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 ≈ 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]

M2.(a) (i) (Mass change in u=) 1.71×10^{-3} (u)
or (mass Be−7) – (mass He−3) – (mass He−4) seen with numbers

C1

2.84×10^{-30} (kg)
or Converts their mass to kg

Alternative 2nd mark:
*Allow conversion of 1.71×10^{-3} (u) to MeV by multiplying by 931 (=1.59 (MeV)) **seen***

C1

Substitution in $E = mc^2$ *condone their mass <u>difference</u> in this sub but must have correct value for c^2 $(3\times10^8)^2$ or 9×10^{16}*

Alternative 3rd mark:
Allow their MeV converted to joules ($\times 1.6 \times 10^{-13}$) ***seen***

C1

2.55×10^{-13} (J) to 2.6×10^{-13} (J)

Alternative 4th mark:
Allow 2.5×10^{-13} (J) for this method

A1

4

(ii) Use of $E=hc/\lambda$ ***ecf***

C1

Correct substitution in rearranged equation with λ *subject* ***ecf***

C1

7.65×10^{-13} (m) to 7.8×10^{-13} (m) ecf

A1

3

(b) (i) Use of E_p formula:

C1

Correct charges for the nuclei <u>**and**</u> correct powers of 10

C1

$2.6(3) \times 10^{-13}$ J

A1

3

(ii) Uses $KE = 3/2\,kT$: ***or*** *halves KE_T, $KE = 1.3 \times 10^{-13}$ (J)* ***seen ecf***

C1

Correct substitution of data **and** makes T subject **ecf**
Or uses KE_T value **and** divides T by 2

C1

6.35×10^9 (K) or 6.4×10^9 (K) or 6.28×10^9(K) or 6.3×10^9 (K) **ecf**

A1

3

(c) (i) Deuteron / deuterium / hydrogen−2

B1

Triton / tritium / hydrogen−3

B1

2

(ii) Electrical heating / electrical discharge / inducing a current in plasma / use of e−m radiation / using radio waves (causing charged particles to resonate)

B1

1

[16]

M3.D

[1]

M4.(a) the amount of energy required to separate a nucleus ✓
into its separate neutrons and protons / nucleons ✓
(or energy released on formation of a nucleus ✓
from its separate neutrons and protons / constituents ✓)

1st mark is for correct energy flow direction

2nd mark is for binding or separating nucleons (nucleus is in the question but a reference to an atom will lose the mark)

ignore discussion of SNF etc

both marks are independent

2

(b) (i) $2\,^{1}_{0}n$ or $^{1}_{0}n + ^{1}_{0}n$ ✓

must see subscript and superscripts

1

(ii) binding energy of U
= 235 × 7.59 ✓ (= 1784 (MeV))
binding energy of Tc and In
= 112 × 8.36 + 122 × 8.51 ✓
(= 1975 (MeV))
energy released (= 1975 – 1784) = 191 (MeV) ✓ (allow 190 MeV)

1st mark is for 235 × 7.59 seen anywhere
2nd mark for 112 × 8.36 + 122 × 8.51 or 1975 is only given if there are no other terms or conversions added to the equation (ignore which way round the subtraction is positioned)
correct final answer can score 3 marks

3

(iii) energy released
= 191 × 1.60 × 10^{-13} ✓
(= 3.06 × 10^{-11} J)
loss of mass (= E / c^2)
= 2.91 × 10^{-11} / (3.00 × 10^{8})^2)
= 3.4 × 10^{-28} (kg) ✓
or
= 191 / 931.5 u ✓ (= 0.205 u)
= 0.205 × 1.66 × 10^{-27} (kg)
= 3.4 × 10^{-28} (kg) ✓

allow CE from (ii)
working must be shown for a CE otherwise full marks can be given for correct answer only

note for CE
answer = (ii) × 1.78 × 10^{-30}

(2.01 × 10^{-27} is a common answer)

2

(c) (i) line or band from origin, starting at 45° up to Z approximately = 20
reading Z = 80, N = 110→130 ✓

initial gradient should be about 1 (ie Z = 20 ; N = 15 → 25) and overall must show some concave curvature. (Ignore slight waviness in the line)
if band is shown take middle as the line
if line stops at N > 70 extrapolate line to N = 80 for marking

1

(ii) fission fragments are (likely) to be above / to the left of the line of stability ✓

fission fragments are (likely) to have a larger *N* / *Z* ratio than stable nuclei

or

fission fragments are neutron rich owtte ✓

and become neutron or β^- emitters ✓

ignore any reference to α emission
a candidate must make a choice for the first two marks
stating that there are more neutrons than protons is not enough for a mark
1st mark reference to graph
2nd mark – high N / Z ratio or neutron rich
3rd mark beta minus
note not just beta

3

[12]