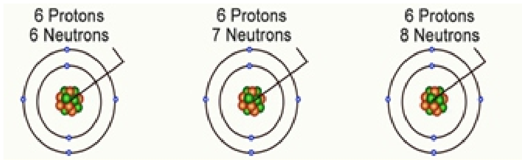



Fig 2.23 Isotopes of Carbon

### (4) Isotopes of Chlorine

There are two isotopes of Chlorine with atomic number 17 and mass number 35 and 37. as shown in figure 2.24. Chlorine 35 is 75% and chlorine 37 is 25% abundant in nature.

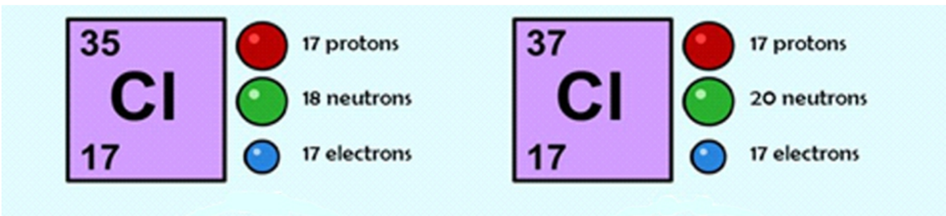



Fig 2.24 Isotopes of Chlorine

## Table 2.3 Applications of Isotopes

| S. No | Name of Radioactive Isotopes | Fields | Uses |
|---|---|---|---|
| (1) | Phosphorous -32 or strontium -90 | Radiotherapy | • Treatment of skin cancer |
| (2) | Cobalt-60 | Radiotherapy | • Treatment of body cancer due to more penetrating power. |
| (3) | Iodine isotopes | Radiotherapy | • Detestations of thyroid glands in he neck. |
| (4) | Technetium | Radiotherapy | • To monitor the bone growth in fracture healing. |
| (5) | Gamma ray of cobalt – 60 | Medical instrumentation | • To sterilization of medical instruments and dressings from harmful bacteria. |
| (6) | Americium -241 | Safety measures & industries | • Used in back scatter gauges, smoke detectors fill height detectors and measuring ash content of coal. |
| (7) | Gold -198 and Technetium - 99 | Sewage & liquid waste movement for water pollution | • Tracing factory waste causing ocean pollution<br>• Tracing sand movement in rivers and oceans. |
| (8) | Uranium -235 | Power Generation | • Conversion of water energy from steam to generate electricity. |
| (9) | Plutonium -238 | Medicine | • Used to stimulate a regular heart beat in heart pace maker. |
| (10) | Carbon -14 | Archaeology and Geology | • Used to estimate the age of fossils. |

### Test Yourself

- Which of the isotopes of hydrogen contains greater number of neutrons?
- Why do isotopes of same elements have same chemical but different physical properties?
- How the isotopes of Carbon are different from isotopes of Hydrogen?

## Summary

- The Electron is lightest particle carrying a negative charge in an Atom discovered by J.J.Thomson and William Crooks.
- The Proton is positively charged particle discovered by Goldstein in 1886.J.J.Thomson investigated properties of proton in 1897.
- In 1932 Chadwick become successful to discover Neutron.
- Lord Rutherford in 1911, carried out series of experiments and proposed a new model for the atom that an atom contains nucleus at the center and electrons revolve around this nucleus.
- In 1913 Neil Bohr proposed another atomic model. This atomic model was different in this manner that it shows two folds, first to remove the Rutherford atomic model and second explain the line spectrum of Hydrogen atom based on quantum theory of Max Planck.
- In 1923 Lois De Broglie extend the wave particle duality to electron, and propose a hypothesis that all matter has particle as well as wave nature at the sub microscopic level.
- The Energy levels or Shell or Orbit are all possible paths on which electrons are revolving around nucleus. Which is shown by 'n'. these Shells are named as K, L, M, N, O, P.
- Main energy level are divided in to sub energy levels and known as sub shells.
- The distribution of electrons among the different orbits/shells and subshells is known as the electronic configuration of an atom.
- Atoms of the same elements having same atomic number but different atomic masses are called isotopes. They have same number of electron and same number of protons, but different number of neutrons.
- The Isotopes are used in worldwide applications of daily life. Research laboratories, medical centers, industrial facilities, food irradiation plants and many consumer products all use or contain isotopes.

# EXERCISE

## SECTION- A: MULTIPLE CHOICE QUESTIONS

**Tick Mark (✓) the correct answer**

1. In an atom number of protons and neutrons are added to obtain:
   (a) number of electrons (b) number of nucleons
   (c) atomic number of element (d) number of isotopes
2. If proton number is 19, electron configuration will be:
   (a) 2, 8, 9 (b) 2, 8, 8, 1
   (c) 2, 8, 1 (d) 2, 8, 3
3. If nucleon number of potassium is 39 and its atomic number is 19 then, number of neutrons will be:
   (a) 39 (b) 19
   (c) 20 (d) 29
4. The isotope C-12 is present in abundance of:
   (a) 96.9% (b) 97.6%
   © 98.89% (d) 99.7%
5. Electronic configuration is distribution of:
   (a) protons (b) neutrons
   (c) electrons (d) positrons
6. Which one of the following is most penetrating?
   (a) electron (b) Proton
   (c) alpha particle (d) neutron
7. How many subshells in a L shell:
   (a) one (b) two
   (c) three (d) four
8. De Broglie extend the wave particle duality to electron in:
   (a) 1920 (b) 1922
   (c) 1923 (d) 1925
9. Name the material of screen which is used in Rutherford atomic model :
   (a) Aluminum foil (b) zinc sulphide
   (c) sodium sulphide (d) Aluminum sulphide
10. Which rays are used for sterilization of medical instruments :
   (a) $\alpha$-rays (b) $\beta$-rays
   (c) $\gamma$-rays (d) x-rays

## SECTION- B: SHORT QUESTIONS:

1. Draw the structure of isotopes of chlorine to justify the definition of isotopes?
2. An atom has 5 electrons in M shell than:
   (a) Find out its atomic number?
   (b) Write Electronic configuration of atom?
   (c) Name the element of atom?
3. Justify that Rutherford atomic model has defects?
4. Describe wave particle duality of electron of De Broglie Hypothesis?
5. What are Limitations of Bohr's Atomic Model?
6. Differentiate between shell and sub shell with examples?
7. How the atoms of $O_8^{17}$ and $O_8^{16}$ are similar or different from each other?
9. Write down the names of sub atomic particles their masses in a.m.u with their unit charges.

## SECTION- C: DETAILED QUESTIONS:

1. Discuss Rutherford' gold metal foil experiment in the light of structure of atom.
2. Writ down the applications of isotopes in daily life.
3. Explain how Bohr's atomic model is different from Rutherford atomic model.
4. Prove that modern theory of De Broglie is related with Einstein and Plank's equations.
5. How are cathode rays produced? What are their major characteristics?
6. Describe the schrodinger atomic model.
7. Describe briefly the experiments which provide clue and evidences of electron, proton and neutron in an atom.
8. How many protons, neutrons and electrons are present in the following elements ?
   (i) $Fe_{26}^{56}$ (ii) $O_8^{17}$ (iii) $Cl_{17}^{37}$ (iv) $U_{92}^{235}$ (v) $C_6^{14}$