PHYSICS

CLASS NOTES FOR CBSE

Chapter 28. Atoms

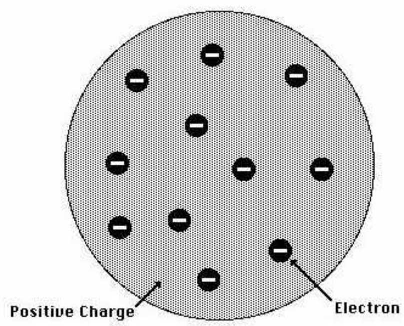
01. Thomson's Atom Model

From the study of discharge of electricity through gases, it became clear that an atom consists of positive and negative charges. As the atom is electrically neutral, the number of positive and negative charges (electrons) must be equal.
A theoretical explanation for the structure of atom is called an atom model.
In 1898, J.J. Thomson gave the first explanation about the arrangement of positive charges and the electrons inside the atom.
According to him, an atom is a sphere of positive charges having radius of the order of 10^{-10}m. The positive chare is uniformly distributed over the entire sphere and the electrons are embedded in the sphere of positive charges just like seed in a watermelon or plums in the pudding as shown in Figure. For this reason, Thomson's atom model is also known as ***plumpudding model***. The total positive charge inside the atom is equal to the total negative charge carried by electrons, so that every atom is electrically neutral. The electrons were supposed to be located in the cloud of positive charges, such that the system is stable*. If the atom gets slightly perturbed, the electrons in the atoms oscillated about their equilibrium position and result in the emission of radiation of definite frequencies in the form of infra-red, visible or ultraviolet light.

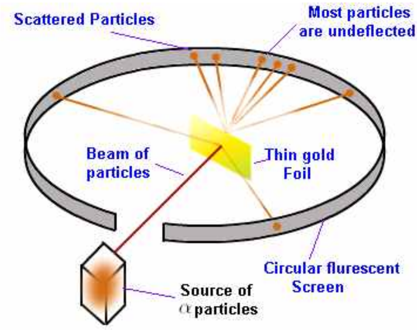
Failure of Thomson's atom model. Thomson's atom model is a plausible model for atom only apparently. It had to be discarded, because of th following limitations:

(i) It could not explain the origin of the spectral lines in the form of series as in the case of hydrogen atom.

(ii) It could not account for the scattering of α-particles through large angles (even upto 180^o) as observed in the case of **Rutherford's α-scattering experiment**.



02. Alpha-Particle Scattering and Rutherford's Nuclear Model of Atom



H. Geiger and E. Marsden performed an experiment on α-particles scattering, in 1911, as suggested by Ernst Rutherford.

In this experiment, they used a beam of 5.5 MeV, α-particles obtained from $^{214}_{83}\text{Bi}$ radioactive source and bombarded it on a thin gold foil. Scattering of α-particles was observed though a rotatable detector made up of zinc sulphide screen and a microscope.

Observations :

(i) Most of the α-particles passed though the foil without any deviation.

(ii) About 0.14% of the incident α-particles scattered by more than 1^o.

(iii) Deflection of more than 90^0 was observed in about 0.0125% of the incident α-particles.

Inferences :

(i) Most of the space in an atom is unoccupied as about 99.86% α-particles passed without deviation.

(ii) There must be an extremely small region of concentrated positive charge at the centre of an atom. This small region is called nucleus. The scattering of α-particles is due to encounter between the α-particle and the nucleus of the atom.

(iii) The nucleus of the atom is so massive as compared with the α-particles that it remains at rest during the encounter, whereas electrons, owing to their little mass, cannot appreciably deflect the far more massive α-particles.

(iv) Electrons revolve around the nucleus in orbits just like planets revolve around the sun.

(v) When an α-particle strikes the metal foil, it can penetrate the outer electron cloud and approaches the nucleus closely. It then moves under the action of coulomb's force of repulsion, and its path is hyperbola with the nucleus as the external forces.

03. Impact Parameter

Let us consider an α-particle travelling with velocity μ towards a nucleus having charge Z e. In case, the α-particle travels along a path as shown in Figure, then after coming close to the nucleus up to certain distance, it scatters along a path making an angle θ with the initial path. The scattering of an α-particle from the nucleus of an atom depends upon the **impact parameter.** *Impact parameter of the alpha particle is defined as the perpendicular distance of the velocity vector of the alpha particle from the centre of the nucleus, when it is far away from the atom.* It is denoted by b.

$$b=\frac{1}{4\pi\varepsilon_0}\cdot\frac{Ze^2\cot\theta/2}{\frac{1}{2}mu^2}$$

Discussion. Following inferences can be drawn from the above equation:

(i) If the impact parameter b is large, then cot $\theta/2$ is also large i.e. the angle of scattering θ is small and vice-versa.

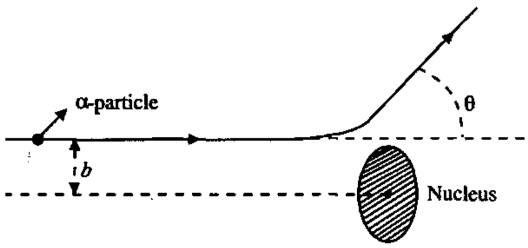
Thus, *if an α-particle has large impact parameter, it gets scattered though a very small angle and may practically go undeviated and if he α-particle has small impact parameter, it will get scattered though a large angle.*

(ii) If the impact parameter b is zero, then

$\cot\ \theta/2 = 0$ or $\theta/2 = 90^\circ$

or $\theta = 180^\circ$

Thus, *if an α-particle has impact parameter zero (i.e. if the α-particle travels directly towards the centre of the nucleus), it will be scattered through* 180°



04. Distance of Closest Approach

Let r_0 be the distance of closest approach of the α-particles to the nucleus.

The (positive) charge on he nucleus is Ze, and that on the α-particles is 2e, where e is the electronic charge.

Therefore, the electrostatic potential energy or the particle at the instant of closest approach is $\frac{1}{4\pi\varepsilon_0}\frac{Ze}{r_0}(2e)=\frac{1}{4\pi\varepsilon_0}\frac{2Ze^2}{r_0}$

At this instant, the α-particles is momentarily at rest and the initial kinetic energy E is entirely converted into electrostatic potential energy. Hence, at this instant

$$E=\frac{1}{4\pi\varepsilon_0}\frac{2Ze^2}{r_0} \qquad \therefore \qquad \boxed{r_0=\frac{1}{4\pi\varepsilon_0}\frac{2Ze^2}{E}}$$ ...[Distance of closest approach]

This is the expression for the distance of closest approach r_0 of the α-particles. It shows that for a given nucleus, r_0 depends upon the initial kinetic energy E of the α-particle.

When the kinetic energy E exceeds a certain value, the distance of closest approach r_0 becomes so small that the nucleus no longer appears as a point charge to the α-particle. Then the Coulomb's inverse-square law and hence the Rutherford formula breaks down.