



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

PRINT EDITION

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 $A = 64$.
 $R_0 = 1.2 \times 10^{-15} \text{ m}$ [2]

- A3** State what the relationship $R = R_0 A^{1/3}$ 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 $A = 27$.

$$R_0 = 1.2 \times 10^{-15} \text{ m}$$

[2]

B2 Taking the mass of a nucleon as $1.66 \times 10^{-27} \text{ kg}$ and the volume per nucleon as that of a sphere of radius R_0 , estimate the density of nuclear matter.

$$R_0 = 1.2 \times 10^{-15} \text{ m}$$

[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 $6.0 \times 10^{-15} \text{ m}$. Determine the nucleon number of the nuclide.
 $R_0 = 1.2 \times 10^{-15} \text{ m}$ [2]

- B6** The radius of a gold atom is $1.35 \times 10^{-10} \text{ m}$ and the radius of a gold nucleus is $7.0 \times 10^{-15} \text{ m}$. 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.
 $k = 8.99 \times 10^9 \text{ N m}^2 \text{ C}^{-2}$, $e = 1.60 \times 10^{-19} \text{ C}$ [4]

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

$$k = 8.99 \times 10^9 \text{ N m}^2 \text{ C}^{-2}, e = 1.60 \times 10^{-19} \text{ C}, 1 \text{ MeV} = 1.60 \times 10^{-13} \text{ J}$$

[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, $2.3 \times 10^{17} \text{ kg m}^{-3}$. Estimate the radius of a neutron star of mass $4.0 \times 10^{30} \text{ kg}$.

[3]