Access Tuition

A-Level Physics

Rutherford Scattering Experiment

Mark Scheme

Time available: 61 minutes
Marks available: 42 marks

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Mark schemes

1. (a) Electromagnetic ✓

Reject electrostatic as it is not one of the fundamental forces.

1

(b) Arrow drawn at X in a direction radially away from the centre of the gold nucleus ✓

1

(c) Answer number 5 or 6 plus one consistent justification ✓

First mark must come with at least one justification.

One more consistent justification ✓

List of justifications:
Cannot be 1, 2, or 3 as these s alpha's deflect up. Or must be 5 to 9 as these all alpha's deflect down.

Cannot be 4 as this would backscatter or is scattered at 180°

Cannot be 7, 8 or 9 as the deflection would be too small. Or must be 2, 3, 5, 6 as these have a greater deflection than alpha1.

The second mark is possible to obtain with two consistent justifications even if the first mark is missed.

E.g. if an answer 7 is given then quoting the first two justifications gains a mark.

2

(d) (Using of potential energy = $\frac{Qq}{4\pi\varepsilon_0 r}$

Substituting the values of the two charges multiplied together into an equation
$(2 \times 1.6 \times 10^{-19})(79 \times 1.6 \times 10^{-19})$✓$_1$

PE = $\frac{2\times79\times(1.6\times10^{-19})^2}{4\pi\times8.9\times10^{-12}\times5.5\times10^{-14}}$ or 6.58×10^{-13} (J) ✓$_2$

$_2$ The substitution may be inferred at the next stage of the calculation that uses

$KE = \frac{1}{2}mv^2 = PE$

(loss of KE = $\frac{1}{2}mv^2$ = gain in PE}

$$\left(v = \left(\frac{2 \times 6.58 \times 10^{-13}}{6.8 \times 10^{-27}}\right)^{1/2}\right)$$

$v = 1.4 \times 10^7$ (m s^{-1})✓$_3$

3

(e) Using by substitution or rearrangement $R = r_o A^{1/3}$ ✓

$R_{Ag} = 5.7 \times 10^{-15}$ (m) ✓

$$\left(R_{Ag} = R_{Au} \times \left(\frac{A_{Au}}{A_{Ag}} \right)^{1/3} \right)$$

$$\left(R_{Ag} = 6.98 \times 10^{-15} \times \left(\frac{107}{197} \right)^{1/3} \right)$$

The use of the equation must involve both nuclei.

2

(f) Nucleons are incompressible / Nucleons have a constant separation / Neutrons and protons have similar masses / Neutrons and protons have similar volumes ✓

A mark can be given for 'nucleons touch' but it must be implied that this is with all 12 neighbours'.

1

[10]

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 <u>and the reason</u> for it.

Or

the scattering distribution changes / becomes less distinct because there is a mixture of nuclear <u>masses</u> (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 t must be shown.

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

1

(ii) **Escalate if clip shows $^{27}_{13}$Al in the question giving R ≈ 4 × 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 × (i).

***Possible escalation*.**

2

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

density = mass / volume
$m = 51 \times 1.67 \times 10^{-27}$
(= 8.5×10^{-26} kg)

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

$v = 4/3\pi\ (5.3 \times 10^{-15})^3$
($6.2(4) \times 10^{-43}$ m^3)

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

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

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

top line = 1.66×10^{-27}

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

✓ for one substitution

density = 1.4×10^{17} ✓
(1.37×10^{17})
kg m^{-3} ✓

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) (i) to prevent absorption/deflection/interaction/collision of the α particle (by the air) **(1)**

(ii) (nucleus) has a positive charge (or same charge sign as an α particle
(nucleus) contains most of the mass (or is very dense) **(1) (1)** (any two)
(nucleus) is small compared to the separation between nuclei

(iii) electromagnetic or electrostatic or Coulomb **(1)**

4

(b) (particle 1) path is straighter than path of particle 2 **(1)**
(particle 3) path is bent more than path of particle 2, with minimum radius of curvature near the minimum separation and in front of the nucleus **(1)**

2

[6]

4. (a) α particles have a short range in air (3–5 cm) **(1)**
(or to minimise collisions between α particles and air molecules) **(1)**

(b) the α particles must not be absorbed by the foil **(1)**
(or the α particles must only be scattered once) **(1)**

(c) a majority of α particles pass straight through **(1)**
most α particles do not pass close enough to be deflected
(or few pass close enough to be deflected significantly) **(1)**

atoms consist mainly of open space **(1)**
nuclei are very small (or nucleus much smaller than the atom) **(1)**
the nucleus is massive (or most of the mass of the atom is contained in the nucleus)
the nucleus is positively charged

(or the nucleus and the α particle have the same charge) **(1)**

The Quality of Written Communication marks were awarded primarily for the quality of answers to this part.

[6]

5. (a) alpha particles undeflected **(1)**
some through small angles **(1)**
(very) small (but significant) number deflected through > 90° **(1)**

max 2

(b) atom mostly empty space **(1)**
positive charge concentrated **(1)**
in a volume much less than total volume [or radius] **(1)**

max 2

[4]

6. (a) to prevent the α particles being absorbed or scattered **(1)**
by air molecules **(1)**

(2)

(b) (i) little or no deflection **(1)**
by a majority of α particles **(1)**

(ii) some α particles suffer large deflection
[or backscattering occurs] **(1)**

(3)

(c) **first** path continues undeflected **(1)**
third path shows backscattering (inside the dotted circle) **(1)**
second path undeflected or deflected downwards and
fourth path undeflected or deflected upwards **(1)**

(3)

[8]