

Chapter 4:- Structure of the Atom

Part-1:

Dalton's atomic theory suggested that an atom was indivisible. However, the discovery of two fundamental particles named as electrons and protons, inside the atom, led to the failure of Dalton's atomic theory.

Fundamental particles of an atom:

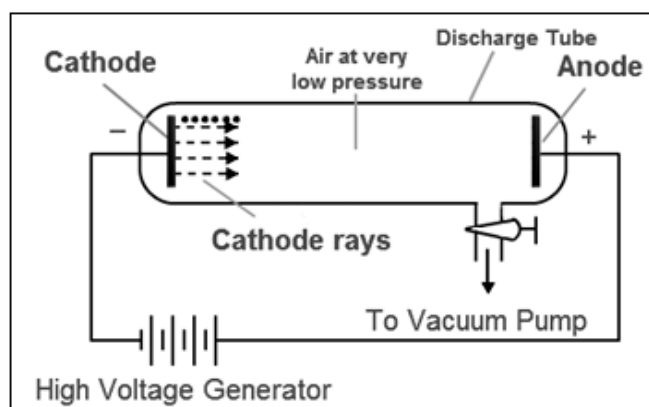
Three particles; electron, proton and neutron from which an atom is consisted of, are called fundamental particles of an atom or sub atomic particles.

Particle	Relative Charge	Relative Mass (amu)	Absolute Charge (C)	Absolute Mass (kg)
Electron (e^-)	-1	1/1836	-1.6×10^{-19}	9.11×10^{-31}
Proton (p^+)	+1	1	$+1.6 \times 10^{-19}$	1.67×10^{-27}
Neutron (n)	Neutral	1	0	1.67×10^{-27}

Discovery of Electron:

By J. J. Thomson in 1897.

He carried a cathode ray experiment in which observed a stream of negatively charged particles coming out of cathode towards the anode. These particles were named as electrons.



Thomson's Cathode Ray Tube Experiment

Discovery of Proton:

By Ernest Goldstein in 1886.

He observed in the same gas discharge tube, with different situations that the anode emitted positive particles which he named as Canal Rays. His experiment led to the discovery of proton.

Discovery of Neutron:

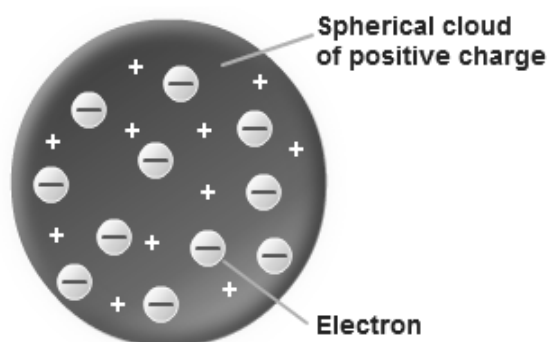
By J. Chadwick in 1932.

Neutron is present in the nucleus of all atoms.

1. Thomson's Model of Atom (by Joseph James Thomson in 1897)

Thomson's model of an atom proposed that:

- An atom is a uniform sphere of positive charges (due to presence of protons) as well as negative charges (due to presence of electrons).
- Atom as a whole is electrically neutral because the negative and positive charges are equal in magnitude.



Thomson's Model of an Atom

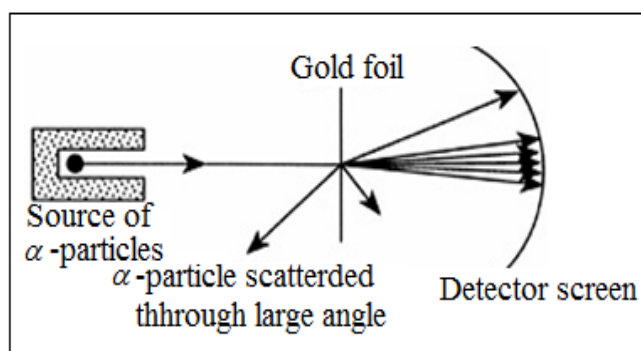
This model is also known as water melon model, plum pudding model and apple pie model.

Limitations of Thomson's Model:

- It failed to explain how protons and electrons were arranged in atom so close to each other.

2. Rutherford's Model of Atom (By Ernest Rutherford in 1909)

This was based on an experiment in which α – particles were bombarded on a thin gold foil.



Rutherford's α -particle scattering experiment

Observations of Rutherford's α -particle scattering experiment are:

(a) Most of the α – particles passed without any hindrance.

- (b) Some of the α – particles deflected from their original path at a noticeable angle.
- (c) Very few of the α – particles bounced back at their original path.

Postulates of Rutherford's Model of Atom:

- (a) Most of the part in an atom is empty.
- (b) There is a positively charged center in atom, which contains nearly the whole mass of atom. The centre is called nucleus.
- (c) The size of nucleus is very small compared to an atom.
- (d) Electrons revolve round the nucleus.

Drawbacks of Rutherford Model

- (a) According to Rutherford's Model, electron revolves round the positively charged nucleus which is not expected to be stable. But a charged particle in an accelerated motion along a circular path would continuously undergo loss of energy and finally would fall into nucleus. This makes an atom unstable while atoms are quite stable.
- (b) Rutherford model could not solve the problem of atomic mass of atom as it proposed only the existence of protons in the nucleus.

3. Bohr's Model of Atom (By Neils Bohr in 1913)

This model of atom states that:

- An atom consists of heavy positively charged nucleus. The whole mass of the atom is concentrated in the nucleus.
- The electrons in an atom revolve around the nucleus in definite circular paths called orbits or energy level.
- Each energy level is associated with definite amount of energy.
- The change in energy takes place when electron jumps from one energy level to another energy level.

Try the following questions:

Q.1 Why is the relative mass of an electron is taken as negligible ?

Q.2 Which observation of Rutherford's scattering experiment established the presence large empty space in atom?

Q.3 What are canal rays? What is the nature of the constituents of canal rays?

Q.4 How was Rutherford's model of atom failed to explain the stability of an atom?

Part-2:

Arrangement of electrons in an atom:

The arrangement of electrons in various shells (energy levels) of an atom of the element is known as Electronic configuration.

The Maximum number of electrons that could be put in a particular shell, i.e., energy levels, was given by Bohr and Bury.

According to Bohr-Bury Scheme:

- The maximum number of electrons that can be accommodated in any energy level is given by $2n^2$ where $n = 1, 2, 3, 4, \dots$ (for K, L, M, N.....)
- The maximum number of electrons in the outermost orbit will be 8 electrons even if it has capacity to accommodate more electrons.
- Electrons, are not accommodated in a given shell. Unless earlier shells are filled, that is stepwise filling of shells is followed.

Orbit

The circular path around the nucleus is called orbit, energy level or shell. Energy level are represented by English alphabets: K, L, M, N, and so on.

Therefore,

- 1st orbit is denoted by K
- 2nd orbit is denoted by L
- 3rd orbit is denoted by M, and so on.

Distribution of Electrons in a Orbit or Shell

The distribution of electrons in an orbit can be obtained by using formulae $2n^2$ where 'n' is number of that orbit.

For example:

Number of electrons in K-shell i.e. in 1st orbit

Here $n = 1$

Therefore, $2n^2 = 2 \times 1^2 = 2$

Thus, maximum number of electrons in K-shell, i.e. 1st shell = 2

Number of electrons in L-shell, i.e. in 2nd orbit

Here $n = 2$, therefore,

$2n^2 = 2 \times 2^2 = 8$

Thus, maximum number of electrons in L-shell = 8

In similar way maximum number of electrons in any shell can be calculated.

Valence Electrons

The electrons present in the outer most shell of an atom are known as valence electrons. These electrons determine the valency of an atom.

Valency

Valency is the combining capacity of an atom, i.e. their tendency to react and form molecules with atoms of the same or different elements.

For the atoms having valence electrons less than or equal to 4, valency is same as that of the number of valence electrons in that atom.

For example, valency of Magnesium (2, 8, 2) = 2

If number of valence electrons exceed 4, then valency = 8 – Number of valence electrons.

For example, valency of Oxygen (2, 6) = 8 – 6 = 2.

Valency of atoms with 8 valence electrons is zero as they have fully filled valence shell and cannot gain or lose electrons to form, molecules or compounds.

Atomic number (Z)

Atomic number of an element is equal to the number of protons present in the nucleus of an atom.

Since an atom is electrically neutral, thus number of protons and number of electrons are equal, therefore:

Atomic number (z) = number of protons = number of electrons.

Mass Number (A)

The total number of the protons and neutrons present in the nucleus of an atom is called mass number. It is denoted by A.

The protons and neutrons together are called nucleon.

The number of neutrons present in the nucleus of an atom is represented by N.

Isotopes

Atoms of the same element having same atomic number but different mass numbers are known as Isotopes.

For example:

(i) Carbon; $^{12}_6\text{C}$ and $^{14}_6\text{C}$

(ii) Hydrogen; ^1_1H and ^2_1H

(iii) Chlorine; $^{35}_{17}\text{Cl}$ and $^{36}_{17}\text{Cl}$

Applications of Isotopes

- Isotope of uranium is used as a fuel in nuclear reactor
- Isotope of cobalt is used in treatment of cancer
- Isotope of iodine is used in treatment of goitre.

Isobars

Atoms of different elements having same mass numbers are known as Isobars,
For example:

Potassium, K and Argon. Ar both have the mass numbers equal to 40.

Try the following questions:

Q 1. Helium atom has an atomic mass of 4 u and two protons in its nucleus. How many neutrons does it have?

Q 2. Number of electrons and neutrons in an atom are 3 and 4 respectively. Find its:

(a) Atomic number

(b) Mass number?

Q 3. Name the particles which determine the mass of an atom.

Q 4. What is octet rule?

Q 5. Why does Helium has Zero valency?

Q 6. The isotopes of an atom are chemically same. Why?