STRUCTURE OF ATOM

DISCOVERY OF SUB-ATOMIC PARTICLE

❖ ATOMIC STRUCTURE
INTRODUCTION

The word atom is a Greek word meaning indivisible, i.e., 'an ultimate particle which cannot be further subdivided. The idea that all matter ultimately consists of extremely small particles was conceived by ancient Indian and Greek philosophers. The old concept was put on firm footing by John Dalton in the form of atomic theory which he developed in the years 1803-1808.

This theory was a landmark in the history of chemistry. According to this theory, atom is the smallest indivisible part of matter which takes part in chemical reactions. Atom is neither created nor destroyed. Atoms of the same element are similar in size, mass and characteristics; however, atoms of different elements have different size, mass and characteristics.

In 1833, Michael Faraday showed that there is a relationship between matter and electricity. This was the first major breakthrough to suggest that atom was not a simple indivisible particle of all matter but was made up of smaller particles.

Discovery of electrons, protons and neutrons discarded the indivisible nature of the atom proposed by John Dalton.

The complexity of the atom was further revealed when the following discoveries were made in subsequent years:

(i) Discovery of cathode rays.

(ii) Discovery of positive rays.

(iii) Discovery of X-rays.

(iv) Discovery of radioactivity.

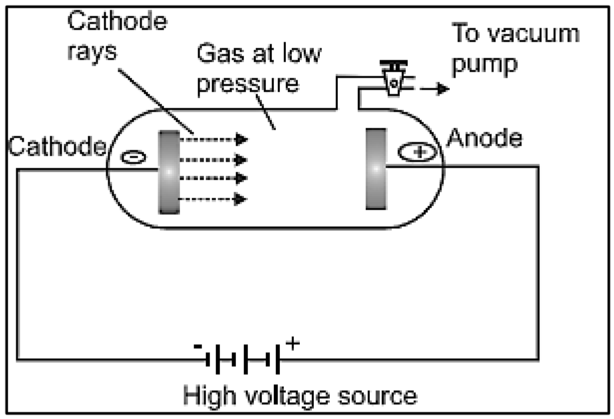
(v) Discovery of isotopes and isobars.

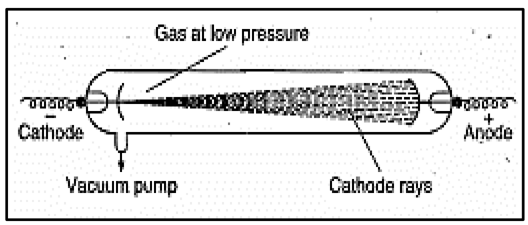
(vi) Discovery of quarks and the new atomic model.

During the past 100 years, scientists have made contributions which helped in the development of modern theory of atomic.

structure. The works of J.J. Thomson and Ernest Rutherford actually laid the foundation of the modern picture of the atom. It is now believed that the atom consists of several particles called subatomic particles like electron, proton, neutron, positron, neutrino, meson, etc. Out of these particles, the electron, the proton and the neutron are called fundamental particles and are the building blocks of the atoms.

Cathode Rays- Discovery of Electron





In 1859, Julius plucker started the study of conduction of electricity through gases at low pressure in a discharge tube. When a high voltage of the order 10, 000 volts or more was applied across the electrodes, some sort of invisible rays moved from the –ve electrode to the +ve electrode. Since the –ve electrode is referred to as cathode, these rays were called cathode rays. Since, the negative electrode is referred to as cathode, these rays were called cathode rays.

Further investigations were made by W. Crookes, 1. Perrin, 1.1. Thomson and others. Cathode rays possess the following properties:

(1) They travel in straight lines away from cathode with very high velocity (about one - tenth of velocity of light).

(2) A shadow of metallic object placed in the path is cast on the wall opposite to the cathode.

(3) They produce a green glow when Strick the glass wall matter. Light is emitted when they strike the zinc-sulphide screen.

(4) When a small pin wheel is placed in their path, the blades of the wheel are set in motion. Thus, the cathode rays consist of material particles which have mass and velocity.

(5) They are deflected by the electric and magnetic fields. When the rays are passed between two electrically charged plates, these are deflected towards the positively charged plate. It

shows that cathode rays carry -ve charge. These particles carrying negative charge were called negatrons by Thomson. The name negatron was changed to 'electron' by Stoney

(6) They produce heat energy when they collide with the matter. It shows that cathode rays posses' Kinetic energy which is converted into heat energy when stopped by matter.

(7) These rays affect the photographic plate.

(8) Cathode rays can penetrate the thin foil of solid materials.

(9) Cathode rays can ionize the gases through which they pass.

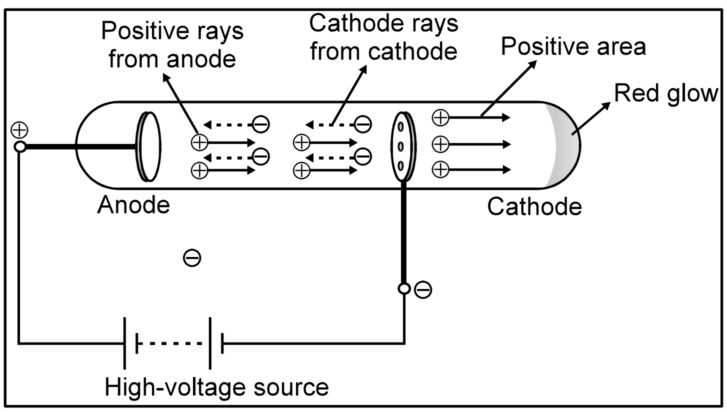
(10) The nature of cathode rays is independent of

(a) The nature of cathode

(b) The gas in discharge tube.

ANODE RAYS OR POSITIVE RAYS - (DISCOVERY OF PROTON)

- The first experiment that lead to the discovery of the +ve particle was conducted by 'Goldstein'.
- He used a perforated cathode in the modified cathode ray tube.



- It was observed that when a high potential difference was applied b/w the electrodes, not only cathode rays were produced but also a new type of rays were produced simultaneously from anode moving towards cathode and passed through the holes or canals of the cathode. These rays were termed canal rays since these passed through the canals of the cathode. These were also named anode rays as these originated from anode.
- When the properties of these rays were studied by Thomson, he observed that these rays consisted of positively charged particles and named them as positive rays.
- The following characteristics of the positive rays we recognised:

(i) These rays travel in straight lines and cast a shadow of the object placed in their path.

(ii) Like cathode rays, these rays also rotate the wheel placed in their path and also have heating effect. Thus, the rays passess K.E. i.e., mass particles are present.

(iii) The rays are deflected by electric and magnetic fields towards the negatively charged plate showing thereby that these rays carry +ve charge.

(iv) The rays produce flashes of light on ZnS screen

(v) These rays can pass through thin metal foil.

(vi) These rays can produce ionisation in gases.

(vii) Positive particles in these rays have e/m value much smaller than that of e^-.
For a small value of e/m, it is definite that positive particles possess high mass.

(viii) e/m value is dependent on the nature of the gas taken in the discharge tube, i.e., +ve particles are different in different gases.

- Accurate measurements of the charge and the mass of the particles in the discharge tube containing hydrogen, the lightest of all gases, were made by J.J. Thomson in 1906. These particles were found to have the e/m value as $+9.579 \times 10^4$ coulomb/g. This was the maximum value of e/m observed for any +ve particle.
- It was thus assumed that the positive particle given by the hydrogen represents a fundamental particle of +ve charge. This particle was named proton by Rutherford in 1911. Its charge was found to be equal in magnitude but opposite in sign to that of electron.

Thus, charge on proton = $+ 1.602 \times 10^{-19}$ columb i.e. one unit +ve charge

- The mass of the proton, thus can be calculated.

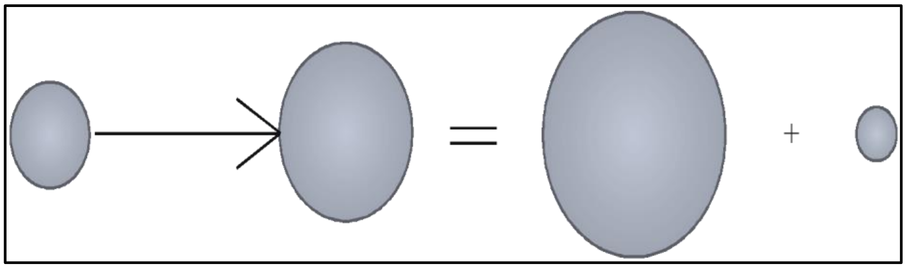
$$\text{Mass of the proton} = \frac{e}{e/m} = \frac{1.602\times10^{-19}}{9.579\times10^{4}} = 1.672\times10^{-24}\ \text{g} = 1.672\times10^{-27}\ \text{kg}$$

$$\text{Mass of proton in amu} = \frac{1.672\times10^{-24}}{1.66\times10^{-24}} = 1.00757\ \text{amu.}$$

❖ NEUTRON

In 1920, Rutherford suggested that in an atom, there must be present at least a third type of fundamental particles which should be electrically neutral and posses' mass nearly equal to that of proton. He proposed the name for such fundamental particles as neutron.

In 1932, Chadwick bombarded beryllium with a stream of α-particles. He observed that penetrating radiations were produced which were not affected by electric & magnetic fields. These radiations consisted of neutral particles, which were called neutrons. The nuclear reaction can be shown as



α-particle	Be-atom	Carbon	Neutron
Charge = +2	Atom Atomic No. = 4	Atomic No. = 6	Charge = 0
Mass = 4 amu	Mass = 9 amu	Mass = 12 amu	Mass = 1 amu
$[{}^4_2He$	$+{}^9_4Be \longrightarrow$	${}^{12}_6C$	$+{}^1_0n]$

Thus, a neutron is a sub atomic particle which has a mass 1.675×10^{-24} g approximately 1amu, or nearly equal to the mass of proton or hydrogen atom and carrying no electrical charge.

- The e/m value of a neutron is zero.

ATOMIC STRUCTURE

Atom is actually made of 3 fundamental particles

1. Electron
2. Proton
3. Neutron

Fundamental Particle	**Discovered By**	**Charge**	**Mass**	**$\frac{\text{Charge}}{\text{mass}}$ (Specific Charge)**
Electron (e^- or β)	J.J. Thomson	-1.6×10^{-19} coloumb -4.8×10^{-10} esu -1 Unit	9.1×10^{-31}kg 9.1×10^{-28} g 0.000548amu	1.76×10^8C/g
Proton (P) (Ionized H atom, H^+)	Goldstein	$+1.6 \times 10^{-19}$ coloumb $+4.8 \times 10^{-10}$ esu +1 Unit	1.672×10^{-27}kg 1.672×10^{-24} g 1.00757amu	9.58×10^4C/g
Neutron	James Chadwick	0	1.675×10^{-27}kg 1.675×10^{-24} g 1.00893 amu	0

Order of Specific Charge

$$\left(\frac{e}{m}\right)_n < (e/m)_p < (e/m)_{e^-}$$

$$\left(\frac{\text{mass of proton}}{\text{mass of electron}}\right)\frac{m_p}{m_{e^-}} = 1837$$

❖ MEASUREMENT OF E / M FOR ELECTRON

In 1897, J.J. Thomson determined the e/m value (charge/mass) of the electron by studying the deflection of cathode rays in electric & magnetic fields.

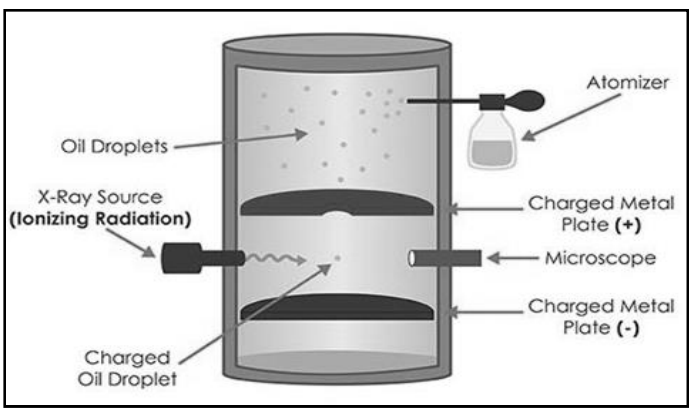
The value of e/m has been found to be -1.7588×10^8 coulomb/g.

- By performing a series of experiments, Thomson proved that whatever gas be taken in the discharge tube and whatever be the material of the electrodes the value of e/m is always the same.
- Electrons are thus common universal constituents of all atoms.

❖ DETERMINATION OF THE CHARGE ON AN ELECTRON

The absolute value of the charge on an e^- was measured by R.A. Milikan in 1909 by the Milikan's oil drop experiment.

- The apparatus used by him is shown in fig.



- An oil droplet falls through a hole in the upper plate. The air between the plates is Then exposed to X-rays which eject electrons from air molecules. Some of these e^- are captured by the oil droplet and it acquires a negative charge.

  The metal plates were given an electric charge, and as the electric field between the plates was increased, it was possible to make some of the drops travel upwards at the same speed as they were previously falling.

By measuring the speed, and knowing things like the strength of the field and the density of the oil, radius of oil drops, Milikan was able to calculate the magnitude of the charge on the oil drops. He found that the smallest charge to be found on them was approximately 1.59×10^{-19} C. This was recognized as the charge on an e^-.

The modern value is 1.602×10^{-19} C.

- **MASS OF THE ELECTRON**

Mass of the e^- can be calculate from the value of e/m and the value of e

$$m = \frac{e}{e/m} = \frac{-1.602\times10^{-19}}{-17588\times10^{8}}$$

$$= 9.1096 \times 10^{-28}\ g \quad \text{or}$$

$$= 9.1096 \times 10^{-31}\ kg$$

This is termed as the rest mass of the electron i.e. mass of the electron when moving with low speed. The mass of a moving e^- may be calculate by applying the following formula.

$$\text{Mass of moving } e^- = \frac{\text{rest mass of } e^-}{\sqrt{1-(v/c)^2}}$$

Where v is the velocity of the e^- and c is the velocity of light.

When $v = c \Rightarrow$ mass of $e^- = \infty$

$v > c \Rightarrow$ mass of e^- = imaginary