In the Rutherford scattering experiment the distance of closest approach for an alpha particle is d. If alpha particle is replaced by a proton, how much kinetic energy in comparison to alpha particle will it require to have the same distance of closest approach d?

Answer

In scattering experiments such as Rutherford's, simple considerations can be used to calculate the distance of closest approach of the incoming particle to the target.

Initially, the total energy of the system consists of the kinetic energy of the alpha particle.

At the point of closest approach, a distance d from the centre of the nucleus, the alpha particle stops and is about to turn back.

The total energy now is the electrical potential energy of the alpha particle and the nucleus, given by: $E = k\frac{Qq}{d} = k\frac{(2e)(Ze)}{d} = k\frac{2Ze^2}{d}$.

Assuming that the nucleus does not recoil, its kinetic energy is zero. Then, by conservation of energy: $E_k = k\frac{2Ze^2}{d}$.

If alpha particle is replaced by a proton

$$E_k^{proton} = k\frac{Qq}{d} = k\frac{(e)(Ze)}{d} = k\frac{Ze^2}{d}$$

So $E_k^{proton} = \frac{1}{2}E_k$ for have the same distance of closest approach d.

Answer: half of kinetic energy in comparison to alpha particle.