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Problem 30.21 (RHK)

A gold nucleus contains a positive charge equal to that of 79 *protons and has a radius of* 7.0 fm. *An alpha particle* (*which consists of two protons and two neutrons*) *has kinetic energy K at points far from the nucleus and is travelling directly toward it. The alpha particle just touches the surface of the nucleus where its velocity is reversed in direction. We have to calculate* (a) *K. The actual alpha particle energy used in the experiment of Rutherford and his collaborators that lead to the discovery of the concept of the atomic nucleus was* 5.0 MeV. (b) *What do we conclude?*

Solution:

Charge of the gold nucleus is

$q = +79e = 79 \times 1.6 \times 10^{-19}\ \text{C} = 1.264 \times 10^{-17}\ \text{C}.$

Radius of the gold nucleus is $R = 7.0\ \text{fm} = 7.0 \times 10^{-15}\ \text{m}.$

It is given that alpha particle reverses its velocity when it touches the surface of the gold nucleus. Therefore, the kinetic energy K of the alpha particle when it is far away

from the nucleus will be equal to the potential energy of the alpha particle – gold nucleus system when the alpha particle just touches the surface of the gold nucleus. This condition implies that

$$K = V\left(r = R\right) = \frac{79e \times 2e}{4\pi\varepsilon_0 R} = \frac{8.99\times10^9 \times 158 \times \left(1.6\times10^{-19}\right)^2}{7.05\times10^{-15}} \text{ J}$$

$$= \frac{8.99\times10^9 \times 158 \times 1.6\times10^{-19}}{7.05\times10^{-15}} \text{ eV}$$

$$= 32.2\times10^6 \text{ eV} = 32.2 \text{ MeV}.$$

The actual alpha particle energy used in the experiment of Rutherford and collaborators was 5.0 MeV. These alpha particles do not touch the surface of the gold nucleus and reverse their velocity much before reaching the surface of the gold nucleus.