AQA

A Level

A Level Physics

Particle physics

Name:

M M E

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Total Marks: /30

1. Rutherford's experiment challenged the paradigm of Thomson's 'plum pudding' model - that the atom comprised a collection of negative plums in a positive pudding.

Total for Question 1: 15

(a) Describe Rutherford's experiment and explain why it demonstrates the key principles of the nuclear model: that the majority of a nucleus is empty space and that the centre of the atom is positively charged. [4]

(b) Why must the sheet of metal used be extremely thin (10^{-7} m)? [1]

(c) An ${}^{4}_{2}He^{2+}$ particle is travelling towards the nucleus of an ${}^{108}_{47}Ag$ atom. Its kinetic energy is 1.4×10^{-12} J. Calculate an upper limit for the radius of the Ag nucleus. Why is it an upper bound? [3]

(d) By first determining the magnitude of the electrostatic repulsion, calculate the maximum acceleration of the alpha particle. [3]

The radius of a metal nucleus can also be determined by considering the number of incident alpha particles that are deflected through large angles. Joe attempts this by firing alpha particles at a sheet of aluminium which is 3000 atoms thick. 1 in 10,000 are direct hits (i.e. they scatter at angles close to 180°).

(e) Calculate the radius of the aluminium nucleus. You may assume the following: that the aluminium is layered such that there is no overlap between nuclei; that there is no 'empty space' in the foil; that the radius of an aluminium atom is 118 pm. [4]

2. Using observations from experiments like that of Rutherford, experimental values of nuclear radii can be obtained.

Total for Question 2: 15

(a) Estimate the density of a ${}^{7}_{3}Li$ atom (with a radius of 152 pm) and of its nucleus. Explain your results in the context of the nuclear model. Assume that the radius of a proton is 1.2 fm. [4]

(b) Calculate the gravitational attraction and the electrostatic repulsion between the two protons in a helium nucleus, which are separated by a distance of approximately 10^{-15} m. [4]

(c) It should be clear that a third force is required to keep the protons together. Describe the nature of this force and illustrate its variation with distance. [3]

Nuclear radii can be determined accurately using electron diffraction patterns. The first order minimum will occur at an angle governed by $\sin\theta = 1.22\frac{\lambda}{d}$, where λ is the wavelength of the electron and d is the diameter of the particle.

(d) A beam of electrons with energy 560 MeV is fired at a particle. The resulting diffraction pattern indicates that the particle has a radius of 4.6×10^{-15} m. At what angle was the first order minimum measured? [4]