

1

Which of the following is equal to $\frac{\text{radius of a nucleus of } {}^{125}_{51}\text{Sb}}{\text{radius of a nucleus of } {}^{64}_{20}\text{Zn}}$??

A 1.19 ☐

B 1.25 ☐

C 1.33 ☐

D 1.40 ☐

(Total 1 mark)

2

- (a) Scattering experiments are used to investigate the nuclei of gold atoms. In one experiment, alpha particles, all of the same energy (monoenergetic), are incident on a foil made from a single isotope of gold.

- (i) State the main interaction when an alpha particle is scattered by a gold nucleus.

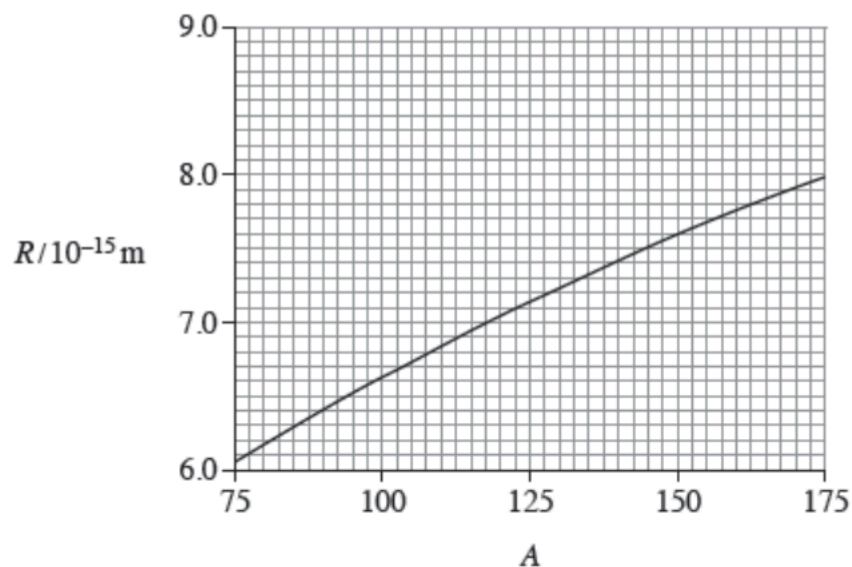
(1)

- (ii) The gold foil is replaced with another foil of the same size made from a mixture of isotopes of gold. Nothing else in the experiment is changed.

Explain whether or not the scattering distribution of the monoenergetic alpha particles remains the same.

(1)

- (b) Data from alpha-particle scattering experiments using elements other than gold allow scientists to relate the radius R , of a nucleus, to its nucleon number, A . The graph shows the relationship obtained from the data in a graphical form, which obeys the relationship $R = r_0 A^{\frac{1}{3}}$



- (i) Use information from the graph to show that r_0 is about $1.4 \times 10^{-15} \text{ m}$.

(1)

- (ii) Show that the radius of a ${}^{51}_{23}\text{V}$ nucleus is about $5 \times 10^{-15} \text{ m}$.

(2)

- (c) Calculate the density of a ${}^{51}_{23}\text{V}$ nucleus.

State an appropriate unit for your answer.

density _____ unit _____

(3)

(Total 8 marks)

3

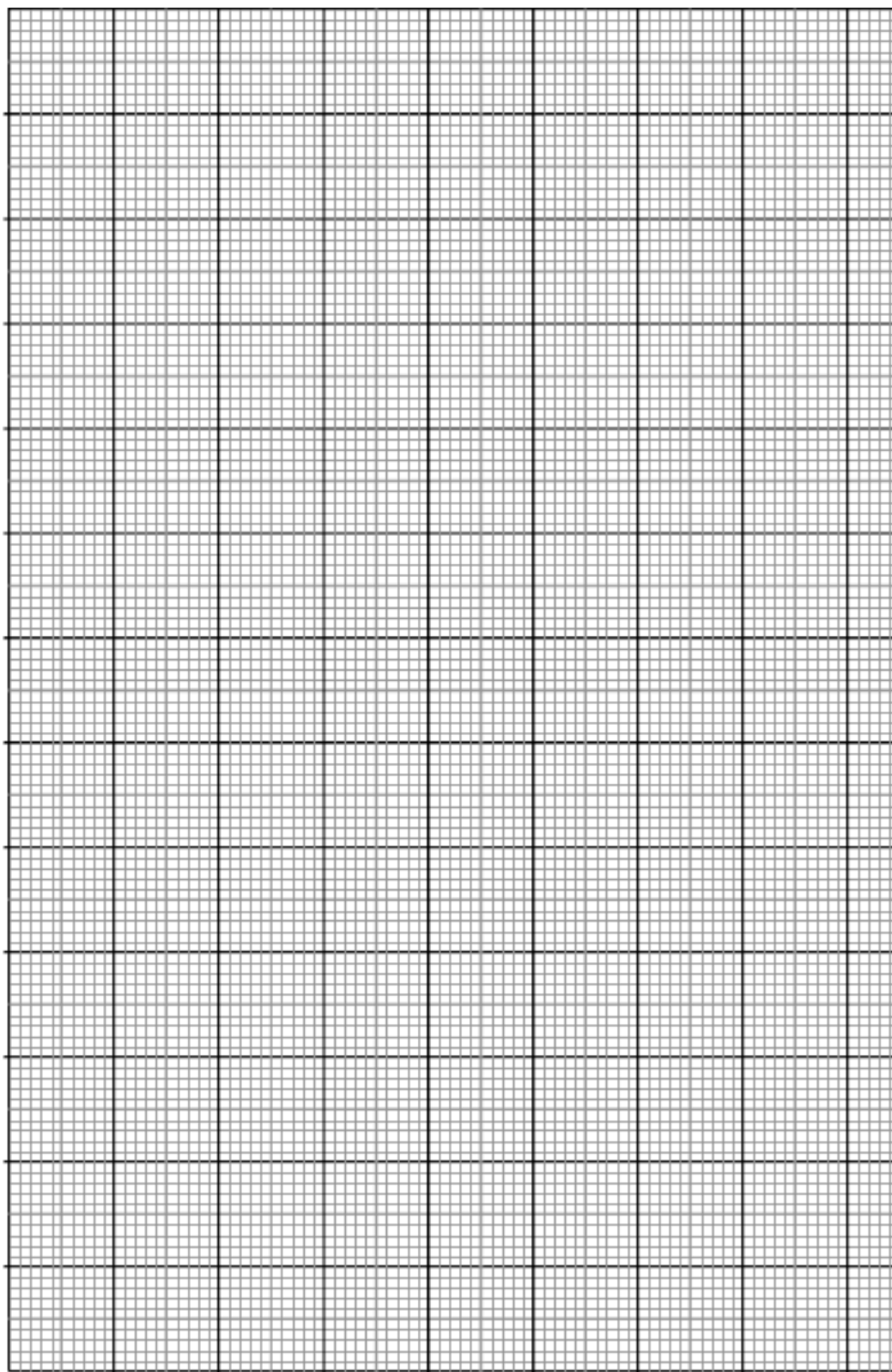
The radius of a nucleus, R , is related to its nucleon number, A , by

$$R = r_0 A^{1/3}, \text{ where } r_0 \text{ is a constant.}$$

The table lists values of nuclear radius for various isotopes.

Element	$R/10^{-15} \text{ m}$	A	
carbon	2.66	12	
silicon	3.43	28	
iron	4.35	56	
tin	5.49	120	
lead	6.66	208	

- (a) Use the data to plot a straight line graph and use it to estimate the value of r_0 .



(8)

- (b) Assuming that the mass of a nucleon is 1.67×10^{-27} kg, calculate the approximate density of nuclear matter, stating **one** assumption you have made.

(4)

(Total 12 marks)

4

- (a) (i) Sketch a graph to show how the neutron number, N , varies with the proton number, Z , for naturally occurring stable nuclei over the range $Z = 0$ to $Z = 90$. Show values of N and Z on the axes of your graph and draw the $N = Z$ line.



- (ii) On your graph mark points, one for each, to indicate the position of an unstable nuclide which would be likely to be

an α emitter, labelling it A,

a β^- emitter, labelling it B.

(5)

- (b) State the changes in N and Z which are produced in the emission of

- (i) an α particle,

(ii) a β^- particle.

(2)

(c) The results of electron scattering experiments using different target elements show that

$$R = r_0 A^{\frac{1}{3}}$$

where A is the nucleon number and r_0 is a constant.

Use this equation to show that the density of a nucleus is independent of its mass.

(3)

(Total 10 marks)

Mark schemes

1

B

[1]

2

- (a) (i) electromagnetic / electrostatic / Coulomb (repulsion between the alpha particles and the nuclei) ✓

The interaction must be named not just described.

1

- (ii) the scattering distribution remains the same (because the alpha particles interact with a nucleus) whose charge / proton number / atomic number remains the same or the (repulsive) force remains the same

The mark requires a described distribution and the reason for it.

Or

the scattering distribution changes / becomes less distinct because there is a mixture of nuclear masses (which gives a mixture of nuclear recoils) ✓
(owtte)

A reference must be made to mass and not density or size.

1

- (b) (i) use of graph to find r_0
e.g. $r_0 = 6.0 \times 10^{-15} / 75^{1/3}$ ✓
(or $8.0 \times 10^{-15} / 175^{1/3}$)
($r_0 = 1.43 \times 10^{-15}$ m)

Substitution and calculation must be shown.

Condone a gradient calculation on R against $A^{1/3}$ graph (not graph in question) as $R \propto A^{1/3}$

1

- (ii) **Escalate if clip shows $^{27}_{13}\text{Al}$ in the question giving $R \approx 4 \times 10^{-15}$ m.**

(using $R = r_0 A^{1/3}$)
 $R = 1.43 \times 10^{-15} \times 51^{1/3}$ ✓
 $R = 5.3 \times 10^{-15}$ (m) ✓
($R = 5.2 \times 10^{-15}$ m from
 $r_0 = 1.4 \times 10^{-15}$ m)

First mark for working.

Second mark for evaluation which must be 2 or more sig figs allow CE from (i) $R = 3.71 \times$ (i).

Possible escalation.

2

- (c) **Escalate if clip shows $\frac{27}{13}$ in the question and / or the use of 27 in the working.**

density = mass / volume

$$m = 51 \times 1.67 \times 10^{-27}$$

$$= 8.5 \times 10^{-26} \text{ kg}$$

Give the first mark for substitution of data into the top line or bottom line of the calculation of density.

$$v = \frac{4}{3}\pi (5.3 \times 10^{-15})^3$$

$$(6.2(4) \times 10^{-43} \text{ m}^3)$$

In the second alternative the mark for the substitution is only given if the working equation is given as well.

Or

$$\text{density} = A \times u / \frac{4}{3}\pi (r_0 A^{1/3})^3$$

$$= u / \frac{4}{3}\pi (r_0)^3$$

51 × 1.67 × 10⁻²⁷ would gain a mark on its own but 1.66 × 10⁻²⁷ would need u / $\frac{4}{3}\pi (r_0)^3$ as well to gain the mark.

$$\text{top line} = 1.66 \times 10^{-27}$$

$$\text{bottom line} = \frac{4}{3}\pi (1.43 \times 10^{-15})^3$$

✓ for one substitution

$$\text{density} = 1.4 \times 10^{17} \checkmark$$

$$(1.37 \times 10^{17})$$

$$\text{kg m}^{-3} \checkmark$$

*Expect a large spread of possible answers. For example
If $R = 5 \times 10^{-15}$ $V = 5.24 \times 10^{-43}$ and density = 1.63×10^{17} .*

Possible escalation.

3

[8]

3

- (a) $(R^3 = R_0^3 A)$

plot R^3 against A with axes labelled **(1)**

units on axes **(1)**

scales chosen to use more than 50% of page **(1)**

element	$R/10^{-15} \text{ m}$	A	$R^3/10^{-45} \text{ m}^3$
carbon	2.66	12	18.8
silicon	3.43	28	40.4
iron	4.35	56	82.3
tin	5.49	120	165.5
lead	6.66	208	295

calculate data for table (1)

plot data (1)(1) lose one mark for each error

calculation of gradient

e.g. gradient = $\frac{1}{3}$ (1) ($= 1.41 \times 10^{-45} \text{ m}^3$)

$r_0 (= \text{gradient})^{1/3}$ (1)

$= (1.41 \times 10^{-45})^{1/3} = 1.1(2) \times 10^{-15} \text{ m}$ (1)

alternative:

plot R against $A^{1/3}$ with axes labelled (1)

units on axes (1)

scales chosen to use more than 50% of page (1)

element	$R/10^{-15} \text{ m}$	A	$A^{1/3}$
carbon	2.66	12	2.29
silicon	3.43	28	3.04
iron	4.35	56	3.83
tin	5.49	120	4.93
lead	6.66	208	5.93

calculate data for table (1)
 plot data (1)(1) lose one mark for each error
 calculation of gradient

$$\text{e.g. gradient} = \frac{6.72 \times 10^{-15}}{6.0} \quad (1) = (1.1(2) \times 10^{-45} \text{ m}^3)$$

$$r_0 = \text{gradient} \quad (1)$$

$$= 1.1(2) \times 10^{-15} \text{ m} \quad (1)$$

[or plot $\ln R$ against $\ln A$...]

(max 8)

- (b) assuming the nucleus is spherical
 ignoring the gaps between nucleons
 assuming all nuclei have same density
 assuming total mass is equal to mass of constituent nucleus
 any one assumption (1)

$$M = \frac{4}{3} \pi R^3 \rho \quad (1)$$

$$\left(\therefore M = \frac{4}{3} \pi R_0^3 a \rho \right)$$

$$\left(\therefore \rho = \frac{3m}{4\pi R_0^3} \right) = \frac{3 \times 1.67 \times 10^{-27}}{4\pi \times (1.12 \times 10^{-15})^3} \quad (1)$$

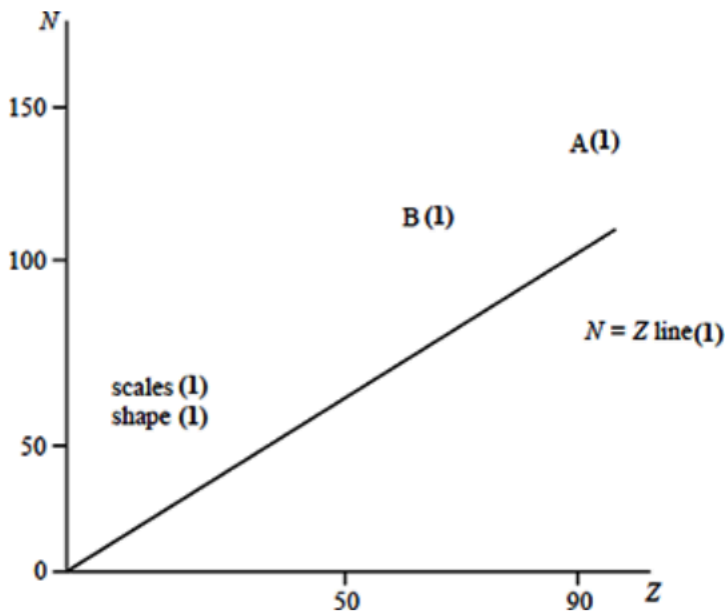
$$= 2.8 \times 10^{17} \text{ kg m}^{-3} \quad (1)$$

(4)

[12]

4

(a)



(5)

(b) (i) α emitter: $N \downarrow 2$, $Z \downarrow 2$ (1)

(ii) β^- emitter: $N \downarrow 1$, $Z \uparrow 1$ (1)

(2)

(c) density = $\frac{\text{mass}}{\text{volume}}$ (1)

mass $\propto A$

volume $\propto R^3$ and $R \propto A^{\frac{1}{3}}$ hence volume $\propto A$ (1)

hence density = $\frac{\text{mass}}{\text{volume}}$ is independent of A (1)

(3)

[10]