A level Physics B

H557/02 Scientific literacy in physics

Question Set 11

1 This question is about determining the diameter of the atomic nucleus.

(a) In 1909, a team led by Ernest Rutherford fired alpha particles at a thin sheet of gold. Most of the alpha particles passed through the sheet with little deflection but about one alpha particle in ten thousand 'bounced back'.

(i) Explain why such scattering experiments are carried out in a vacuum.

[3]

(ii) We can assume that the alpha particles come to rest for an instant at the point where the electrical potential energy of the particle is equal to the kinetic energy of the particle at a large distance from the nucleus.

Calculate the distance of closest approach of a 4.5 MeV alpha particle ($^{4}_{2}He$) to a gold nucleus ($^{197}_{79}Au$) and explain why the use of more energetic alpha particles would result in a different value for the radius of the gold nucleus.

distance of closest approach = ……………………………m

[3]

(b) Accelerated electrons can also be scattered by atomic nuclei.

The electrons are diffracted by the nuclei giving a minimum at angle θ where $\sin\theta = \frac{1.2\lambda}{d}$ and d is the diameter of the nucleus and λ is the de Broglie wavelength of the electrons.

(i) Show that the velocity of an electron accelerated through 1.5×10^{8} V is very close to the velocity of light.

rest energy of electron = 0.51 MeV

[4]

(ii) Calculate the angle of the diffraction minimum for a beam of electrons accelerated through 1.5×10^{8} V scattered from a nucleus of diameter 3.0×10^{-14} m.

For relativistic particles, momentum = $\frac{E}{c}$ where E is the energy of the particle and c is the velocity of light.

minimum angle = ………………………………………..° **[4]**

(c) Electron scattering experiments show that the radius r of a nucleus of nucleon number A isproportional to $\sqrt[3]{A}$.

This relationship suggests that the radius of a silver nucleus ($^{107}_{47}Ag$) is about four-fifths the radius of the gold nucleus. However, calculations similar to those in **(a)(ii)** suggest that the maximum radius of the silver nucleus is smaller than this.

Use the relationship $r \propto \sqrt[3]{A}$ to calculate the ratio $\frac{\text{radius of a silver atom}}{\text{radius of a gold atom}}$ and show that it is significantly greater than the ratio given by the closest approach method used in **(a)(ii)**.

[4]

Total Marks for Question Set 11: 18