We have learnt that atoms and molecules are the fundamental building blocks of matter. The existence of different kinds of matter around us is due to different types of atoms and molecules present in them. Dalton assumed that atom is indivisible, i.e. it has no constituent particles. But, a series of experimental evidences revealed that an atom is not the smallest particle but some other particles smaller than the atom are also present which are called sub-atomic particles, i.e. electrons, protons and neutrons. The atoms of different elements differ in the number of electrons, protons and neutrons. In this chapter, we will describe how electrons, protons and neutrons were discovered and the various models that have been proposed to explain how these particles are arranged within the atom.

Charged Particles in Matter: - The particles that carry an electric charge are called charged particles. Generally, on rubbing the two objects together, they become electrically charged. It means that some charged particles are present within the atom or atom is made up of some charged particles. Two such particles are electrons and protons.

Cathode Rays

Discharge of Electricity through Gases**:** At normal pressure air or any other gas is a nonconductor of electricity, but at low pressures the gases become conductors of electricity. This can be demonstrated by a device known as the discharge tube. The apparatus consists of a long glass tube. At the two ends of the tube two metal plates are sealed. The plates are called the electrodes. These electrodes are connected to a high-voltage source. The electrode which is connected to the positive terminal of the source is called the anode, while the one connected to the negative terminal is called the cathode. The terms 'anode' and 'cathode' are used following the convention established by Michael Faraday. The pressure of the gas inside the tube can be reduced by pumping it out through the opening at P**.** A number of interesting things happen when a high voltage (say, 10,000 V) is applied across the electrodes of the discharge tube, and the pressure of the gas inside the tube is lowered. The phenomena observed under reduced pressure and high voltage depends upon the nature of the gas in the tube. It was discovered by **JJ Thomson.**

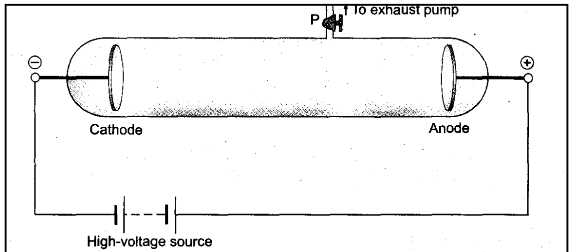


Fig. 4.1 Discharge tube

1. When the pressure of the gas in the discharge tube is at atmospheric pressure and a high voltage is applied across the electrodes, nothing noticeable happens. But, as the pressure is lowered and/or the voltage is increased, sparking, or irregular streaks of light are seen in the tube.

2. When the pressure of the gas is lowered to about 10 mm of mercury, the irregular streaks of light become a continuous column of light that glows. The column starts from the anode and reaches almost up to the cathode. This column is called the positive column. The colour of the column of light depends on the nature of the gas taken. In case of air, the colour is reddish, and for carbon dioxide it is bluish.

Properties of Cathode Rays:

1. They emanate normally from the surface of the cathode and travel in straight lines at a high velocity.
2. They are a beam of minute material particles.
3. They consist of negatively charged particles
4. The nature of cathode rays does not depend upon the nature of gas in the discharge tube and nature of cathode material.

5. For each negatively charged particle of cathode rays, the ratio of charge (e) to mass (m) is constant. Electrons are negatively charged particles and are denoted by 'e'.

Characteristics of Electrons:

1. Mass: The mass of an elec6on is about 1/1838 the mass of a hydrogen atom. The mass of a hydrogen atom is 1 amu (atomic mass unit), hence the relative mass of an electron is equal to 1/1838 amu. As you know, the atomic mass unit, or amu, is a unit of mass used to express relative atomic masses. It is equal to 1/12 of the mass of an atom of carbon -12 and is equal to 1.660 x 10^{-27} kg. The absolute mass of an electron is 9.109 x 10^{-28} g. Since this is negligibly small, the mass of an electron is assumed to be zero.

2. Charge: The electron is found to carry 1.6 x 10^{-19} C of negative charge. This quantity of charge has been shown to be the smallest negative charge carried by any particle. Thus, charge carried by an electron is taken to be a unit negative charge (i.e., -1).

Origin of Cathode Rays: The gas in the discharge tube is made up of atoms. All the atoms contain electrons. When high voltage is applied, the electrical energy knocks out some of the electrons from the atoms. These electrons constitute the cathode rays.

Anode Rays

An atom is electrically neutral but the formation of cathode rays has shown that all the atoms contain negatively charged electrons. So, atoms must also some positively charged particles to balance negative charge of electrons. This was the basis of discovery of protons. Before the identification of electron, E. Goldstein in 1886 discovered the presence of new radiations known as canal rays or anode rays. These are the positively charged rays which are seen moving from the anode towards cathode in a specially designed discharge tube (with a porous cathode), when a high voltage is applied across the electrodes. Porous cathode is used to provide the path for passing anode rays. It led to the discovery of another sub-atomic particle, the proton. Protons are positively charged particles and are denoted by 'p^+'

Properties of Anode Rays:

1. Anode rays travel along straight paths and hence they cast shadows of objects placed in their path.
2. They rotate a light paddle wheel placed in their path. This shows that anode rays are made up of material particles.
3. They are deflected towards the negative plate of an electric field. This shows that these rays are positively charged.
4. For different gases used in the discharge tube, the charge to mass ratio (elm) of the positive particles constituting the positive rays is different. When hydrogen gas is taken in the discharge tube, the e/m value obtained for the positive rays is found to be maximum. Thus, the positive particle obtained from hydrogen gas is the lightest among all the positive particles obtained from different gases. This particle is called the proton.

Characteristics of Protons:

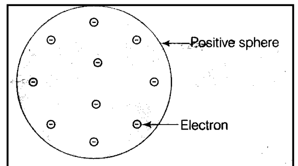
1. A proton is a positively charged particle present in the atoms of all elements.
2. The mass of a proton is 1838 times that of an electron. The relative mass of a proton is equal to 1.005757 amu which is taken to be equal to 1 amu. The absolute mass of a proton is 1.672 x 10^{24} g.
3. The charge on a proton is equal in magnitude but opposite in sign to that of an electron. The charge carried by a proton is equal to 1.602 x 10^{-19}C which is taken to be one unit of positive charge (i.e., +1). Thus, a proton is said to carry a unit positive charge.

Conclusion: The mass of a proton is taken as one unit and its change is (+ 1), whereas the mass of an electron is considered to be negligible and its charge is (-1). It seems that an atom is composed of protons and electrons, mutually balancing their charges.

ABHYAS Academy, Behind Pragat Shiv Mandir, Near Govt. College, Nishat Cinema Road, Ambala Cantt.
Ph No. +91-171-2631595, 9416541198, e-Mail: anusethi1968@yahoo.com Website: www. abhyasonline.in

Structure of an Atom: According to Dalton's atomic theory, atom was indivisible and indestructible. Now, the discovery of two fundamental particles (electrons and protons) inside the atom, led to the failure of this aspect of in Dalton's theory. To know the arrangement of electrons and protons within an atom, many scientist proposed various atomic models.

Thomson's Model of an Atom: J.J. Thomson was the first scientist to propose a model for the structure of an atom. Thomson's model of an atom was similar to Christmas pudding. The electrons in a sphere of positive charge were like currants (dry fruits) in a spherical Christmas pudding. It can also be compared to a watermelon, in which, the positive charge in an atom is spread all over like the red edible part, while the electrons studded in the positively charged sphere, like the seeds in the watermelon.



Thomson's model of an atom

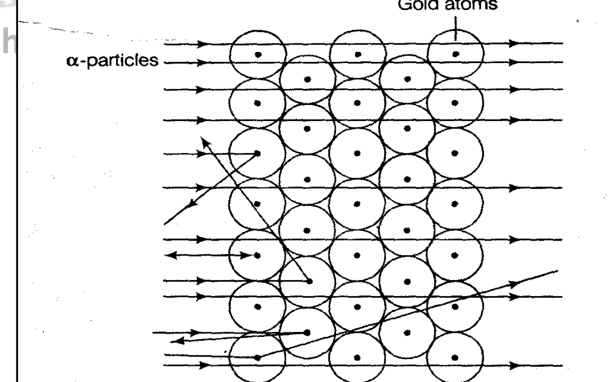
Following are the postulates of this model:

1. Electrons are embedded in the sphere of positive charge.
2. The negative and positive charges are equal in magnitude. Therefore, the atom as a whole is electrically neutral.
3. The mass of an atom is assumed to be uniformly distributed throughout the atom.

Limitations of Thomson's Model of an Atom:

1. J.J. Thomson's model could not explain the experimental results of other scientists such as Rutherford, as there is no nucleus in the atomic model proposed by Thomson.
2. It could not explain the stability of an atom, i.e. how positive and negative charges could remain, so close together.

Rutherford's Model of an Atom: Ernest Rutherford With the help of Geiger and Marsden designed an experiment to know how the electrons are arranged within an atom. He bombarded thin sheets of gold foil with fast moving a-particles (these are doubly charged helium ions having a mass of 4 u). He selected a gold foil because he wanted a layer as thin as possible. This gold foil was about 1000 atoms thick. The following observations were made by Rutherford:



Scattering of α-particles by gold foil

1. Most of the fast moving alpha-particles passed straight through the gold foil.
2. Some of the a-particles were deflected by the foil by small angles.
3. Very few a-particles (one out of 12000) appeared to rebound.

<u>On the basis of his experiment, Rutherford concluded that:</u>

1. Most of the space inside the atom is empty because most of the alpha-particles passed through the gold foil without getting deflected.
2. Very few particles were deflected from their path, indicating that the positive charge of the atom occupies very little space.
3. A very small fraction i.e. 1 in 1,00,000 of alpha-particles were deflected by 180º (i.e. they rebound), indicating that all the positive charge and mass of atom were concentrated in a very small volume within the atom.

On the basis of his experiment, Rutherford put forward the nuclear model of an atom, having the following features:

ABHYAS Academy, Behind Pragat Shiv Mandir, Near Govt. College, Nishat Cinema Road, Ambala Cantt.
Ph No. +91-171-2631595, 9416541198, e-Mail: anusethi1968@yahoo.com Website: www. abhyasonline.in

1.There is a positively charged, highly densed centre in an atom, called nucleus. Nearly, the whole mass of the atom resides in the nucleus.
2. The electrons revolve around the nucleus in circular path called orbits.
3.The number of electrons in the orbits is equal to the number of positive charge.
4.Most of the space in the atom is empty.
5.The size of the nucleus (10^{-5}m) is very small as compared to the size of the atom (10^{-10}m).

Note Rutherford suggested that his model of atom was similar to that of our solar system. In the ‘solar system, the different planets are revolving around the Sun. In the same manner, in an atom the electrons are revolving around the nucleus. So, these electrons are also called planetary electrons.

Limitations of Rutherford’s Model of an Atom:

1. Rutherford had proposed that electrons revolve at high speed in circular orbits around a positively charged nucleus. But, such a model has a defect. To remain in a circular orbit the electron would have to be accelerated centripetally or radially. But, according to electromagnetic theory, if a charged body (electron) is accelerated around another charged body (nucleus) then there would be a continuous radiation of energy from the moving body. This loss of energy would slow down the speed of the electron and eventually the electron would fall into the nucleus. But, such a collapse does not occur—Rutherford’s model could not explain why.
2. Rutherford’s model could not explain the distribution of electrons in the extra nuclear portion of the atom.

<u>Discovery of neutron</u>

The helium atom has 2 electrons and 2 protons. So, the mass of the helium atom was expected to be twice the mass of the hydrogen atom, which has 1 electron and 1 proton. But, actually the mass of the helium atom is four times that of the hydrogen atom. It was found that atoms of all the elements (except hydrogen) were at least twice as heavy as could be explained by the number of protons they had. To explain this it was predicted that other particles with no charge, but mass equal to that of a proton, must be present in all atoms except hydrogen. This prediction was proved to be correct with the discovery of the neutron.

In 1932, James Chadwick bombarded the element beryllium with alpha-particles. He observed the emission of a radiation with the following properties.
1. The radiation was highly penetrating.
2. The radiation remained unaffected in an electric or magnetic field, i.e., the radiation was neutral.
3. The particles constituting the radiation had the same mass as that of the proton. Thus the relative mass of such a particle = 1 amu and the absolute mass $=1.6x10^{-24}$g. Because of their electrical neutrality, these particles were called neutrons.

• It is now well-established that the neutron, like the electron and the proton, is a fundamental constituent of an atom. Neutrons are located in the nucleus along with the protons.