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QUESTION WORKBOOK

Nuclear radius and density

Nuclear physics · Year 13

AQA 3.8.1.5 · OCR A 6.4.1(c), 6.4.1(f), 6.4.1(g)

18 questions · 49 marks

NAVY SCREEN EDITION

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SECTION A · Warm-up

A1 State the equation relating nuclear radius to nucleon number, and give the approximate value of the constant R_0. [2]

A2 Calculate the radius of a nucleus with nucleon number A = 64.
$R_0 = 1.2 \times 10^{-15}$ m [2]

A3 State what the relationship $R = R_0A^{1/3}$ implies about the density of nuclear matter. [2]

A4 State typical values for the radius of an atom and for the radius of a nucleus. [2]

A5 A student has measured nuclear radii R for nuclides covering a wide range of nucleon numbers A. State the graph the student should plot to obtain a straight line through the origin, and state what the gradient of that line represents. [2]

SECTION B · Standard

B1 Calculate the radius of an aluminium nucleus, for which $A = 27$.
$R_0 = 1.2 \times 10^{-15}$ m [2]

B2 Taking the mass of a nucleon as 1.66×10^{-27} kg and the volume per nucleon as that of a sphere of radius R_0, estimate the density of nuclear matter.
$R_0 = 1.2 \times 10^{-15}$ m [3]

B3 Calculate the ratio of the radius of a nucleus with $A = 125$ to the radius of a nucleus with $A = 8$. [2]

B4 Explain how the near-constant density of nuclei supports the idea that nucleons are closely packed. [3]

B5 Electron diffraction shows that a nuclide has a nuclear radius of 6.0×10^{-15} m. Determine the nucleon number of the nuclide.
$R_0 = 1.2 \times 10^{-15}$ m [2]

B6 The radius of a gold atom is 1.35×10^{-10} m and the radius of a gold nucleus is 7.0×10^{-15} m. Calculate the fraction of the volume of the atom occupied by the nucleus, and comment on your answer. [3]

B7 Explain why high-energy electrons are a suitable probe for measuring the radius of a nucleus. [2]

SECTION C · Stretch

C1 An alpha particle with kinetic energy 5.0 MeV is fired head-on at a gold nucleus (Z = 79). Estimate the distance of closest approach.
$k = 8.99 \times 10^{9}$ N m^{2} C^{-2}, $e = 1.60 \times 10^{-19}$ C [4]

C2 Calculate the density of a carbon-12 nucleus (A = 12), taking the nucleon mass as 1.66×10^{-27} kg and $R_0 = 1.2 \times 10^{-15}$ m. Compare your value with the density of nuclear matter in general, 2.3×10^{17} kg m^{-3}. [4]

C3 Describe how electron diffraction can be used to determine the radius of a nucleus. [3]

C4 Determine the minimum initial kinetic energy, in MeV, that an alpha particle needs in order to approach within 4.0×10^{-14} m of the centre of a gold nucleus (Z = 79) in a head-on collision.
$k = 8.99 \times 10^{9}$ N m^{2} C^{-2}, $e = 1.60 \times 10^{-19}$ C, 1 MeV = 1.60×10^{-13} J [4]

C5 For one nuclide, the closest-approach method with 5 MeV alpha particles gives a nuclear radius estimate of 4.5×10^{-14} m, while electron diffraction gives 7.2×10^{-15} m. Explain why the two values differ, and deduce which is the better estimate of the nuclear radius. [4]

C6 A neutron star can be modelled as a sphere with the density of nuclear matter, 2.3×10^{17} kg m^{-3}. Estimate the radius of a neutron star of mass 4.0×10^{30} kg. [3]