5 Structure of Atom

5.1 Introduction

The substance is made up of molecules or atoms. Atom is the smallest, indivisible particle having independent existence. This concept was developed by John Dalton in the 19th century. It was useful in understanding the chemical reactions and the properties of gases as well as useful in expressing relative masses of different atoms. The experiments carried out during 1895 and 1905, have substantiated the explanation about structure of atom.

It has been proved from the study of hydrogen spectrum, that hydrogen atom contains one electron and from the study of spectrum of sodium, it has been proved that there are more than one electrons in its atom.

5.2 Fundamental Experiment of Electric Discharge Tube and Discovery of Electron

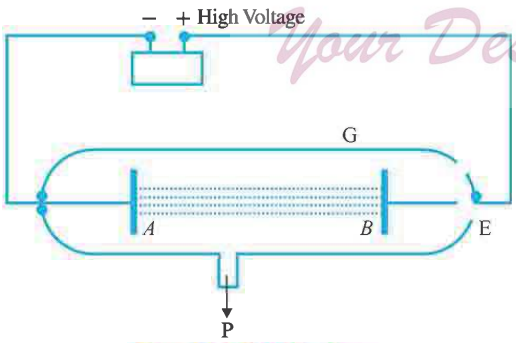


Figure 5.1 Cathode Rays

In the Figure 5.1, the line diagram of electric discharge tube is given. Vacuum is created in this discharge tube with the help of vacuum pump P. A and B are metal plates in the tube, which are cathode and anode respectively. When they are connected to high voltage, the cathode rays are produced from cathode A and as they have negative charge they move towards the anode with speed. This cathode rays are really the flow of electrons having negative charge and it is deviated under the effect of electromagnetic field. Scientists J. J. Thomson and Crookes proved from the experimental observations that the cathode rays emitted from cathode is the flow of electron and this flow of electrons possesses negative charge.

5.3 X-ray and Radioactivity

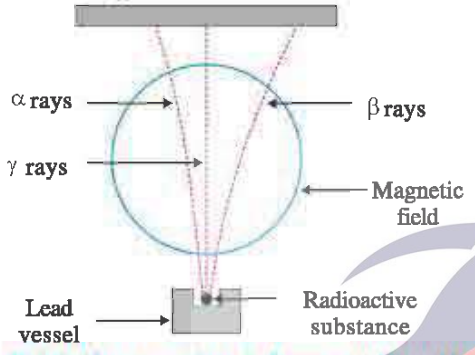
In 1896, Rontgen produced cathode rays by passing electric current in electric discharge tube but when these rays struck with the wall of the tube or anticathode, a new type of rays were produced from them. These rays were travelling in a straight line like the light rays but when passed through electromagnetic radiation, they were not deviated. In addition, they were able to pass through the opaque substance like black paper. These rays also affected the photographic plate covered by opaque substance. These unknown rays were called X-rays. Now they are also known as Rontgen rays.

Cathode rays is the beam of electrons. While X-rays are electromagnetic waves having very short wavelength. If the electrons having very high velocity are stopped by putting some type of resistance (anticathode) the X-rays are produced.

X-rays are mostly used in medical science. X-rays are used to detect a fracture in the bone, to observe defect in lungs, to diagnose cancer of oesophagus and to diagonise physical disabilities.

In 1889, scientist Ernest Rutherford designated two types of radiations from radioactive atom like uranium as alpha (α) rays and beta (β) rays. Afterwards French scientist Willard discovered third type of rays which he called γ-rays. With the help of the strong electromagnetic field it is shown that α - rays possess positive electric charge and β - rays possess negative electric charge while γ - rays do not possess any electric charge.

Alpha (α) rays are fast moving helium nuclei (He^{2+}) and their penetration power is least. Beta (β) rays are fast moving electrons and their penetration power is more than α - rays. Gamma rays are electromagnetic rays and their penetration power is the highest.



Radiations emitted from radioactive substance in presense of magnetic field.

From the systematic study it has been shown that the rays emitted from certain minerals are not able to pass through opaque substance like black paper. Obviously, these rays must have been emitted from the atoms. From this it is clear that certain atoms can be divided and they are unstable.

Atoms must have been made up of at least two types of very small particles. Some of these very small particles must be possessing positive electric charge and some other very small particles must be possessing negative electric charge. In addition the number of particles possessing positive charge and particles possessing negative charge must be equal because the atom on the whole is electrically neutral. The very small particles possessing positive electric charge were given the name protons and the very small particles possessing negative charge were given the name electrons.

5.4 Atomic Model Proposed by Thomson

Thomson's atomic model : Scientist Thomson first of all proposed atomic model describing arrangement of protons and electrons in atom. In this model, atom is like a spherical ball and the positive electric charge is uniformly spread on its total volume.

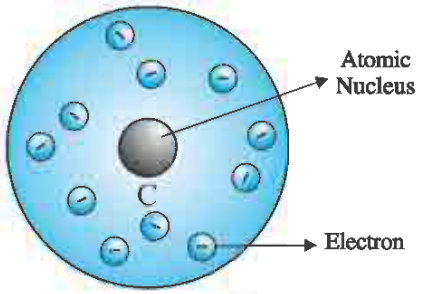


Figure 5.3

In this spherical ball protons possessing positive electric charge and the negative electric charge possessing electrons are arranged at definite places. If we accept this imagination then because of the attraction of positive and negative electric charges they should mix with each other and become chargeless. Over and above, this, the arrangement could not explain the different chemical properties of different elements. Thus, this model was not accepted.

5.5 Experiments of Ernest Rutherford

In the combined atom composed of proton and electron, the proton possessing positive electric charge is 1836 times heavier than the electron possessing negative charge. How these two types of very small particles are arranged in an atom can be explained from Rutherford's experiment. Rutherford presented the experiment to show how very small electrons are arranged an the atom.

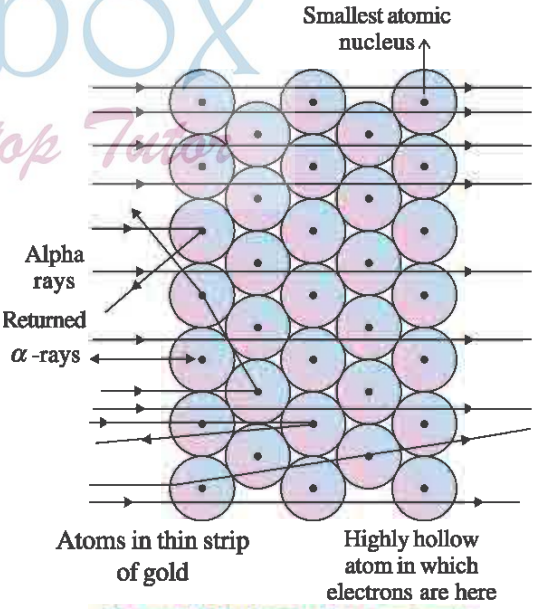


Figure 5.4 Rutherford's experiment : Scattering of α-rays by foil of gold

Rutherford made alpha (α) rays emitted from radioactive element polonium (Po) incident from one side on the foil (0.004 mm thick) of gold.

If the atom is completely filled uniformly in its volume, then all the α rays should return (reflect) after striking the gold foil and should be deviated more or less but Rutherford observed that most of the rays passed through in straight way from the gold foil, while very few rays returned in a different path after striking the gold foil.

The proportion of alpha rays returning after deviation and the alpha rays passing through in straight way was about 1:1200.

From this Rutherford determined that in the middle of the atom of gold there must be very small, heavy and positive electric charge possessing centre (nucleus.). Around this centre (nucleus) electrons with negligible weight and possessing negative charge (particles) must have been arranged. Only very less alpha rays were returning after striking with the nucleus of the atom. Most of the alpha rays were passing through and so the atom must be hollow.

When the thickness of the gold foil was doubled, the number of alpha particles reflecting after striking was also doubled. Rutherford found out from calculations that atomic nucleus is 10^5 times smaller than the total area of the atom. The radius of the atom is 10^{-8} centimeter (10^{-10} meter) and the radius of the nucleus is 10^{-13} centimeter (10^{-15} meter). Hence, we can say that atom is relatively hollow. In the centre of the atom heavy nucleus is there which is responsible for the mass of the atom and the electrons possessing negligible mass are arranged around the nucleus.

The arrangement of electrons around the nuecleus of an atom containing protons was explained by scientist Niels Bohr.

Upto 1910, proton (p^+) and electron (e^-) were the two fundamental particles discovered. Mass of proton is 1836 times more than that of electron. Hence, the atom can be described by placing all the protons in the nucleus and arranging same number of electrons moving around it. Mass of proton is 1.00723u and mass of electron is 0.00055u. In SI units u is written instead of amu. (atomic mass unit.)

5.6 Atomic Model of Bohr

Bohr proposed atomic model in 1912. Bohr mentioned that electrons are moving around the nucleus in atomic levels at a definite distance from the positively charged nucleus. This atomic level at a definite distance from the centre (nucleus) is called energy level or orbit. The electron continuously moving in this orbit does not lose energy and so such orbits are called stationary orbits. The energy of the orbit which is nearest to the nucleus is least. The energy of the orbits away from the nucleus gradually increases.

According to atomic model of Bohr, the arrangement of the electrons around the atomic nucleus can be shown as follows :

(i) The first orbit nearest to the nucleus (K orbit) can accommodate two electrons.

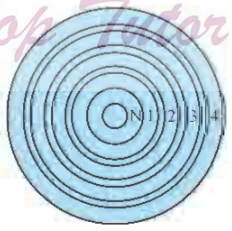
(ii) The second orbit (L orbit) can accommodate 8 (eight) electrons.

(iii) The third orbit (M orbit) can accommodate 18 (eighteen) electrons.

(iv) The fourth orbit (N orbit) can accommodate 32 (thirty two) electrons.

(v) In second, third, fourth orbits there are subsidiary orbits which are called orbitals. We shall study the difference between orbit and orbital later on.

(vi) Generally the electrons are arranged in an order. After filling the first orbit with electrons, the extra electrons are arranged stepwise.



n = Fourth level (N level)
n = Third level (M level)
n = Second level(L level)
n = First level (K level)
N = Centre of Atom

Figure 5.5 Orbits of an atom

The number of protons or electrons in neutral atom of element is called atomic number (Z) of an element. In the table 5.1 the structure of atoms showing arrangements of electrons according to Bohr's atomic theory of elements no. 1 to 20 are given.

Table 5. 1 Distribution of electrons in orbits of first 20 elements of periodic table

Name of element	Symbol	Atomic number	Number of protons	Number of neutrons	Number of electrons	Arrangement of electrons in orbits				
						K	L	M	N	Valency
Hydrogen	H	1	1	-	1	1	-	-	-	1
Helium	He	2	2	2	2	2	-	-	-	0
Lithium	Li	3	3	4	3	2	1	-	-	1
Beryllium	Be	4	4	5	4	2	2	-	-	2
Boron	B	5	5	6	5	2	3	-	-	3
Carbon	C	6	6	6	6	2	4	-	-	4
Nitrogen	N	7	7	7	7	2	5	-	-	3
Oxygen	O	8	8	8	8	2	6	-	-	2
Fluorine	F	9	9	10	9	2	7	-	-	1
Neon	Ne	10	10	10	10	2	8	-	-	0
Sodium	Na	11	11	12	11	2	8	1	-	1
Magnesium	Mg	12	12	12	12	2	8	2	-	2
Aluminium	Al	13	13	14	13	2	8	3	-	3
Silicon	Si	14	14	14	14	2	8	4	-	4
Phosphorus	P	15	15	16	15	2	8	5	-	3,5
Sulphur	S	16	16	16	16	2	8	6	-	2
Chlorine	Cl	17	17	18	17	2	8	7	-	1
Argon	Ar	18	18	22	18	2	8	8	-	0
Potassium	K	19	19	20	19	2	8	8	1	1
Calcium	Ca	20	20	20	20	2	8	8	2	2

5.7 Valence Electrons and Valency

The electrons present in an atom are arranged in different orbits having increase in energy around the nucleus. When electrons are arranged, the electrons in the outermost orbit are responsible for emission spectra and the chemical properties of the elements. They are called valence electrons. The number of electrons in the valence orbit is the valency of the atom.

Valency = Number of electrons in valence orbit

5.8 Discovery of Neutron

Rutherford had suggested in 1920 that the element helium (He) after hydrogen (H) has two protons and so its mass should be almost double of that of hydrogen but it was found to be about four times. So it was necessary to know the reason behind the increase in mass. There is a possibility of the existence of particles having mass almost equal to that of proton (1.00833u). These particles are mentioned as neutrons (n). Eventhen, for a number of years there was no direct proof of existence of neutrons. But Chadwick in 1932 doing research on radioactivity discovered this fundamental particle of the atom called neutron. Neutron does not possess any type of electric charge. It is neutral and its mass is almost equal to the mass of proton and is 1838 times more than that of electron. Hence the mass of an atom of any element is the sum of number of protons and number of neutrons in the nucleus. It is called atomic mass.

$\therefore A = p + n$

For example, the atomic mass of carbon possessing six protons and six neutrons is equal to 6+6=12. Similarly the atomic mass (A) of sodium possessing 11 protons and 12 neutrons is equal to 11 + 12 = 23

5.9 Isotopes and Radioactivity

From the experimental observations of mass spectrometer it has been found that mass of atoms of certain elements have more than one value. Such type of different mass possessing atoms are called isotopes of each other.

Suppose the number of protons in atomic nucleus of two or more than two atoms of an element is same but the number of neutrons is different; then there will be change in atomic masses of the same element.

The atomic masses of these isotopes are different but their chemical properties are similar.

The word isotope means iso = same and topos = place. Thus the atoms of the elements whose position in the periodic table is same are called isotopes.

e.g. Hydrogen atom has three isotopes :

protium ($^{1}_{1}H$), deuterium ($^{2}_{1}H$) or (D), tritium ($^{3}_{1}H$) or (T)

The number of neutrons in protium is 0 (zero). The number of neutrons in deuterium is 1 and that in tritium is 2. They are called isotopes because the number of neutrons is different.

Similarly, $^{16}_{8}O$ has two other isotopes $^{17}_{8}O$ and $^{18}_{8}O$. $^{232}_{92}U$ has other isotopes $^{235}_{92}U$ and $^{238}_{92}U$.

The isotopes of some elements having high atomic masses possess the property of radioactivity. e.g. Uranium (U). In fact, this is an old concept because element like lead (Pb) possesses high atomic mass even then it is not radioactive. The other radioactive elements like uranium having unstable nucleus emits very small particles like alpha and beta and neutral gamma rays. As the atomic mass of an element increases, the number of protons increases and along with that if number of neutrons also increases, the atom becomes unstable and so they are radioactive. If the ratio of neutrons to protons exceeds 1.6, the property of radioactivity is acquired.

Radioactive isotopes are used in determining age of old trees, age of fossils of man and animals, radiometric dating, medical treatments, industries etc and also in the treatment of diseases like cancer.

What have you learnt ?

- You have developed the understanding about substance, being made up of molecule or atom and it is the smallest indivisible particle.
- Discussed about the discovery of electron and fundamental experiments of electric discharge tube.
- The achievements of various scientists, Thomson, Crookes, Rontgen, Dalton and Rutherdford have been discussed in this unit.
- Discussion of α-rays and radioactivity α, β, γ radiations.
- Thomson's atomic model, Rutherdford's experiment, Bohr's atomic model, discovery of neutron.
- You have been able to learn about valence electrons and valency as well as isotopes.
- You have been able to learn about radioactivity and its utility.

EXERCISE

1. Select the proper choice from the given multiple choices :

(1) What is correct from the following about cathode rays ?

(A) Positively charged particles (B) Negatively charged particles

(C) Radiations (D) Beam of electrons

(2) What is correct from the following about X-rays ?

(A) Beam of electrons (B) Electromagnetic waves

(C) Positively charged particles (D) Negatively charged particles

(3) Who is the discoverer of X-rays from the following ?

(A) Willard (B) Rontgen (C) Rutherdford (D) Chadwick

(4) Who discovered the particles emitted with γ-rays other than the γ-rays ?

(A) Willard (B) Rontgen (C) Chadwick (D) Rutherdford

(5) Which particles possess positive electric charge ?

(A) X-rays (B) β - particles (C) γ radiation (D) α particles

(6) Which scientist discovered neutrons ?

(A) Thomson (B) Rutherdford (C) Niels Bohr (D) Chadwick

(7) According to Rutherdford's suggestion how many times smaller should be the atomic nucleus than the total area of an atom ?

(A) 10^{15} (B) 10^{10} (C) 10^{8} (D) 10^{5}

(8) Which radiation was discovered by Willard ?

(A) α-rays (B) β-rays (C) γ-rays (D) X-rays

(9) Which of the elements, has electronic configuration 2, 8, 7 arrangement in atomic structure ?

(A) Br (B) Cl (C) F (D) I

(10) In which atom the electronic configuration 2, 8, 2 is available ?

(A) Fe (B) Mg (C) Mn (D) Mo

(11) Which of the following does not undergo deviation ?

(A) β-rays (B) α-rays (C) γ-rays (D) X-rays

2. Answer the following questions in short :

(1) What is indicated by hydrogen and sodium spectrum ?

(2) What is cathode rays ?

(3) What effect is experienced by cathode rays in electromagnetic field ?

(4) Give difference between cathode rays and α-rays ?

(5) Write properties of X-rays.

(6) Write uses of X-rays.

(7) How X-rays can be produced from flow of electrons ?

(8) What information about atomic nucleus was given by Rutherdford from his experiment ?

(9) What type of rays are obtained from uranium metal ?

(10) α-rays possess positive charge and β-rays possess negative charge. How can this be indicated ?

(11) Why Thomson's atomic model was not accepted ?

(12) On what basis Rutherford said that atom is hollow ?

(13) Mention the symbols of first, second and third orbit of an atom and how many electrons can be accommodated in each of them.

(14) Give definitions : Atomic number, atomic mass, isotope.

(15) What is called a stationary (stable) orbit ?

(16) What is called a valence electron ?

(17) Mention the importance of valence electrons.

(18) Which scientist and by which discovery invented neutrons ?

(19) Give names of isotopes of hydrogen. Mention the number of protons and neutrons in them.

(20) Which isotopes are called radioactive ? Give examples.

(21) Give information about properties of isotopes.

(22) Mention the importance of radioactive isotopes.

(23) Give arrangement of electrons of following elements in their orbits :

$_{11}Na$, $_{13}Al$, $_{19}K$, $_{16}S$, $_{8}O$

(24) Write electronic structure of following atoms on the basis of Bohr's model :

$_{10}Ne$, $_{12}Mg$, $_{15}P$, $_{17}Cl$, $_{20}Ca$

3. Answer the following questions in detail :

(1) Write in brief about the production of cathode rays and its properties.

(2) Mention the production of X-rays, its properties and uses.

(3) Explain Rutherford's experiment in brief and give the results.

(4) Write a short note about Niels Bohr's atomic model.

(5) Write a short note on discovery of neutron.

(6) Write a short note on isotopes and radioactivity.

(7) What is meant by valency ? What is the relation between valency and electronic structure ? Explain it.