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Quantum Mechanical Concepts of Atomic Structure : Rutherford's and Bohr's Atomic Models

Rutherford's α-particle scattering experiment : Discovery of nucleus

The discovery of electrons, protons and neutrons made it clear that an atom is made up of these three fundamental particles. In order to know how and where these particles are located in an atom, Rutherford (1911) performed α-particle scattering experiment, in which he produced α-particles ($_2^4He$) from a radioactive element, like radium, placed in a lead block and allowed them to strike a very thin gold foil. A movable circular screen, coated with ZnS was placed on the other side of the foil. This screen helped in detecting the direction in which α-particles moved, when they struck the foil.

Observations and conclusions

When α-particles were allowed to strike the thin gold foil, it was observed that (See Fig. 1.1).

(*i*) Some α-particles were deflected back through small angles (*small deflection*) and some through large angles (*large deflection*). This was explained by assuming that the atom contained a positively-charged part at its centre, and called it **nucleus.** It is this positively charged nucleus which repels the positively-charged α-particles to deflect back.

(*ii*) Most of the α-particles passed through the gold foil, without undergoing any deflection

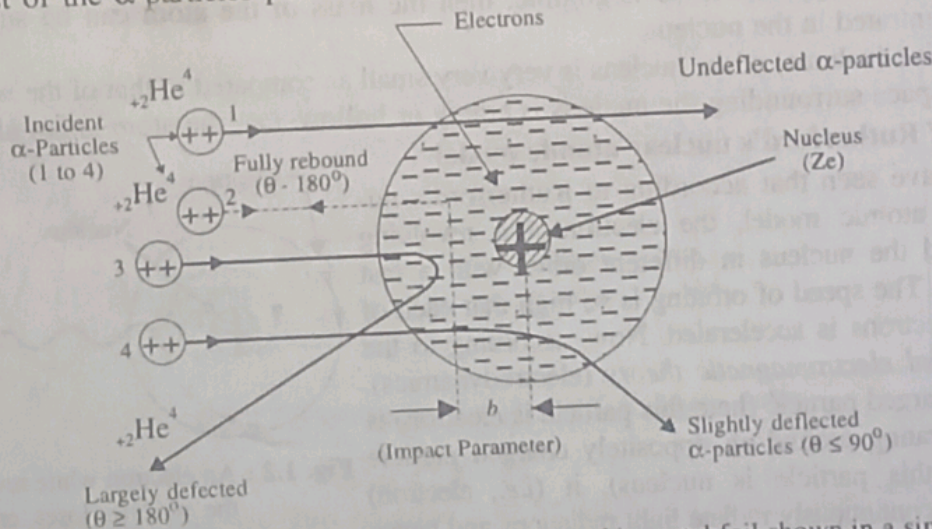

Fig. 1.1 : Three types of deflections of α-particles by a thin metal foil shown in a simple way.

from their original path (*No deflection state*). This was explained by saying that most of the space round the nucleus is empty, which allows the α-particles to pass undeflected through the foil. Thus an atom is not all solid, but *extraordinarily hollow.*

(*iii*) The number of of α-particles, which completely rebounded on hitting the gold foil and turn back to their original path, was very small. This was explained by assuming that the nucleus is very *dense*, *hard* and *rigid*.

Practically the whole mass of an atom is concentrated at its nucleus. Since the number of α-particles which come back to their original path is very small, the volume occupied by the nucleus is only very minute fraction of the total volume of the atom.

What is nucleus?

The conclusions drawn from the observations of Rutherford's α-particle scattering experiment clearly established the fact that the nucleus is the central part of the atom which, due to the presence of protons in it, is positively-charged. It is very dense and rigid. Besides, the whole mass of the atom is concentrated in this nucleus.

Rutherford's Nuclear Model of Atom (Solar or planetary model of atom)

On the basis of the conclusions drawn from the α-particle scattering experiment, Rutherford gave a nuclear model of atom. According to this model :

(*i*) An atom consists of a positively-charged, very dense and rigid, nucleus, which is situated at the centre of the atom. This nucleus is composed of protons (positively-charged particles) and neutrons (neutral particles). It is due to the presence of protons that the nucleus is positively-charged.

(*ii*) Electrons (negatively-charged particles) are revolving round the nucleus, with high speed, in different orbits. Since the atom is electrically neutral, the number of electrons is equal to that of protons. The electrons keep on revolving in orbits round the nucleus, just as the planets revolve round the Sun. Thus, Rutherford's nuclear model of the atom bears a close resemblance with the Solar system, in which the Sun plays the role of the *nucleus* and the planets play the role of the revolving electrons. It is due to this close resemblance of Rutherford's nuclear model of the atom with the Solar system, that the electrons revolving round the nucleus are generally referred to as *planetary electrons* and Rutherford's nuclear model is also called *Solar model* or *Planetary model of the atom.*

(*iii*) Since the nucleus is made up of protons and neutrons, the mass of the nucleus is the sum of the masses of all protons and neutrons in it. If the mass of electrons revolving round the nucleus is supposed to be negligible, then the mass of the atom can be supposed to be concentrated in the nucleus.

(*iv*) The size (volume) of the nucleus is very very small as compared to that of the whole atom.

(*v*) The space surrounding the nucleus is empty or hollow, *i.e.*, the atom is not all solid.

Drawbacks of Rutherford's nuclear atomic model

(*i*) We have seen that according to Rutherford's nuclear atomic model, the electrons are revolving around the nucleus in different orbits with a fast speed. The speed of orbiting is so high that each of the electrons is accelerated. Now, according to the *classical electromagnetic theory* (electrodynamics), if a charged particle (here this particle is electron) is accelerating around an oppositely charged particle (here this particle is nucleus), it (*i.e.*, electron) would continuously radiate light radiations and hence its energy and speed both go on decreasing. Due to this, the electron will gradually come closer to the nucleus by a spiral path. The ultimate result of this

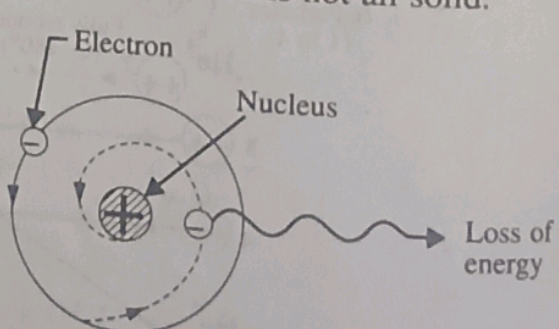

Fig. 1.2 : An electron while revolving round the nucleus loses energy and its speed is decreased, and ultimately the electron falls into the nucleus by a spiral path.