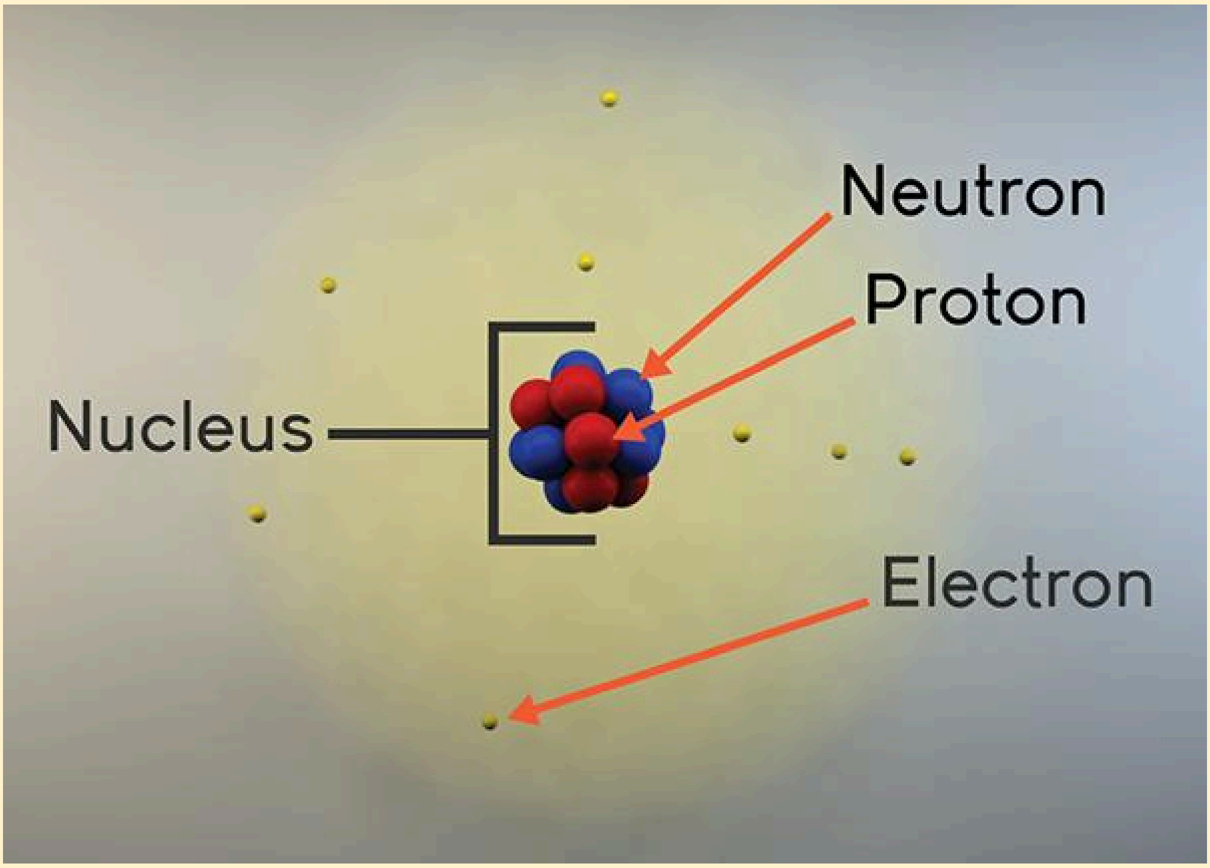
Chapter-04 : Structure of the atom

Charged particles in matter : Atoms have three types of sub-atomic particles. They are electrons, protons and neutrons. Electrons are negatively charged (e^-), protons are positively charged (p^+) and neutrons have no charge (n).

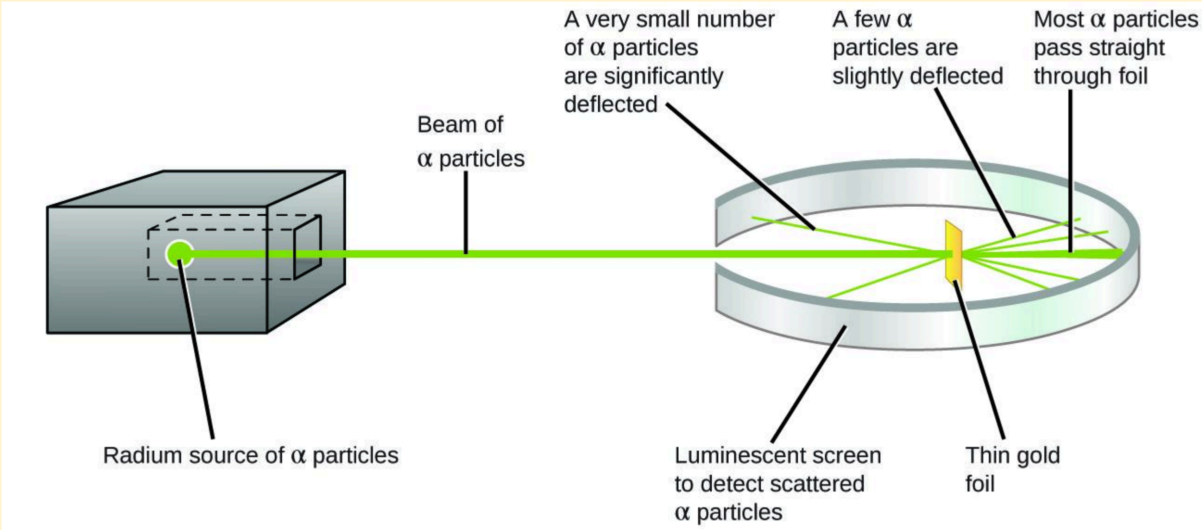
- The mass of an electron is 1/2000th mass of a hydrogen atom. The mass of a proton is equal to the mass of a hydrogen atom and is taken as 1 unit. The mass of a neutron is equal to the mass of a hydrogen atom and is taken as 1 unit.



Discovery of sub-atomic particles:

- J. J. Thomson discovered the presence of the negatively charged particles called electrons in the atom in 1900.

- E. Goldstein discovered new radiations in gas discharge in 1886 and called them canal rays. These rays were positively charged.



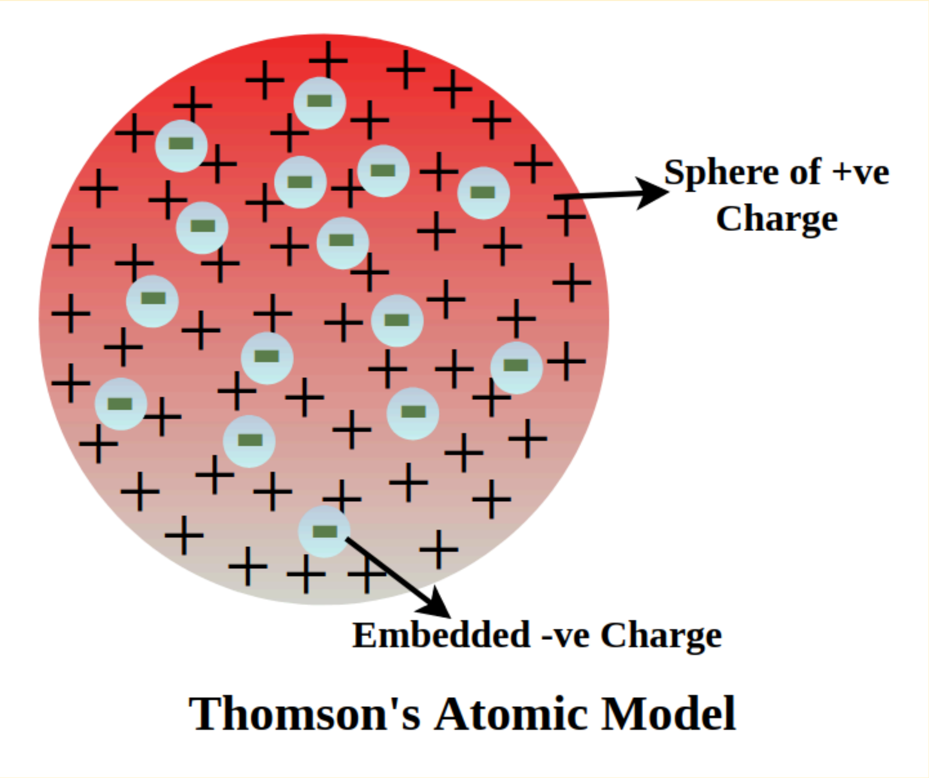
This later led to the discovery of the positively charged particles called protons in the atom.

- James Chadwick discovered the presence of particles having no charge in the atom in 1932 called neutrons.

Thomson's model of an atom :

- According to Thomson, an atom is similar to a Christmas pudding. The pudding had positive charge and the electrons having negative charge were like plums on the pudding.
- He proposed that :

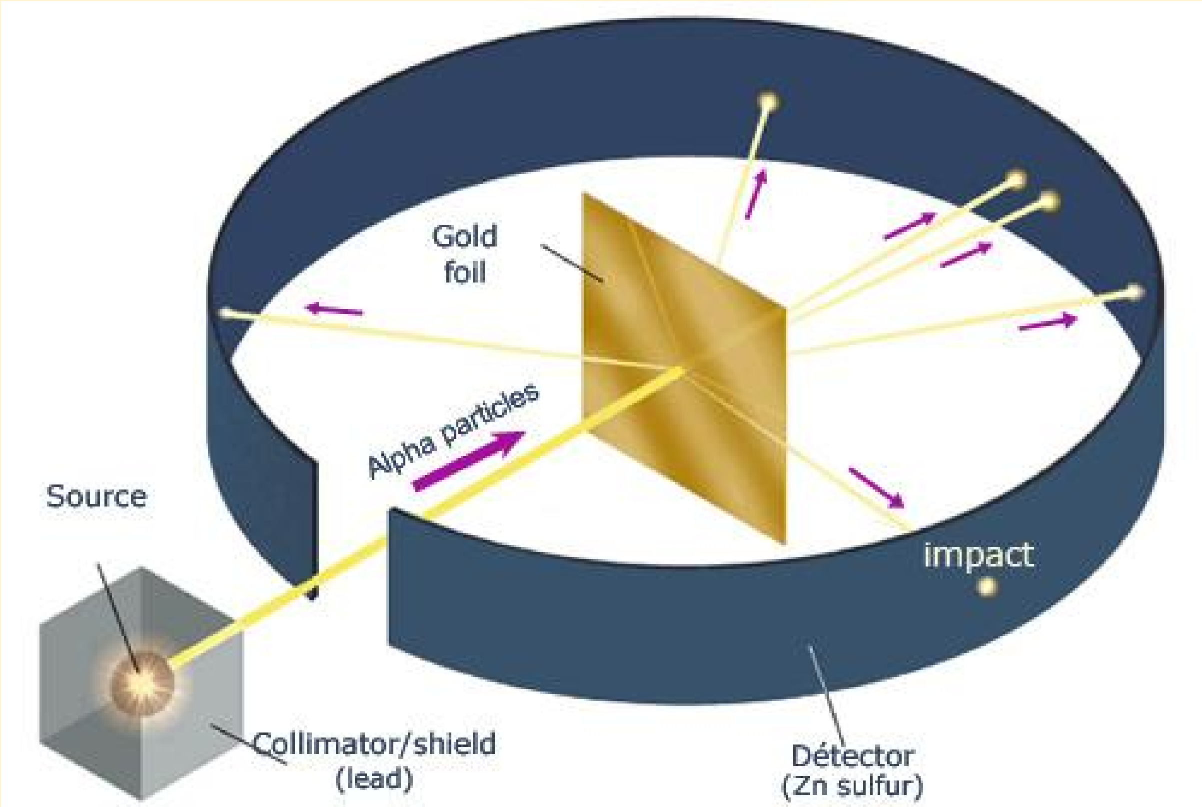
1. An atom consists of a positively charged sphere and the electrons are embedded in it.
2. The negative and positive charges are equal in magnitude. So, the atom as a whole is electrically neutral.



Rutherford's model of an atom :

1. **Rutherford's alpha scattering experiment :** Rutherford allowed a beam of fast moving alpha particles (α-particles) having positive charge to fall on a thin gold foil. He observed that :

- Most of the α-particles passed straight through the gold foil.
- Some of the α-particles were slightly deflected by small angles.
- Very few α-particles appeared to rebound.



Conclusions from Rutherford's alpha scattering experiment :

- Most of the space inside an atom is empty because most of the α–particles passed straight through the gold foil.
- The atom had a small nucleus having positive charge because some of the α–particles having positive charge were slightly deflected by small angles.
- The size of the nucleus is very small compared to the size of the atom because very few α–particles appeared to rebound and most of the positive charge and mass of the atom is in the nucleus.

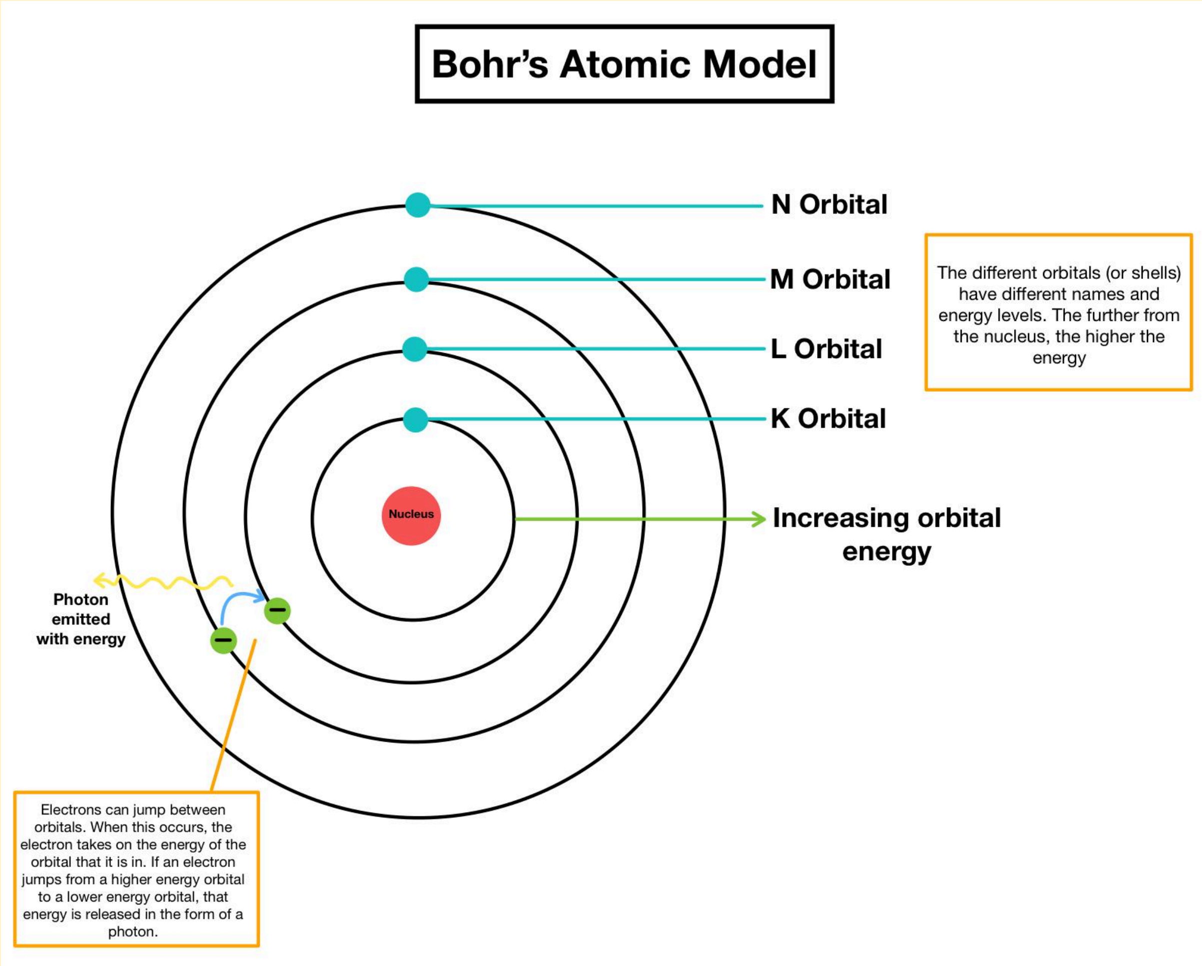
Rutherford's model of an atom :

- An atom has a positively charged nucleus at its centre and most of the mass of the atom is in the nucleus.
- The electrons revolve around the nucleus in different orbits.
- The size of the nucleus is very small compared to the size of the atom.

Defects of Rutherford's model of the atom : Any particle in a circular orbit would
undergo acceleration and during acceleration the charged particle would radiate energy.
So, the revolving electrons would lose energy and fall into the nucleus and the atom would
be unstable. We know that atoms are stable.

Bohr's model of an atom :

- An atom has a positively charged nucleus at its centre and most of the mass of the atom is in the nucleus.
- The electrons revolve around the nucleus in special orbits called discrete orbits.
- These orbits are called shells or energy levels and are represented by the letters K, L, M, N etc. or numbered as 1, 2, 3, 4 etc.
- While revolving in the discrete orbits the electrons do not radiate energy.



Distribution of electrons in different shells :

- The distribution of electrons in the different shells was suggested by Bohr and Bury.
- The following are the rules for filling electrons in the different shells :

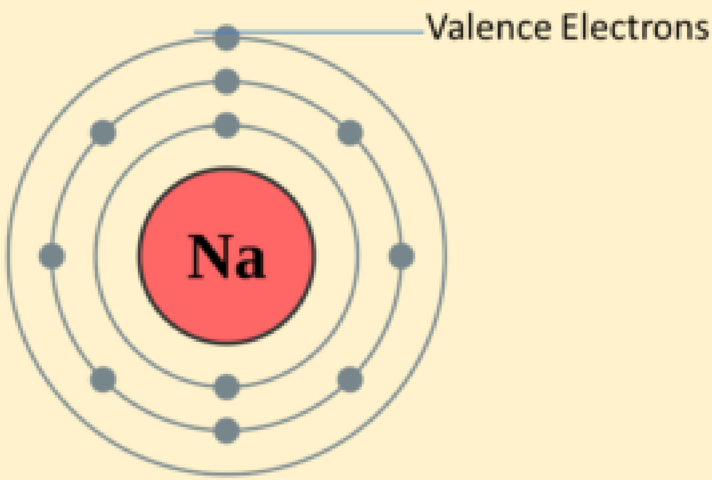
The maximum number of electrons in a shell is given by the formula 2n2 where n is the number of the shell 1, 2, 3 etc.

- First shell or K shell can have = $2n^2 = 2 \times 1^2 = 2 \times 1 \times 1 = 2$ electrons
- Second shell or L shell can have = $2n^2 = 2 \times 2^2 = 2 \times 2 \times 2 = 8$ electrons
- Third shell or M shell can have = $2n^2 = 2 \times 3^2 = 2 \times 3 \times 3 = 18$ electrons

- Fourth shell or N shell can have = $2n^2 = 2 \times 4^2 = 2x4x4 =$ 32 electrons and so on.

- The maximum number of electrons that can be filled in the outermost shell is 8.
- Electrons cannot be filled in a shell unless the inner shells are filled.

Valency : Valency is the combining capacity of an atom of an element.



- The electrons present in the outermost shell of an atom are called valence electrons.
- If the outermost shell of an atom is completely filled then they are inert or least reactive and their combining capacity or valency is zero.
- The inert elements like Helium atom has 2 electrons in the outermost shell and the atoms of other elements have 8 electrons in their outermost shell. Atoms having 8 electrons in their outermost shell are having octet configuration and are stable.

- If the outermost shell of an atom is not completely filled then it is not stable. It will try to attain stability by losing, gaining or sharing electrons with other atoms to attain octet configuration.
- The number of electrons lost, gained or shared by an atom to attain octet configuration is the combining capacity or valency of the element. E.g.

- Hydrogen, Lithium, Sodium atoms can easily lose 1 electron and become stable. So, their valency is 1.
- Magnesium can easily lose 2 electrons. So, its valency is 2.
- Aluminium can easily lose 3 electrons. So, its valency is 3.
- Carbon shares 4 electrons. So, its valency is 4.
- Fluorine can easily gain 1 electron and become stable. So, its valency is 1.
- Oxygen can easily gain 2 electrons. So, its valency is 2.
- Nitrogen can easily gain 3 electrons. So, its valency is 3.

Atomic number (Z) : The atomic number of an element is the number of protons present in
the nucleus of the atom of the element. All the atoms of an element have the same atomic number.

E.g.- Hydrogen – Atomic number = 1 (1 proton)

Helium – Atomic number = 2 (2 protons)
Lithium – Atomic number = 3 (3 protons)

Mass number (A) : The mass number of an element is the sum of the number of protons
and neutrons (nucleons) present in the nucleus of an atom of the element. The mass of an atom is mainly the mass of the protons and neutrons in the nucleus of the atom.
E.g.-

- Carbon – Mass number = 12 (6 protons + 6 neutrons), Mass = 12u
- Aluminium – Mass number = 27 (13 protons + 14 neutrons), Mass = 27u
- Sulphur – Mass number = 32 (16 protons + 16 neutrons), Mass = 32u

In the notation of an atom the atomic number and mass number are written as :

$$^{\text{Mass number}}_{\text{Atomic number}}X$$

E.g.- $^{14}_{7}N$

Isotopes : Isotopes are atoms of the same element having the same atomic numbers but
different mass numbers. E.g.-

- Hydrogen has three isotopes. They are Protium, Deuterium (D) and Tritium (T).

$^{1}_{1}H$ | $^{2}_{1}H$ | $^{3}_{1}H$

Protium | Deuterium | Tritium

- Carbon has two isotopes. They are $^{12}_{6}C$ and $^{14}_{6}C$.
- Chlorine has two isotopes. They are $^{35}_{17}Cl$ and $^{37}_{17}Cl$.

Isobars : Isobars are atoms of different elements having different atomic numbers but same
mass numbers. These pairs of elements have the same number of nucleons. E.g.-
Argon and Calcium have different atomic numbers (18 and 20 respectively) but have the
same mass numbers (40).
Iron and Nickel have different atomic numbers (26 and 28 respectively) but have the same
atomic mass numbers (58).