WHAT IS MEANT BY THE ELECTRIC DUSCHARGE THROUGH GASES?

Electrical discharge through gases is studied by using a specially designed glass tube commonly called as a discharge tube. It consists of a cylindrical glass tube having a side tube, and two metallic electrodes one at each end. These electrodes can be connected to the respective terminals of a high-tension power supply. Air from inside the tube can be pumped out by connecting the side tube to a vacuum pump, and a desired pressure can be maintained inside the tube.

HOW ARE THE CATHODE RAYS PRODUCED?

When a very high electrical potential (10,000 volts) is applied across a gas taken in a discharge tube at a very low pressure (≈ $10^{-=5}$ atm or 0.001 torr; 1 torr = 1 mm of Hg column), some radiations are emitted from the cathode. These radiations are called cathode rays.

The emission of cathode rays in a discharge tube is shown in the fig. At this stage, the glass (walls) of the discharge tube opposite to the cathode starts glowing with a faint greenish light. This fluorescence of the walls is due to the bombardment of the glass by some rays emerging from the cathode. Therefore, these rays were called cathode rays.

THOMSON'S MODEL OF AN ATOM :-

J.J. Thomson assumed that an atom is a uniform sphere of positive charges with electrons embedded in it. The atom may thus be visualized as a pudding or Christmas cake with resins (electrons) embedded in it. Later on, this model of an atom came to be known as the 'resins pudding model'. In 1904, Thomson proposed the following:

1) An atom consists of a positively charged sphere and the electrons are embedded in it.
2) The negative and the positive charges balance each other.
3) Atom as a whole is neutral.

This model explained the results of experiments conducted by other scientists.

THE ELECTRON:-

Properties of the cathode rays showed that these consist of streams of negatively charged particles having very small mass. Sir J.J. Thomson called these particles as *corpuscles of negative electricity.* Later, G.J. Stoney called these particles *electrons,*

Thus, Electron is a negatively charged particle having very small mass. Mass and charge of an electron are given below.

1) **Mass of an electron**(m_e). The mass of an electron is about $\frac{1}{1840}$ times that of a hydrogen atom. Its absolute mass is ,

$m_e = 9.108 \times 10^{-31}$ kg = 9.108×10^{-28} g

It is a very light particle, and therefore, it makes very little contribution to the total mass of the atom in which it is contained.

2) **Charge on an electron(e).** An electron possesses one unit negative charge. It has been found to be the smallest negative charge that any particle can carry.

Charge on an electron, e = -1.602×10^{-19} coulombs.

Canal Rays(Anode Rays):-

E. Goldstein another scientist in 1886 repeated Thomson's experiment using a perforeated cathode (a cathode with holes) Fig. 4.2. when he passed electric discharge through the gas under reduced pressure (very low pressure) in a discharge tube with a perforated cathode, he found faint red glow of stream of rays passing through the holes of the cathode moving away from the anode behind the cathode. When these rays strike the walls of the discharge tube, they produce a faint red light. Evidently these rays carry positive charge. These are moving away from positively charged electrodes towards negatively charged electrodes. These rays are therefore called positive rays or anode rays. These rays are also called canal rays because they have passed through canal like perforations in the cathode.

E. Goldstein thus revealed that a positively charged particle other than electron is present inside the atoms.

E. Goldstein found that the charge on each particle is equal in magnitude to that of electron with opposite sign. It has mass equal to that of hydrogen atom. He named these particles as protons. It is represented as 'P' 'P^+'. Its mass and charge are taken as one and plus one (+I) respectively.

Proton is a positively charged particle. Its physical characteristics are:

1. **Mass of a proton: -** The mass of a proton is equal to that of a hydrogen atom. Its mass is about 1840 times that of an electron. Mass of proton = 1.676×10^{-27} kg = 1.676×10^{-24} g.
2. **Charge on a proton: -** Proton carries a charge equal in magnitude, but opposite in sign to that carried by an electron. Thus, it has a unit positive charge. Charge on a proton = + 1.602×10^{-19} coulombs.

HOW WAS THE NEUTRON DISCOVERED?

In 1920, Rutherford found that except hydrogen atom, the atomic masses of other atoms could not be explained on the basis of only electrons and protons. For example, helium atom contains two protons in it. As a result, the atomic mass of helium should be double than that of a hydrogen atom. From the e/m values, it was discovered that the mass of a helium atom (to be precise, that of a helium ion), is four times the mass of hydrogen atom. To explain this, Rutherford in 1920, predicted the presence of another kind of particle in atoms. He further predicted that such a particle should be electrically neutral, and have a mass equal to that of a proton.

Chadwick (in 1931). Discovered the presence of these fundamental neutral particles in to the atom and called them neutrons. Thus, the relative mass of an atom is equal to the sum of the relative masses of all protons and all neutrons present in the atom. This accounts for the relative mass of an atom which is two times the mass of all the protons present in the atom.

WHAT ARE THE CHARACTERISTICS OF A NEUTRON?

1. **Mass of a neutron:-** Mass of a neutron is equal to that of a proton. Thus,
   Mass of a neutron = 1.676×10^{-27} kg = 1.676×10^{-24} g
2. **Charge of a neutron:-** Neutrons do not carry any electrical charge. So, neutrons are neutral particles.

WHAT IS RUTHERFORD'S SCATTERING EXPERIMENT?

In his famous experiment, Rutherford bombarded a thin sheet (0.00006 cm thick) of gold foil with alpha (α) particles in an evacuated chamber. A simplified picture of α - particles scattering by a thin gold foil is shown in fig.

The following observations were made on the results obtained.

1. Most of the α-particles passed through the foil straight without suffering any change in direction.
2. A small fraction of α-particles were deflected through small angles, and a few through larger angles.
3. One particle in every 10,000 returned back. This observation surprised everyone in the laboratory.`

WHAT CONCLUSIONS WERE DERIVED FROM THE SCATTERING EXPERIMENT?

The following conclusions were drawn from the Rutherford's Scattering experiment:-

1. Most of the α-Particles passed straight through the foil without suffering any deflection. This shows the most of the space inside the atom is empty or hollow.
2. Some of the α-particles suffered deflection by 90^0 or even larger angles. For this to happen, α-particles (positively charged) must approach a heavy positively charged core inside the atom (like charges repel each other). This heavy positively charged Core inside the atom was named as Nucleus.
3. Since the number of α - particles which bounced back was very small, the volume occupied by the nucleus is very small as compared to the total volume of the atom.
4. The α-particles have appreciable mass. These are deflected by the nucleus. It means that almost the entire mass of the atom lies at its center, i.e., the entire mass of an atom is concentrated inside its nucleus.

RUTHERFORD'S NUCLEAR MODEL OF ATOM: -

On the basis of the famous α-particle scattering experiment, Rutherford proposed his nuclear model of an atom in 1911. The main points of the Rutherford's nuclear model are described below: -

1. An atom consists of a positively charged nucleus, which is surrounded by electrons moving around it. Nucleus of an atom consists of protons and neutrons.
2. Electrons and the nucleus are held together by electrostatic forces of attraction: electrical charges of opposite sign attract each other.
3. The effective volume of the nucleus is very small as compared to the volume of the atom. That is , the size of the nucleus is very small as compared to the size of the atom.
   Experimentally, it was found that,
   Radius of the nucleus of an atom = 10^{-14} to 10^{-15} m
   Radius of an atom = 10^{-10}m
   Thus the size of the nucleus is about ten – thousandth part of the size of an atom.
4. Almost the entire mass of an atom is concentrated in its nucleus. Since, the nucleus consists of neutrons and protons; hence, the mass of an atom is equal to the total mass of neutrons and protons in its nucleus.
5. Atom, as a whole is electrically neutral. So, number of protons inside the nucleus of an atom and the number of electrons surrounding the nucleus, are equal.

WHAT ARE THE DRAWBACKS IN THE RUTHERFORD'S NUCLEAR MODEL OF AN ATOM?

Rutherford's nuclear model of an atom considers an atom to consist of a positively charged nucleus with electrons revolving around it. The electrons and the nucleus in an atom are held together by electrostatic force of attraction.

Because of the presence of electrostatic attraction between the nucleus and the electrons, the electron should fall into the nucleus. But, it does not happen. In order to explain this, Rutherford postulated that the electrons are not stationary, but are revolving around the nucleus, and attractive forces between the nucleus and electrons are balanced by the centrifugal force acting on the moving electrons.

The Rutherford's model explains the structure of an atom in a very simple way. But, it suffers from the following drawbacks: -

1. An electron revolving around the nucleus gets accelerated towards the nucleus. According to the classical electromagnetic theory, an accelerating charged particle must emit radiation, and lose energy. Because of this loss of energy, the electron would show down, and will not be able to withstand the attraction of the nucleus. As a result, the electron should follow a spiral path, and ultimately fall into the nucleus. If it happens, then the atom should collapse in about 10^{-8} second.

But, this does not happen: atoms are stable. This indicates that there is something wrong in the Rutherford's nuclear model of atom.

2. The Rutherford's model of atom does not say anything about the arrangement of electrons in an atom.

WHAT IS ATOMIC NUMBER?

In 1913, Mosley introduced an atomic parameter called **atomic number**. Atomic number of an element is denoted by Z, and can have only an integral value. According to him,

The atomic number is equal to the nuclear charge. The charge on the nucleus of an atom is equal to the number of protons inside its nucleus. So, the atomic number (Z) of an element is equal to the number of protons present inside the nucleus of its atom.

That is,

Atomic number (Z) = No. Of protons (P) inside the nucleus

An atom has no net change on it. So, in an atom, the total number of electrons is equal to the number of protons inside the nucleus. Thus, in an atom, the total number of electrons is equal to the atomic number of that element.

WHAT IS MASS NUMBER?

Mass number of an element is denoted by A. The mass number of an element is equal to the sum of the number of protons (P) and number of neutrons (N). Thus,

Mass number (A) = No. of protons (P) + No. of neutrons (N)

Or, $A = P + N$

The number of protons (P) inside the nucleus of an atom is equal to the atomic number (Z) of that element. So,

Mass number (A) = Atomic number (Z) + No. of neutrons (N)

Or, $A = Z + N$

The mass number (A) and atomic number (Z) of an element are shown as superscript and subscript respectively, on the left side of the symbol of that element. For example, if A is the mass number, and Z is the atomic number of an element X. Then, the atom ox may be denoted as, ${}^{A}_{Z}X$

HOW TO DETEMINE THE NUMBER OF ELECTRONS, PROTONS AND NEUTRONS IN AN ATOM?

For an atom, we know,

No. of electrons =No. of protons.

But, No. of protons (P) = Atomic number (Z)

So, for an atom No. of electrons = atomic number (Z)

We also know that,

Mass number (A) = No. of protons (P) + No. of Neutrons (N)

= Atomic number (Z) + Number of neutrons (Z)

No. of neutrons (N) = Mass number (A) – Atomic number (Z)

ISOTOPES: -

Atoms of the same element, having the same atomic number, but different mass numbers are called Isotopes of that element.

Since, all isotopes of an element have the same atomic number; hence, all isotopes should contain the same number of protons inside their nuclei. Also, since, different isotopes of an element have different mass numbers, hence, the number of neutrons in the nuclei of isotopes of an element should be different. So, isotopes may also be defined as,

"The atoms of the same element which have the same number of protons but different number of neutrons inside their nuclei are called isotopes of that element."

i.e.,atoms of same elements having same atomic no. but different mass no. are called isotopes.e.g. H^1, H^2, H^3 and Cl^{35}, Cl^{37}.

APPLICATIONS OF SOTOPES:-

Isotopes are said in almost all fields. For example,

1. Isotope of uranium is used as fuel in nuclear reactors.
2. Isotope of cobalt is used in the treatment of cancer.
3. Isotope of iodine is used in the treatment of goitre.
4. C^{14} is used estimating the age of old and dead objects in archaeology.

ISOBARS:-

Isobars may be defined as the atoms of different elements which have the same mass number but different atomic numbers and, hence different chemical and physical properties.

On comparison of atomic masses of various elements, it is found that there are some species which have the same mass number (nucleons = neutrons + protons) and very nearly the same atomic mass even though they have different atomic numbers (protons). The nuclei of isobars have different numbers of protons and neutrons but their sum total is same. These species are called isobars (in Greek '***iso***' means same, '***bars***' means weight). E.g., $_7N^{14}$, $_6C^{14}$.

BOHR'S MODEL OF ATOM: -

Rutherford's nuclear model of atom; could not explain certain observations. A brilliant description of atomic structure was proposed by Niels Bohr in 1913.

WHAT ARE THE POSTULATES OF THE BOHR'S ATOMIC MODEL?

Various postulates of the Bohr's atomic model are:

1. In an atom, the electrons revolve around the nucleus in certain definite circular paths *orbits,* or *shells*.
2. Each shell or orbit corresponds to a definite energy. Therefore, these circular orbits are also known as *energy levels or energy shells*]
3. The orbits or energy levels are characterized by an integer n, where n can have values 1,2,3,4 ……. . The integer n (= 1,2,3, ……) is called the ***quantum number*** of the respective orbit. The orbits are numbered as 1,2,3,4,…….. etc.., starting from the nucleus side. Thus, the orbit for which n = 1 is the lowest energy level.

   The orbits corresponding to n = 1,2,3,4……etc., are also designated as K,L,M,N,…..etc., shells. When the electrons is in the lowest energy level, it is said to be in the **ground state.**

   Since, electrons can be present only in these orbits, hence, these electrons can only have energies corresponding to these energy levels, i.e., **electrons in an atom can have only certain permissible energies.**
4. The electrons present in an atom can move from a lower energy level (E_{lower}) to a level of higher energy (E_{higher}) by absorbing the appropriate energy. Similarly, an electron can jump from a higher energy level to a lower energy level by losing the appropriate energy.

   The energy absorbed or lost is equal to the difference between the energies of the two energy levels, i.e.,

   $\triangle E = E_{\text{higher}} - E_{\text{lower}}$
5. Electrons revolves round the nucleus in stationary states i.e., on revolving round the nucleus , electron neither looses not gains energy.

WHAT IS ELECTRONIC CONFIGURATION?

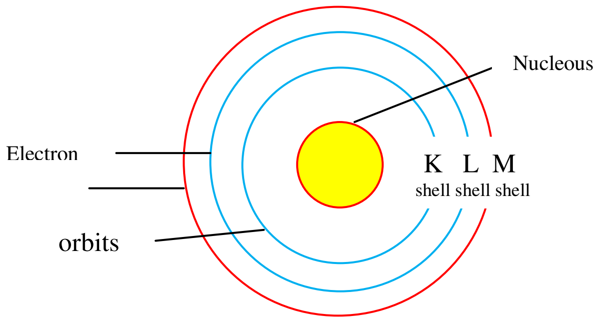
The arrangement of electrons in various energy levels or shells of an atom of the element is called the electronic configuration of the element.

DISTRIBUTION OF ELECTRONS IN ORBITS:-

Bohr and Burry (1921) simultaneously but independently put forward two identical schemes for the distribution of electrons in various orbits. The scheme is, therefore, known as Bohr-Bury scheme. This scheme may be summarized as follows:

(i) The maximum number of electrons that can be accommodated in a shell is given by $2n^2$, where n is the number of shell. Thus,

In the first shell (n = 1) = $2n^2 = 2 \times 1^2$ = 2 electrons
In the second shell (n = 2) = $2n^2 = 2 \times 2^2$ = 8 electrons
In the third shell (n = 3) = $2n^2 = 2 \times 3^2$ = 18 electrons
In the fourth shell (n = 4) = $2n^2 = 2 \times 4^2$ = 32 electrons



(ii) The outermost orbit cannot hold more than 8 electrons, and the penultimate orbit (i.e., the last but one orbit) not more than 18 electrons, even though they may have capacity to hold more electrons. Thus, for example, the atomic number of calcium is 20 and, therefore, has 20 electrons. The first will hold 2 electrons, the second 8 electrons and the third orbit, even though it has a capacity to hold q8 electrons, cannot hold more than 8 electrons, and thus the distribution of electrons in calcium would be 2, 8, 8, 2, and not 2, 8, 10.

(iii) The outermost shell cannot hold more than 2 electrons and the penultimate shell cannot hold more than 8 electrons unless the preceding inner shell (anti-penultimate shell or last but two shells) is filled completely according to rule $2n^{2.}$

WHAT ARE THE VALANCE ELECTRONS?

The electrons in the outermost shell of an atom take part in all the chemical reactions given by that element. Thus, these electrons describe the combining capacity (or valance) of an element. That is why the electrons in the outermost shell of an atom are called its valance electrons. For example, Sodium atom has an electronic configuration of 2, 8, 1. The sodium atom is shown in the fig . The outermost shell, i.e., M-shell of sodium contains only one electron. So, the number of valance electrons in sodium is one.

WHAT IS MEANT BY THE VALENCY OF AN ELEMENT?

The combining capacity of an element to form chemical bonds is called the valency. The combining capacity of the atoms of elements, i.e., their tendency to react and form molecules with themselves or different elements is actually an attempt to acquire a fully-filled outermost shell. An outermost, shell which contains eight electrons are said possess an octet. Every atom reacts to achieve a completed octet. This is done by sharing, gaining loosing electrons. The number of electrons shared, gained or lost to acquire a completed octet gives the valency of the element. For example,

Atomic number of sodium (Na) = 11
Electronic configuration = 2,8, 1
Atomic number of magnesium (Mg) = 12
Electronic configuration = 2, 8, 2

If Na atom looses 1 electron or the magnesium atom looses 2 electrons, present in the outermost shell to form Na^+ or Mg^{2+} ions they will acquire a completed octet. Therefore, these elements are said to have + 1 or + 2 valence respectively.

Valency may be negative as well as positive. Negative valency is found in oxygen , chlorine.