M1.(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 $R \approx 4 \times 10^{-15}$ 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 × (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]

M2.B

[1]

M3. (a) $^{27}_{13}Al + \alpha \rightarrow\ ^{30}_{15}P +\ ^{(1)}_{(0)}n$ ✓

1

(b) kinetic energy lost by the α particle approaching the nucleus is equal to the potential energy gain ✓

$$2.18 \times 10^{-12} = \frac{1}{4\pi \times 8.85 \times 10^{-12}} \times \frac{13 \times 1.6 \times 10^{-19} \times 2 \times 1.6 \times 10^{-19}}{r}$$ ✓

$r = 2.75 \times 10^{-15}$ (m) ✓

3

[4]

M4. (a) R (= $r_0A^{1/3}$) = $1.3 \times 10^{-5} \times (238)^{1/3}$ **(1)**

= $8.0(6) \times 10^{-15}$m **(1)**

2

(b) (use of inverse square law e.g. $\frac{I_1}{I_2} = \left(\frac{x_1}{x_2}\right)^2$ gives)

$10 = \left(\frac{x_2}{0.03}\right)^2$ **(1)**

x = 0.095 m **(1)**

(0.0949 m)

2

(c) (use of $A = A_o exp(-\lambda t$ gives) 0.85 = 1.0 exp ($-\lambda$52) **(1)**

$\lambda = \frac{\ln(100/0.85}{52}$ **(1)**

= $3.1(3) \times 10^{-3} s^{-1}$ **(1)**

3

(d) it only emits γ rays **(1)**

relevant properties of γ radiation e.g. may be detected outside the body/weak ioniser and causes little damage **(1)**

it has a short enough half-life and will not remain active in the body after use **(1)**

it has a long enough half-life to remain active during diagnosis **(1)**

the substance has a toxicity that can be tolerated by the body **(1)**

it may be prepared on site **(1)**

any three **(1)(1)(1)**

3

[10]

M5.(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	$R/10^{-15}$ m	A	$R^3/10^{-45}$ 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 × 10^{-45} m^3)

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

= (1.41 × 10^{-45})$^{1/3}$ = 1.1(2) × 10^{-15} 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	$R/10^{-15}$ 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

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

r_0 = gradient **(1)**
= $1.1(2) \times 10^{-15}$ m **(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)**

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

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

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

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

(4)

[12]