Structure of the atom

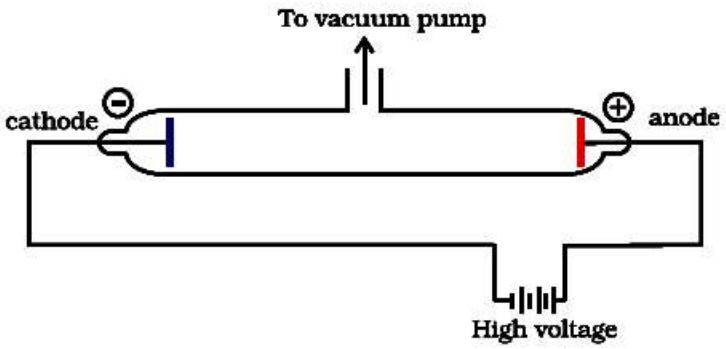
- Dalton's atomic theory suggested that an atom was indivisible.
- However, the discovery of two fundamental particles named electrons and protons inside the atom, led to the failure of Dalton's atomic theory.

Fundamental particles of an atom:

- Atoms are the building blocks of matter. It is the smallest unit of matter that is composed of three sub-atomic particles: the proton, the neutron and the electron.

Discovery of Electron:

- J. J. Thomson discovered the existence of electrons using cathode ray discharge tube experiment.
- When the discharge tube containing the gas is at 1 atm pressure and at high voltage, the gas remains non conducting.
- When the pressure of the gas inside the tube is less than 1 mm of mercury, a dark space appears near the cathode.
- This is known as Crookes dark space.
- When the pressure is further reduced to 10-4 mm Hg, the electric discharge passes between the electrodes and the tube begins to glow.
- This is due to the striking of some invisible rays from the cathode.
- These rays start from the cathode and move towards the anode, in straight lines.
- These rays are called cathode rays or cathode ray particles.
- These rays consist of negatively charged material particles called electrons.



PROPERTIES OF CATHODE RAYS

- Cathode rays travel in straight lines.
- Cathode rays produce mechanical effect, as they can rotate the wheel that placed in their path.
- Cathode rays consist negatively charged particles called electrons.
- Cathode rays travel with high speed.
- Cathode rays can cause fluorescence.
- Cathode rays heat the object on which they fall due to transfer of kinetic energy to the object.
- When cathode rays fall on heavy metals, X-rays are produced.
- Cathode rays possess ionizing power that is they ionize the gas through which they pass.
- The cathode rays produce scintillation on the photographic plates.
- They can penetrate through thin metallic sheets.

Charge to mass ratio

J.J. Thomson for the first time experimentally determined charge/mass ratio called e/m ratio for the electrons. For this, he subjected the beam of electrons released in the discharge tube as cathode rays to influence the electric and magnetic fields. These were acting perpendicular to one another as well as to the path followed by **electrons**.

According to Thomson, the amount of deviation of the particles from their path in presence of electrical and magnetic field depends on,

1. magnitude of the negative charge on particle

2. mass of particle

3. strength of magnetic field

By carrying out accurate measurements on the amount of deflections observed by the electrons on the electric field strength or magnetic field strength, Thomson was able to determine the value of

$$e/m_e = 1.758820 \times 10^{11} C\ kg^{-1}$$

where m_e = Mass of the electron in kg

e = magnitude of charge on the electron in coulomb (C).

Properties of electrons:

- The relative charge on an electron is given as -1.
- The mass of an electron is only about 1/2000 the mass of a proton or neutron.
- It is represented as $^{-1}_{0}e$.
- The actual charge of an electron is -1.6 x 10^{-19} C.
- The actual mass of an electron is 9.1 x 10^{-31} kg.

CALCULATION OF MASS OF THE ELECTRON

From the values of e and e/m, the mass (m) of the electron is calculated by dividing e by e/m.

$$e = 1.602 \times 10^{-19}$$

$$e/m = 1.76 \times 10^{8} C / g$$

$$\frac{e}{e/m} = \frac{1.602 \times 10^{-19}}{1.76 \times 10^{8} C / g}$$

$$m = 9.1 \times 10^{-28} g$$

$$m = 9.1 \times 10^{-31} kg / e^{-}$$

Discovery of Anode ray:

In 1886, Goldstein modified the discharge tube by using a perforated cathode. On reducing the pressure, he observed a new type of luminous rays passing through the holes or perforations of the cathode and moving in a direction opposite to the cathode rays. These rays were named as positive rays or anode rays or canal rays. Anode rays are not emitted from the anode but from a space between anode and cathode.

Properties of anode rays

- These rays deflect towards negative plate of applied electric field. It means these are made up of positively charged particles.
- Property of anode rays depends on the nature of gas.
- These rays travel in straight lines and have mechanical energy.

Properties of protons:

- The relative charge on proton is given as +1.
- The relative mass of a proton is 1 amu.
- It is represented as $^{+}{}_{1}^{1}p$.
- The actual charge of a proton is +1.6 x 10^{-19} C.
- The actual mass of a proton is 1.6 x 10^{-27} kg.

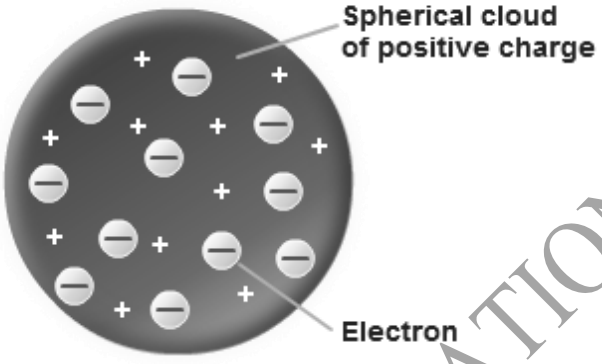
Discovery of Neutron:

- In 1932, Chadwick bombarded Be with a stream of α-particles (He^{+2}). He noticed that penetrating radiations were produced which were not affected by magnetic field and electric field. These radiations consisted of neutral particles, which were called neutrons.

- The relative charge on a neutron is given as 0.
- The relative mass of a neutron is 1 amu.
- It is represented as ${}_{1}^{0}n$.
- The actual charge of a neutron is 0 C.
- The actual mass of a neutron is 1.6 x 10^{-27} kg.

MODELS OF ATOM

1. THOMSON'S MODEL OF AN ATOM:



Thomson's Model of an Atom

- According to this model, an atom was a sphere of positive charge in which sufficient number of electrons were embedded to neutralize the total charge.

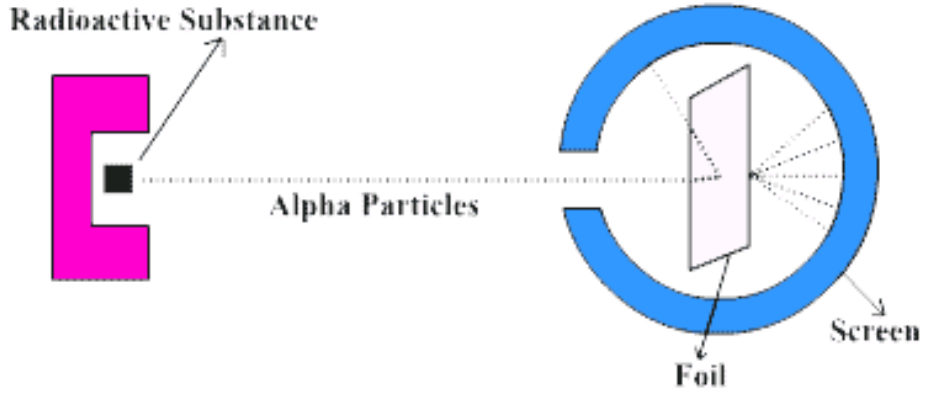
Limitation:

- It could not explain the stability of the atom.
- Neutrons couldn't be placed inside his atomic model.
- The model could not explain the results of the scattering experiment conducted by Rutherford.

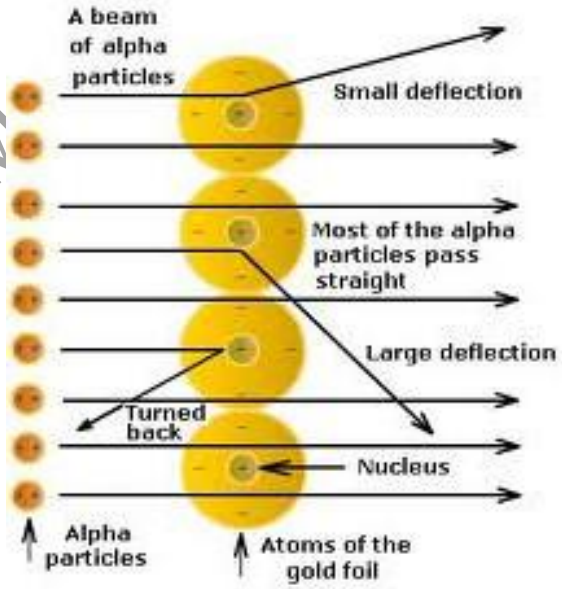
2. RUTHERFORD'S MODEL OF AN ATOM:

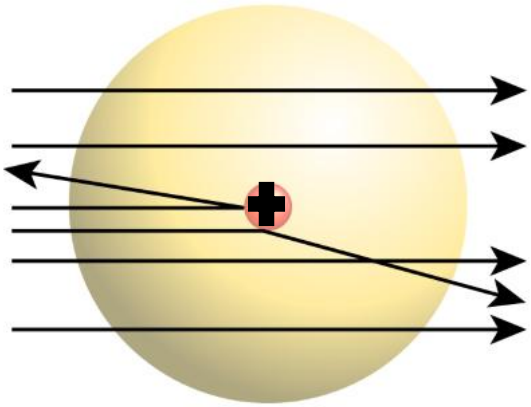
- **Rutherford's alpha(α) ray scattering experiment:** Rutherford placed radium in a cavity block of lead from which the α-rays were produced. These rays were made to hit a thin foil of gold with a beam of fast-moving alpha (α)

particles. The foil was surrounded by a zinc sulphide screen. Whenever α-particles strike the screen, a flash of light is produced at the point on the screen.



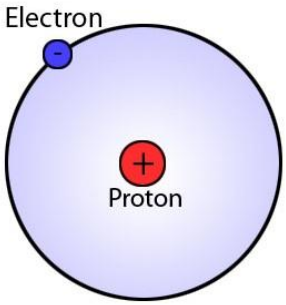
- Observations:
  a) Most of the α-particles (99.9%) passed through the foil without undergoing any deflection.
  b) Some α-particles were deflected through small angles and a few were deflected through large angles.
  c) Very few (one in 12,000) were deflected back at an angle greater than 90^0.





- Conclusions:
  a) A major fraction of the α-particles bombarded against the gold sheet passed through it without any deflection, and hence most of the space in an atom is empty.
  b) Some of the α-particles were deflected by the gold sheet by very small angles, and hence the positive charge in an atom is not uniformly distributed. The positive charge in an atom is concentrated in a very small volume.
  c) Since the α-particles are heavy they could be deflected back only when they strike a heavier body inside the atom.
  d) Very few of the α-particles were deflected back, that is only a few α-particles had nearly 180º angle of deflection. So, the volume occupied by the positively charged particles in an atom is very small as compared to the total volume of an atom.

- Rutherford's nuclear model of atom:



i) An atom consists of a nucleus and an extra nuclear part.

ii) The entire mass of the atom is concentrated at the centre, in the nucleus.

iii) The nucleus is positively charged due to the presence of protons.

iv) The electrons revolve around the nucleus in circular orbits.

- Limitations:

  As per Rutherford's model, electrons revolve around the nucleus in a circular path. But particles that are in motion in a circular path would undergo acceleration, and acceleration causes radiation of energy by charged particles. Eventually, electrons should lose energy and fall into the nucleus and this points to the instability of the atom. But this is not possible because atoms are stable. Hence Rutherford failed to give an explanation on account of this.