5. Atomic Structure

- According to Dalton's atomic theory, the atom is considered to be the smallest indivisible constituent of all matter. This theory could explain the law of conservation of mass, law of constant composition and law of multiple proportions.
- Sir J.J.Thomson discovered that when very high voltage was passed across the electrodes in the cathode ray tube, the cathode produced rays that travel from cathode to anode and were called **cathode rays**.
- Eugen **Goldstein** discovered anode rays by using a perforated cathode (a cathode having holes in it) in the discharge tube filled with air at a very low pressure. The discovery of anode rays established the presence of positively charged proton in the atom.
- According to Thomson's plum-pudding model, atoms can be considered as a large sphere of uniform positive charge with a number of small negatively charged electrons scattered throughout it.
- The α-ray scattering experiment performed by Geiger and Marsden led to the failure of Thomson's model of atom.
- The results of α-ray scattering experiment were explained in terms of Rutherford's model. According to which the atom contains a dense and positively charged region called **nucleus** at its centre and the negatively charged electrons move around it. All the positive charge and most of the mass of atom is contained in the nucleus.
- In 1932, James Chadwick discovered an electrically neutral particle in atom and named it as **neutron**.
- The number of protons in an atom is called the atomic number and is denoted as 'Z'. On the other hand the number of nucleons(protons plus neutrons) in the nucleus of an atom is called its mass number and is denoted as 'A'
- The electrons are distributed in different shells in the order of increasing energy. The distribution is called electronic configuration. The maximum number of electrons present in a shell is given by the formula $2n^2$, where 'n' is the number of the orbit or the shell.
- The valence is the number of chemical bonds that an atom can form with univalent atoms. If the number of valence electrons is four or less, then the valency is equal to the number of the valence electrons. On the other hand, if the number of valence electrons is more than four, then generally the valency is equal to 8 minus the number of valence electrons.

Build Your Understanding

Constituent Particles of Atom

Electron, proton and neutron are the three constituent particles of atom and their properties are given in the following table.

Particle	Symbol	Mass (in kg)	Actual Charge (in Coulombs)	Relative charge
Electron	e	$9.109\ 389 \times 10^{-31}$	$1.602\ 177 \times 10^{-19}$	–1
Proton	p	$1.672\ 623 \times 10^{-27}$	$1.602\ 177 \times 10^{-19}$	1
Neutron	n	$1.674\ 928 \times 10^{-27}$	0	0

Earlier Models of Atom

Thomson Model: The atom can be considered as a sphere of uniform positive charge in which negatively charged electrons are scattered throughout.
Drawback could not explain the results of α-ray scattering experiment:

α-ray Scattering Experiment

A stream of α-particles from a radioactive source was directed on a very thin gold foil and their scattering was observed.

Actual observations

Most of the α-particles passed straight through the gold foil. Some of these were deflected by small angles and very few were deflected by large angles and rarely rebounded back (See figure)

Rutherford's Atomic Model

An atom consists of very small nucleus at the centre which contains all the positive charge and most of its mass. In rest of the space electrons revolve around the nucleus. Results of a-ray scattering could be explained by this model as shown the following figure.

Drawbacks of Rutherfords model

1. Accending to Maxwell's electromagnetic theory, if a charge particle like electron accelerates (revolves) around nucleus it would continuously lose energy and fall into nucleus.
   However, atoms are stable and such a collapse does not occur.
2. This model does not say anything about the way the electrons are distributed around the nucleus.
3. This model is not able to explain the relationship between the atomic mass and atomic number.

Bohr's Model of Atom

This model is based on two postulates

Postulate 1: The electrons move in definite circular paths of fixed energy around a central nucleus. These paths are called **orbits** or **energy level or shells**.

Later on, the concept of circular orbits was modified to energy shells. While a circular orbit is two dimensional, a shell is a three dimensional region. These shells are represented by letters K, L, M, N etc. or by positive integers 1, 2, 3 ... etc. (Fig. ...) The energies of the shells increase with these integers, (represented by n). Shell with n = 1, is of the lowest energy.

Postulate 2: The electron can change its shells or energy level by absorbing or releasing energy. An electron at a lower state of energy E_i can go to final higher state of energy E_f by absorbing a single photon of energy is given by $E = h\nu = E_i - E_f$. Similarly, when an electron changes its shell from a higher initial level of energy E_i to a lower final level of energy, E_f a single photon of energy $h\nu$ is released.

Atomic Number and Mass Number

Atomic number Z = number of protons = number of electrons (in neutral atom)

Mass Number A = Number of nucleons
= Number of protons (Z) + Number of neutrons (n)

Atomic notation

An atom X with atomic number Z and mass number A is denoted as

$$^{A}_{Z}X$$

Distribution of electrons in different orbits

The maximum number of electrons present in a shell is given by the formula $2n^2$ as given in the table below.

Value of n	Shell name	Maximum capacity
1	K-Shell	$2 \times 1^2 = 2$
2	L- Shell	$2 \times 2^2 = 8$
3	M- Shell	$2 \times 3^2 = 18$
4	N- Shell	$2 \times 4^2 = 32$

Valency

It is the number of chemical bonds that an atom can form with univalent atoms. The electrons in the outermost shell are known as, valence electrons valency of an atom is determined by the number of it valence electrons.

- If the number of valence electrons is four or less then the valency is equal to the number of the valence electrons.
- If the number of valence electrons is more than four, then generally the valency is equal to 8 minus the number of valence electrons.

Stretch Yourself

1. We observe that matter present around us in various forms is quite stable which atomic model was rejected on the basis of this observation?
2. Valency of an element is 4 and electron are present in K, L and M shells of its atom. What is the number of protons present in its nucleus.

Test Yourself

1. Name the two constituent particles of atom in each case that have
   (a) equal charges (with opposite signs)
   (b) nearly equal masses
   (c) are present in the nucleus of the atom
2. How does an orbit differ from a shell?
3. Which atomic model could not explain the results of α-ray scattering experiment/
4. What is the maximum number of electrons that can be present in N shell?
5. Find out the number of electrons, protons and neutrons present in an atom $^{17}_{8}X$