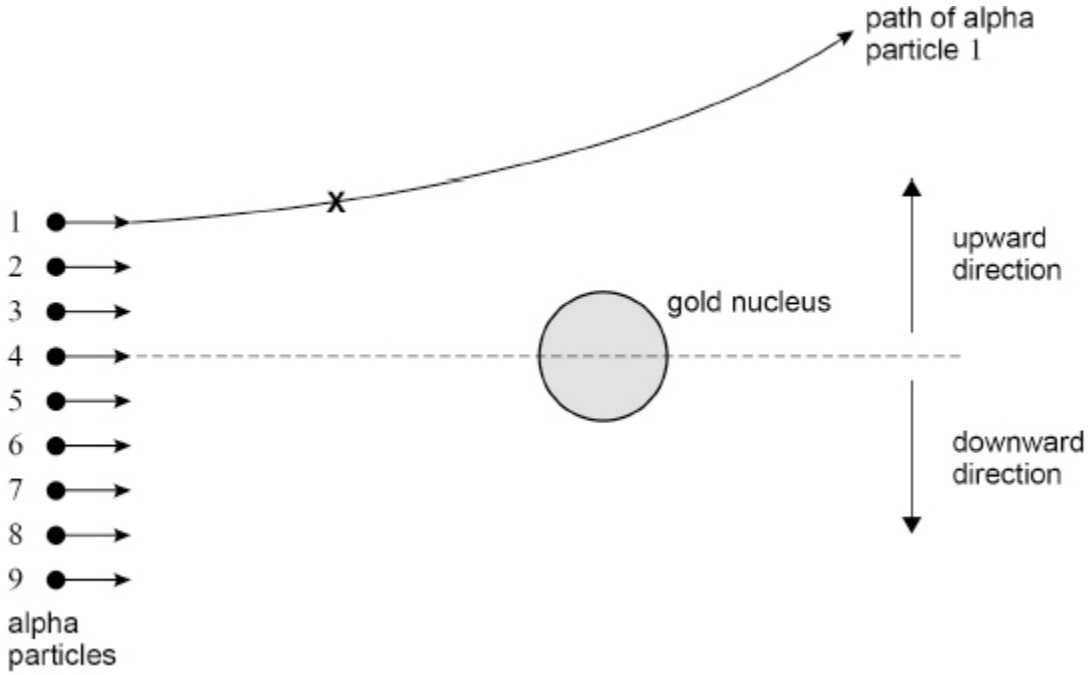
A-Level Physics

Rutherford Scattering Experiment

Question Paper

Time available: 61 minutes
Marks available: 42 marks

1. The diagram shows alpha particles all travelling in the same direction at the same speed. The alpha particles are scattered by a gold ($^{197}_{79}Au$) nucleus.
The path of alpha particle **1** is shown.



(a) State the fundamental force involved when alpha particle **1** is scattered by the nucleus in the diagram.

_____

(1)

(b) Draw an arrow at position **X** on the diagram above to show the direction of the rate of change in momentum of alpha particle **1**

(1)

(c) Suggest **one** of the alpha particles in the diagram above which may be deflected downwards with a scattering angle of 90°

Justify your answer.

alpha particle number = _____

_____

_____

_____

_____

(2)

(d) Alpha particle **4** comes to rest at a distance of 5.5×10^{-14} m from the centre of the $^{197}_{79}\mathrm{Au}$ nucleus.

Calculate the speed of alpha particle **4** when it is at a large distance from the nucleus. Ignore relativistic effects.

mass of alpha particle = 6.8×10^{-27} kg

speed = _____ m s^{-1}

(3)

(e) The nuclear radius of $^{197}_{79}\mathrm{Au}$ is 6.98×10^{-15} m.

Calculate the nuclear radius of $^{107}_{47}\mathrm{Ag}$.

radius = _____ m

(2)

(f) All nuclei have approximately the same density.

State **one** conclusion about the nucleons in a nucleus that can be deduced from this fact.

_____

_____

_____

_____

(1)

(Total 10 marks)

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.

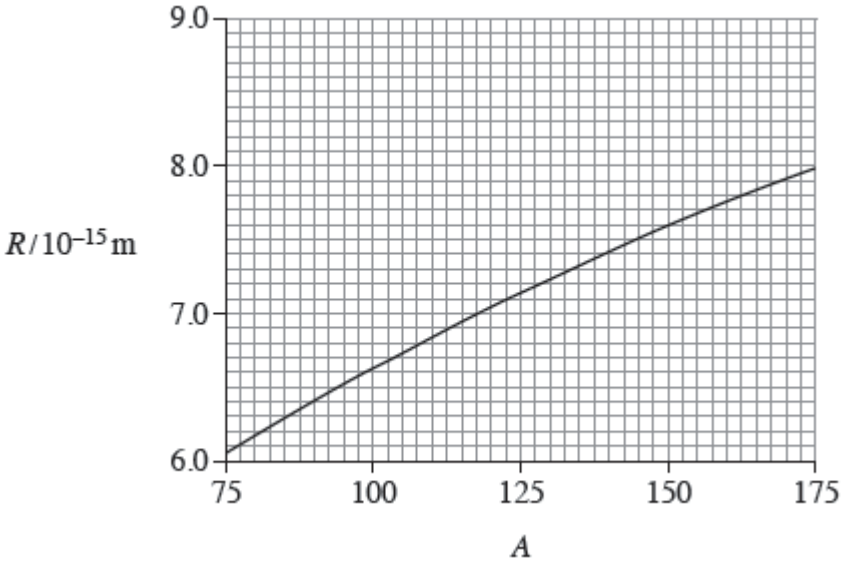
_____

_____

_____

(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 1.4×10^{-15} m.

(1)

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

(2)

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

State an appropriate unit for your answer.

density _____ unit _____

(3)

(Total 8 marks)

3. (a) (i) Why is it necessary to remove the air from the chamber in a Rutherford scattering experiment?

_____

_____

(ii) Give **two** conclusions that can be deduced about the nucleus from the results of such an experiment.

conclusion 1 _____

_____

conclusion 2 _____

_____

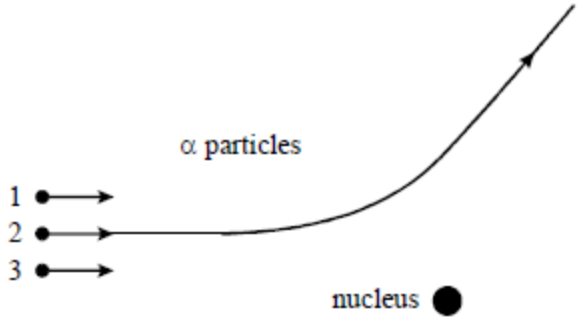
(iii) What force or interaction is responsible for Rutherford scattering?

_____

(4)

(b) The figure shows three α particles, all with the same kinetic energy, directed at a nucleus. The path followed by α particle 2 is given.

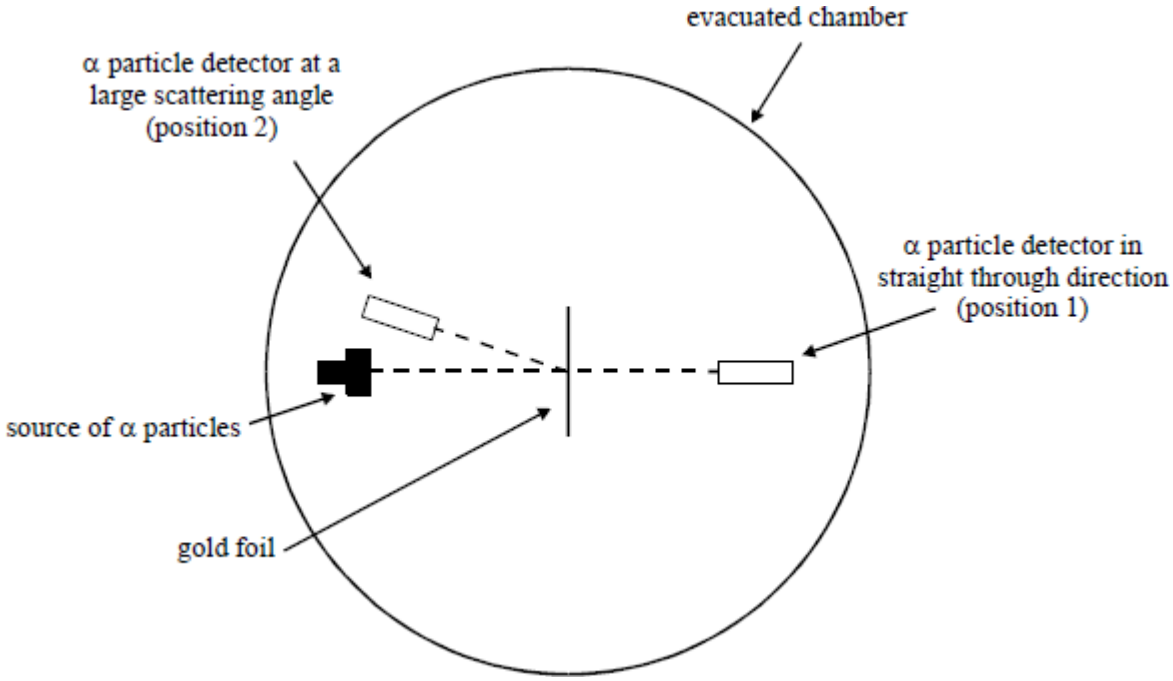
Draw lines on the figure to show the paths followed by α particles 1 and 3.



(2)

(Total 6 marks)

4. The figure below represents an experiment on Rutherford scattering in which α particles are directed at a gold foil. The detector is shown in two positions in the evacuated chamber.



(a) Why is it necessary to remove the air from the apparatus?

_____

_____

(b) Explain why the gold foil should be very thin.

_____

_____

(c) Explain why the count rate from the α particle detector in position 1 is much greater than that in position 2.
What can be deduced from this observation about the structure of the atom and the properties of the nucleus of gold?

_____

_____

_____

_____

_____

(Total 6 marks)

5. In an experiment to investigate the structure of the atom, α particles were aimed at thin gold foil in a vacuum. A detector was used to determine the number of α particles deflected through different angles.

(a) State **two** observations about the α particles detected coming from the foil.

_____

_____

_____

(2)

(b) State **two** features of the structure of the atom which can be deduced from these observations.

_____

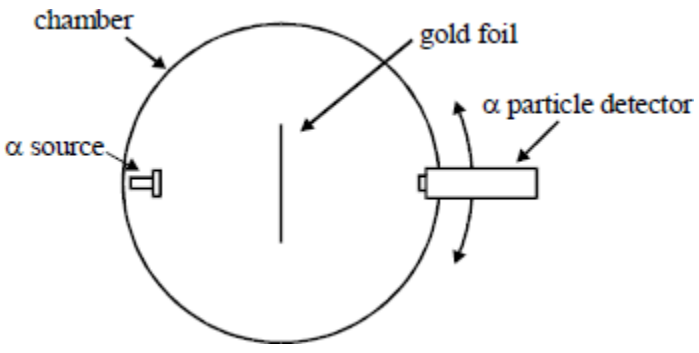
_____

_____

(2)

(Total 4 marks)

6. The diagram below shows the apparatus used to investigate Rutherford scattering, in which α particles are fired at a gold foil.



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(a) Why is it essential for there to be a vacuum in the chamber?

_____

_____

(2)

(b) What observations made with this apparatus support each of the following conclusions? No explanation is required.

(i) The nuclear radius of gold is much smaller than its atomic radius.

_____

_____

(ii) Most of the mass of an atom of gold is contained in its nucleus.

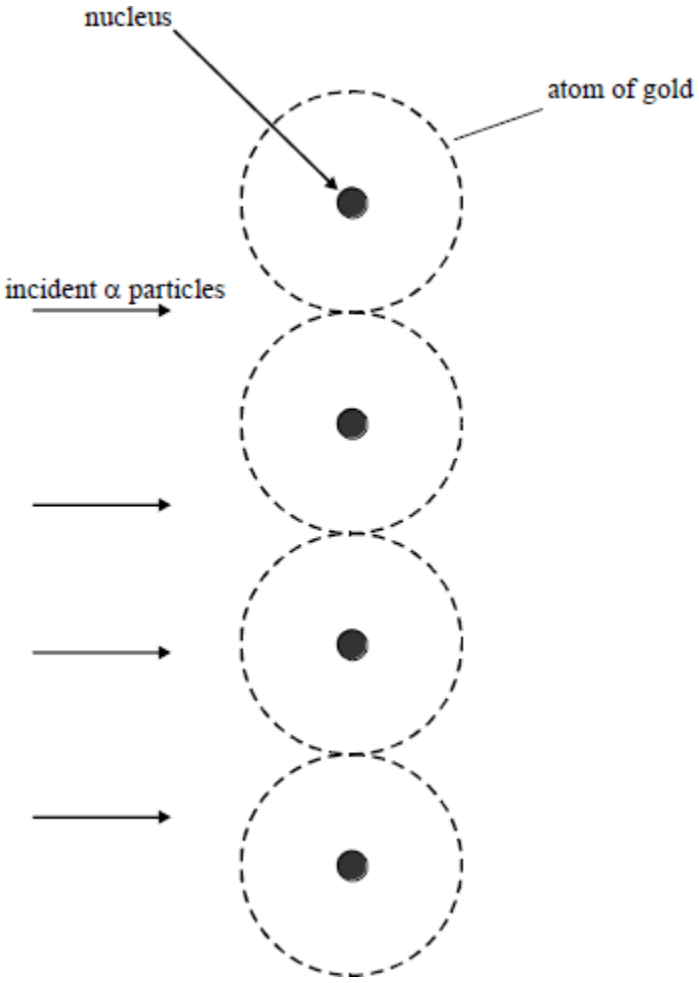
_____

_____

(3)

(c) The drawing below shows α particles incident on a layer of atoms in a gold foil.

On this figure draw the complete path followed by **each** of the α particles shown.



(3)

(Total 8 marks)