

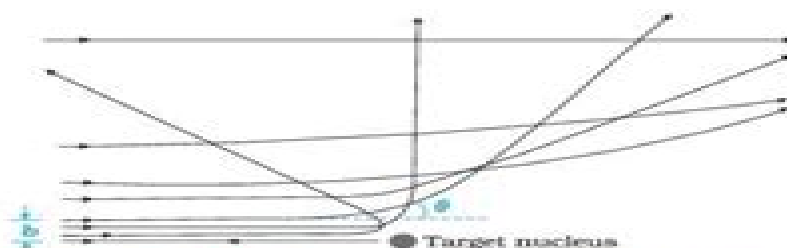
The magnitude of this force is

$$F = \frac{1}{4\pi\epsilon_0} \frac{(2e)(Ze)}{r^2} \quad (12.1)$$

where  $r$  is the distance between the  $\alpha$ -particle and the nucleus. The force is directed along the line joining the  $\alpha$ -particle and the nucleus. The magnitude and direction of the force on an  $\alpha$ -particle continuously changes as it approaches the nucleus and recedes away from it.

### 12.2.1 Alpha-particle trajectory

The trajectory traced by an  $\alpha$ -particle depends on the impact parameter,  $b$  of collision. The *impact parameter* is the perpendicular distance of the initial velocity vector of the  $\alpha$ -particle from the centre of the nucleus (Fig.



**FIGURE 12.4** Trajectory of  $\alpha$ -particles in the coulomb field of a target nucleus. The impact parameter,  $b$  and scattering angle  $\theta$  are also depicted.

12.4). A given beam of  $\alpha$ -particles has a distribution of impact parameters  $b$ , so that the beam is scattered in various directions with different probabilities (Fig. 12.4). (In a beam, all particles have nearly same kinetic energy.) It is seen that an  $\alpha$ -particle close to the nucleus (small impact parameter) suffers large scattering. In case of head-on collision, the impact parameter is minimum and the  $\alpha$ -particle rebounds back ( $\theta = \pi$ ). For a large impact parameter, the  $\alpha$ -particle goes nearly undeviated and has a small deflection ( $\theta = 0$ ).

The fact that only a small fraction of the number of incident particles rebound back indicates that the number of  $\alpha$ -particles undergoing head on collision is small. This,

in turn, implies that the mass and positive charge of the atom is concentrated in a small volume. Rutherford scattering therefore, is a powerful way to determine an upper limit to the size of the nucleus.

**Example 12.1** In the Rutherford's nuclear model of the atom, the nucleus (radius about  $10^{-15}$  m) is analogous to the sun about which the electron move in orbit (radius =  $10^{-10}$  m) like the earth orbits around the sun. If the dimensions of the solar system had the same proportions as those of the atom, would the earth be closer to or farther away from the sun than actually it is? The radius of earth's orbit is about  $1.5 \times 10^{11}$  m. The radius of sun is taken as  $7 \times 10^6$  m.

**Solution** The ratio of the radius of electron's orbit to the radius of nucleus is  $(10^{-10} \text{ m})/(10^{-15} \text{ m}) = 10^5$ , that is, the radius of the electron's orbit is  $10^5$  times larger than the radius of nucleus. If the radius of the earth's orbit around the sun were  $10^5$  times larger than the radius of the sun, the radius of the earth's orbit would be  $10^5 \times 7 \times 10^6 \text{ m} = 7 \times 10^{11} \text{ m}$ . This is more than 100 times greater than the actual orbital radius of earth. Thus, the earth would be much farther away from the sun.

It implies that an atom contains a much greater fraction of empty space than our solar system does.

# Finneytown Physics Chapter 12

**Halliday**



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