



Nuclear Radius

Questions

Name: _____

Class: _____

Date: _____

Time: **98 minutes**

Marks: **70 marks**

Comments:

1

The radius of a nucleus of the iron nuclide ${}_{27}^{56}\text{Fe}$ is $4.35 \times 10^{-15} \text{ m}$.

What is the radius of a nucleus of the uranium nuclide ${}_{92}^{238}\text{U}$?

A $2.69 \times 10^{-15} \text{ m}$

B $2.89 \times 10^{-15} \text{ m}$

C $6.55 \times 10^{-15} \text{ m}$

D $7.05 \times 10^{-15} \text{ m}$

(Total 1 mark)

2

The radius of a uranium ${}_{92}^{238}\text{U}$ nucleus is $7.75 \times 10^{-15} \text{ m}$

What is the radius of a ${}_{6}^{12}\text{C}$ nucleus?

A $1.10 \times 10^{-18} \text{ m}$

B $3.91 \times 10^{-16} \text{ m}$

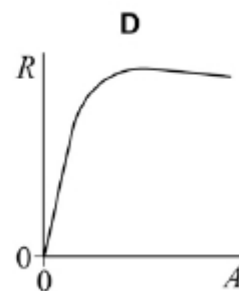
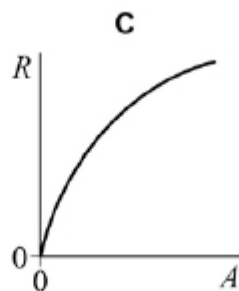
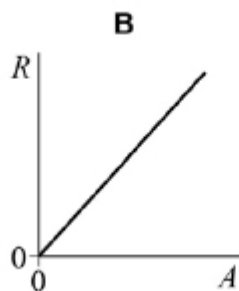
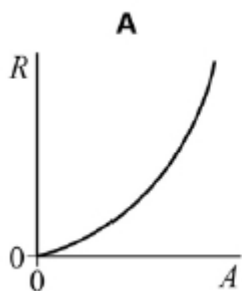
C $2.86 \times 10^{-15} \text{ m}$

D $3.12 \times 10^{-15} \text{ m}$

(Total 1 mark)

3

Which graph best shows how the radius R of an atomic nucleus varies with the nucleon number A ?



A

B

C

D

(Total 1 mark)

4

Which of the following is equal to $\frac{\text{radius of a nucleus of } {}_{51}^{125}\text{Sb}}{\text{radius of a nucleus of } {}_{30}^{64}\text{Zn}}$??

A 1.19

B 1.25

C 1.33

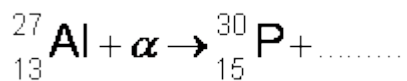
D 1.40

(Total 1 mark)

5

The first artificially produced isotope, phosphorus ${}_{15}^{30}\text{P}$, was formed by bombarding an aluminium isotope, ${}_{13}^{27}\text{Al}$, with an α particle.

(a) Complete the following nuclear equation by identifying the missing particle.



(1)

- (b) For the reaction to take place the α particle must come within a distance, d , from the centre of the aluminium nucleus. Calculate d if the nuclear reaction occurs when the α particle is given an initial kinetic energy of at least 2.18×10^{-12} J.

The electrostatic potential energy between two point charges Q_1 and Q_2 is equal

to $\frac{Q_1 Q_2}{4\pi\epsilon_0 r}$ where r is the separation of the charges and ϵ_0 is the permittivity of free space.

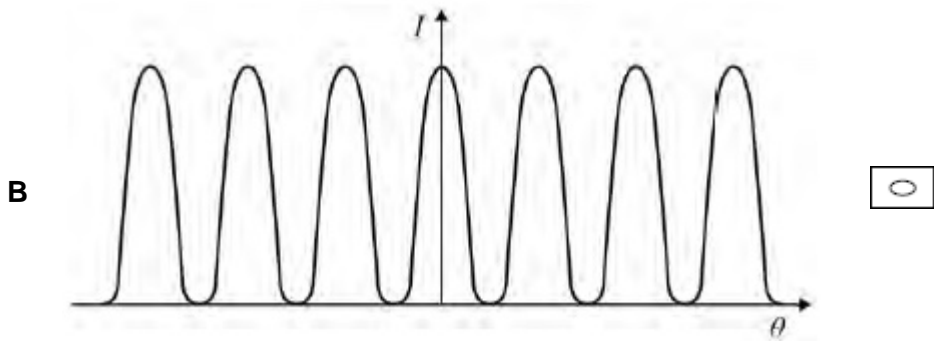
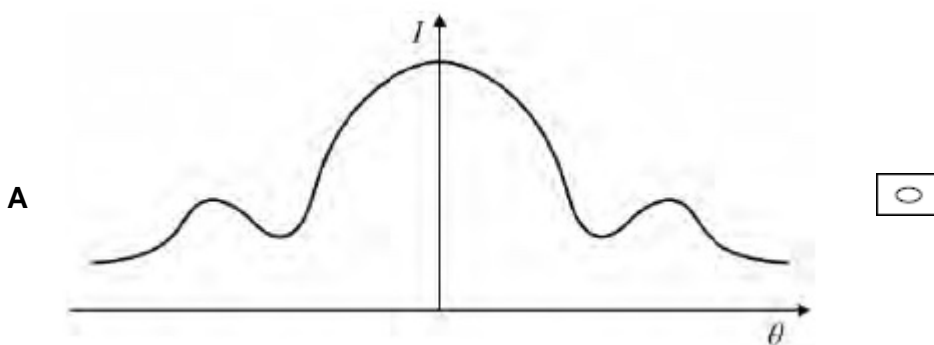
answer = _____ m

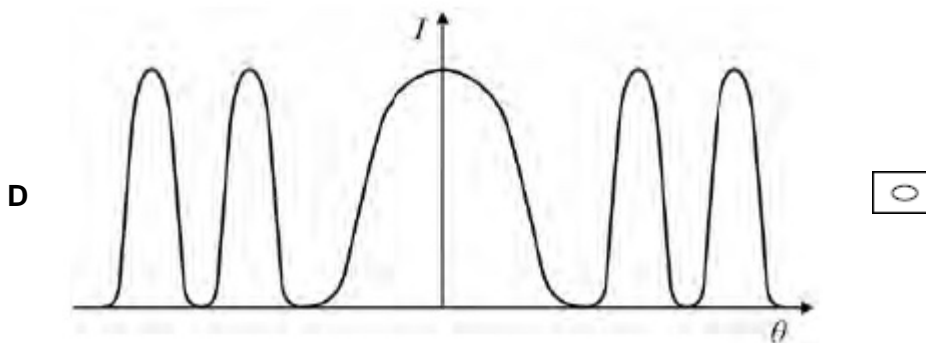
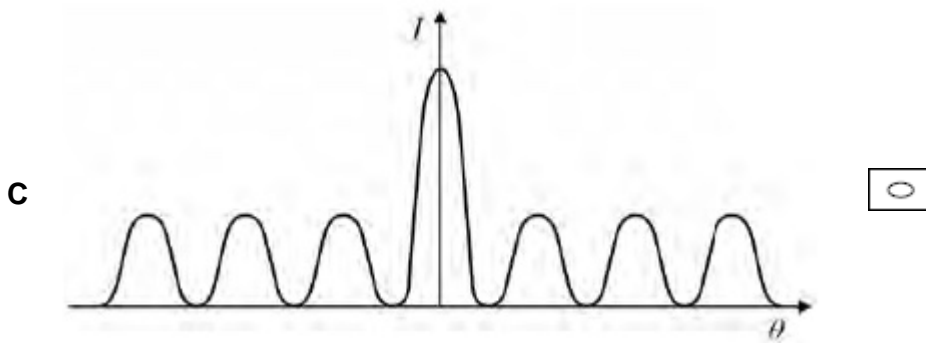
(3)

(Total 4 marks)

6

Which graph shows how intensity I varies with angle θ when electrons are diffracted by a nucleus?





(Total 1 mark)

7

(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.

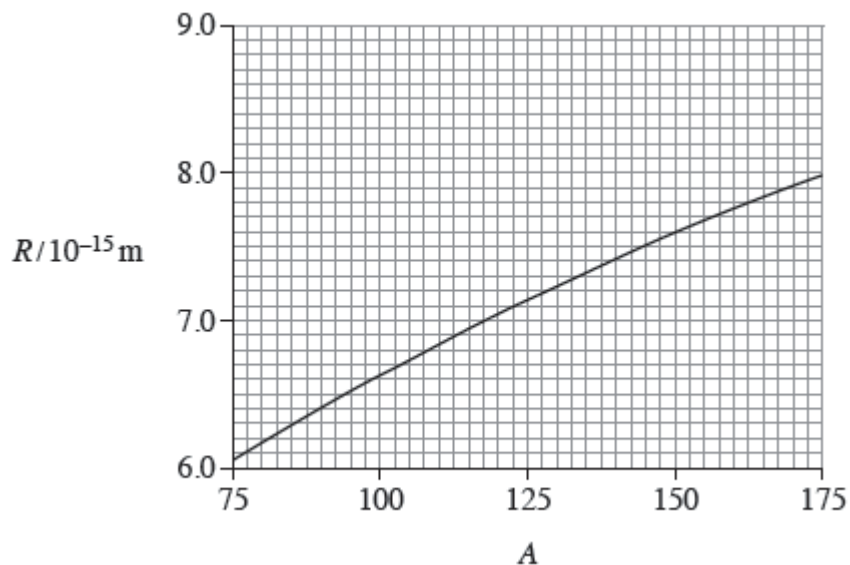
(1)

(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 1.4×10^{-15} m.

(1)

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

(2)

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

State an appropriate unit for your answer.

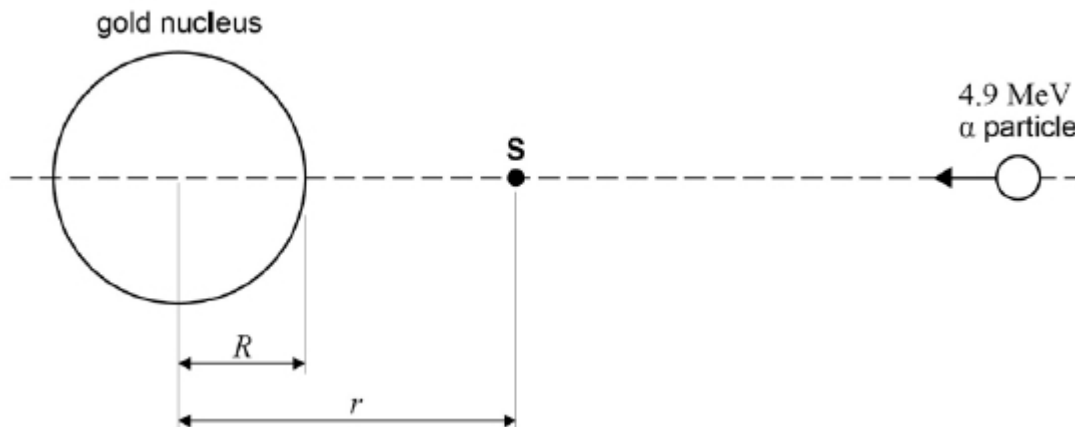
density _____ unit _____

(3)

(Total 8 marks)

8

An α particle with an initial kinetic energy of 4.9 MeV is directed towards the centre of a gold nucleus of radius R which contains 79 protons. The α particle is brought to rest at point **S**, a distance r from the centre of the nucleus as shown in the diagram below.



(a) Calculate the electric potential energy, in J, of the α particle at point **S**.

electric potential energy = _____ J

(2)

- (b) Calculate r , the distance of closest approach of the α particle to the nucleus.

$$r = \text{_____ m}$$

(3)

- (c) Determine the number of nucleons in the gold nucleus.

$$R, \text{ radius of the gold nucleus} = 7.16 \times 10^{-15} \text{ m}$$

$$R_0 = 1.23 \times 10^{-15} \text{ m}$$

$$\text{number of nucleons} = \text{_____}$$

(3)

- (d) The target nucleus is changed to one that has fewer protons. The α particle is given the same initial kinetic energy.

Explain, without further calculation, any changes that occur to the distance r . Ignore any recoil effects.

(2)

(Total 10 marks)

9

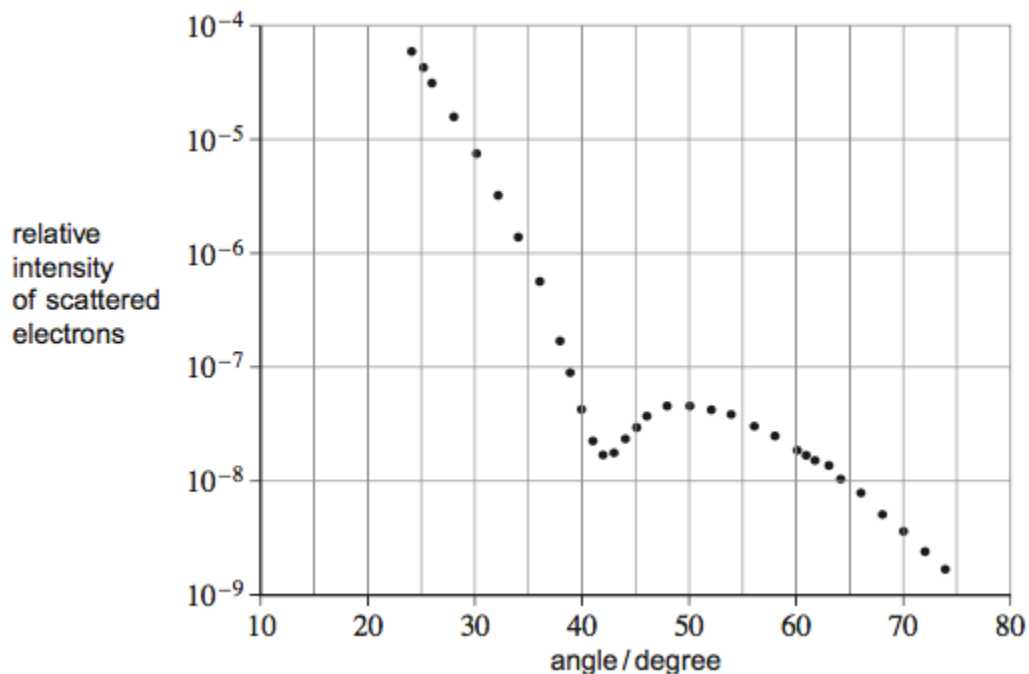
- (a) The radius of a nucleus may be determined by electron diffraction. In an electron diffraction experiment a beam of electrons is fired at oxygen-16 nuclei. Each electron has an energy of $5.94 \times 10^{-11} \text{ J}$.

The approximation, $\text{momentum} = \frac{\text{energy}}{\text{speed of light}}$ can be used for electrons at this energy.

- (i) Show that the de Broglie wavelength λ of each electron in the beam is about 3.3×10^{-15} m.

(2)

- (ii) The graph shows how the relative intensity of the scattered electrons varies with angle due to diffraction by the oxygen-16 nuclei. The angle is measured from the original direction of the beam.



The angle θ of the first minimum in the electron-diffraction pattern is given by

$$\sin \theta = \frac{0.61\lambda}{\text{nuclear radius}}$$

Calculate the radius of an oxygen-16 nucleus using information from the graph.

radius = _____ m

(1)

- (b) Rutherford used the scattering of α particles to provide evidence for the structure of the atom.
- (i) Sketch a labelled diagram showing the experimental arrangement of the apparatus used by Rutherford.

(2)

- (ii) State and explain the results of the scattering experiment.
Your answer should include the following:

- the main observations
- the significance of each observation
- how the observations placed an upper limit on the nuclear radius.

The quality of your written communication will be assessed in your answer.

(6)

(Total 11 marks)

10

- (a) Calculate the radius of the ${}_{92}^{238}\text{U}$ nucleus.

$$r_0 = 1.3 \times 10^{-15} \text{ m}$$

(2)

- (b) At a distance of 30 mm from a point source of γ rays the corrected count rate is C . Calculate the distance from the source at which the corrected count rate is $0.10 C$, assuming that there is no absorption.

(2)

- (c) The activity of a source of b particles falls to 85% of its initial value in 52 s. Calculate the decay constant of the source.

(3)

- (d) Explain why the isotope of technetium, $^{99}\text{Tc}_m$, is often chosen as a suitable source of radiation for use in medical diagnosis.

You may be awarded additional marks to those shown in brackets for the quality of written communication in your answer.

(3)

(Total 10 marks)

11

- (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)

12

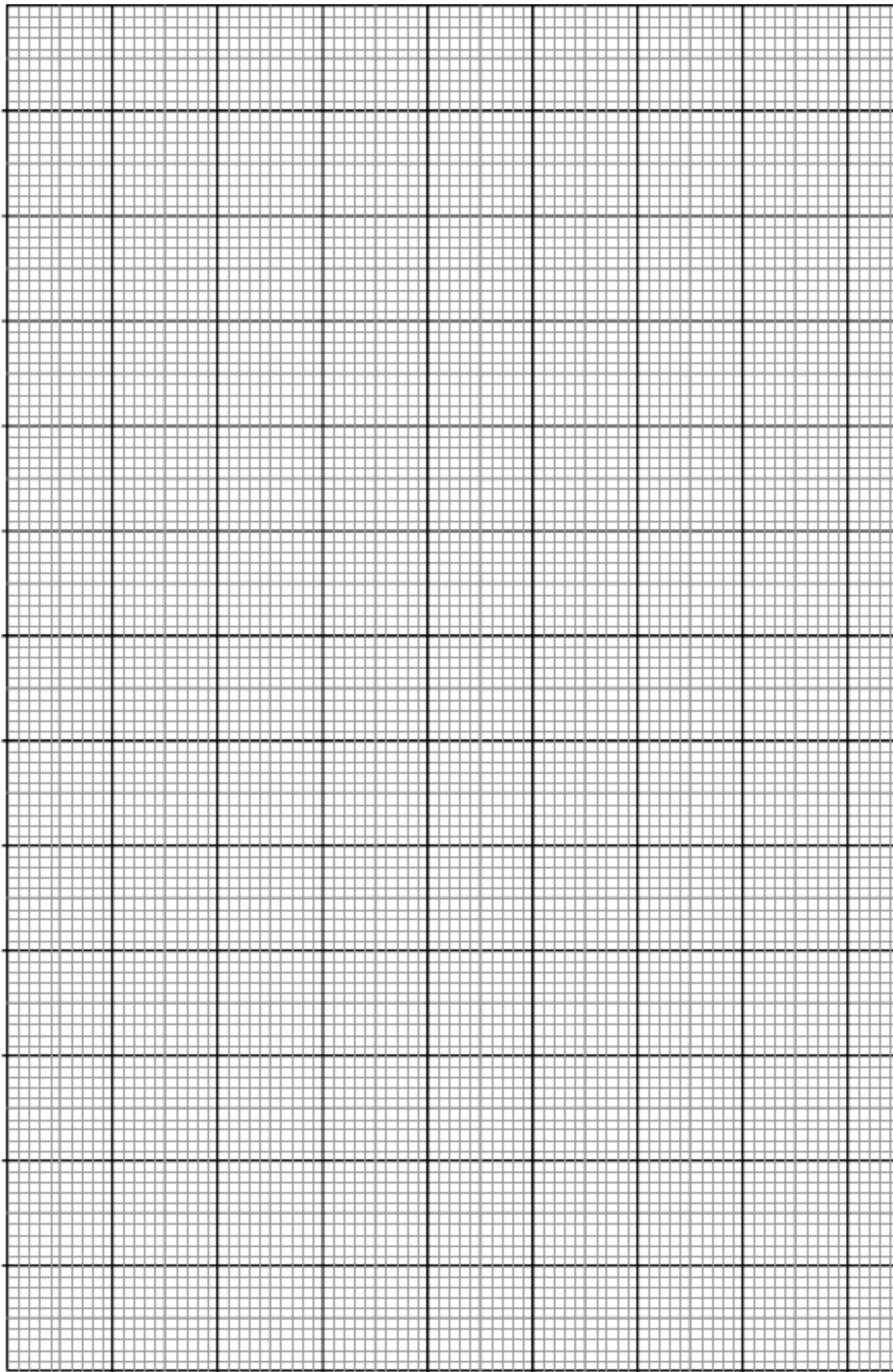
The radius of a nucleus, R , is related to its nucleon number, A , by

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

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)