1. Any **seven** from:
α **-** particle scattering
suitable diagram with source, foil, moveable detector
2 or more trajectories shown
vacuum
most particles have little if any deflection
large deflection of very few
reference to Coulomb's law /elastic scattering
alphas repelled by nucleus (positive charges)
monoenergetic
OR electron scattering
High energy diagram with source sample, moveable detector / film
Vacuum
Electron accelerator or other detail
Most have zero deflection
Characteristic angular distribution with minimum
Minimum not zero
De Broglie wavelength
Wavelength comparable to nuclear size hence high energy B1 × 7

Clearly shows how evidence for the size of the nucleus follows from what is described. (1)

[8]

2. (a) He nucleus, a few cm / 3 to 10 cm
About 1 m / 0.3 to 2 m / several m, 1 to 10 mm Al / 1 mm Pb
(high energy) e-m radiation, 1 to 10 cm of Pb / several m of concrete
only 2 correct 1 mark, only 4 correct 2 marks B3

(b) Source, absorbers placed in front of detector on diagram B1
Explanation of how results identify the source
(2 marks possible) B2
Allowance for background (max 2)
(allow for distance expt to a max 2)

[6]

3. description:
(4) hydrogen or light nuclei/protons are fused together to form a helium/heavier/larger nucleus; (1)
two positrons must also be released; to conserve charge; (2)
the process is more complicated than the summary equation suggests/AW;
mass reduction provides energy release/ $\Delta m = \Delta E/c^2$ (1)
the process requires very high temperatures (to bring the protons together); (1)
normally achieved inside a star; only by man in a bomb so far; (1)
comparison: (2)
Energy release in fusion is much greater than in radioactive decay;
because mass reduction/change in fusion is much greater than in radioactive (1) decay/AW; (1)
as the helium nucleus is so strongly bound; (1)
also energy release from annihilation of positrons; (1) max 5
Quality of Written Communication 2

[7]

4. (a) number of *decayed* U-238 nuclei = ½ × number of *undecayed* U-238 nuclei; (1)
so 1/3 of U-238 has decayed and 2/3 of U-238 has not decayed; (1) 2
(so ratio = 2/3)

(b) *either* $\lambda = 0.693 / T_{½} = 0.693 / (4.47 \times 10^9)$ (= 1.55×10^{-10} y^{-1}) subs. (1)
$N = N_0 e^{-\lambda t}$ so $N / N_0 = e^{-\lambda t}$ and $\ln (N / N_0) = -\lambda t$
$\ln (0.667) = -1.55 \times 10^{-10} t$ alg. / arith. (1)
so $t = 2.61 \times 10^9$ y ans. (1) 3

or $N / N_0 = (½)^x$ so $0.667 = (½)^x$ and $\ln (0.667) = x \ln(0.5)$
and $x = 0.584$ then $t = x T_{½} = 0.584 \times 4.47 \times 10^9 = 2.61 \times 10^9$ y

(c) *either* $N_0 = (5.00 / 238) \times 6.02 \times 10^{23}$ subs. (1)
$= 1.26 \times 10^{22}$ atoms ans. (1) 2

or $N_0 = (5.00 \times 10^{-3}) / (1.67 \times 10^{-27} \times 238)$ (1)
$= 1.26 \times 10^{22}$ atoms (1)

(d) exponential decay graph for U: starts from N_0 and approaches t axis; (1)
exponential growth of Pb from zero: approaches a constant value of N_0 ; (1)
lines sensibly ‘mirror images’; (1) 3

[10]

5. (a) Rb 94
Cs 55
U143
–1 for each error B2

(b)	Values from graph: U 7.4 MeV *allow 7.3 to 7.4* Rb 8.6 MeV *allow 8.5 to 8.6* Cs 8.4 MeV		C1
	Total binding energies: U 235 × 7.4 (1739) Rb 94 × 8.6 (808) Cs 142 × 8.4 (1193)		B2
	Total energy released = 808 + 1193 – 1739 = 262 MeV allow 8.6 + 8.4 – 7.4 = 9.4 MeV for 1 mark only		A1

[6]

6. confines / pulls together plasma / nuclei / ions / nucleons / protons; (1)
so increases density/ concentration / number per unit volume; (1)
and increases frequency / number of collisions among nuclei; (1)
gravitational attraction heats plasma / gravitational p.e. changed to heat; (1)
any 3

[3]

7. (a) (i) to come to rest simultaneously, total mtm. = 0 *or* AW (1) (but initial mtm. not zero) — 1

(ii) initial mtm. = 3 $m\,u$ – 2 $m\,u$ = $m\,u$ (1)
when closest, mtm. = (3m + 2m) v (1) — 2
so 5$m\,v$ = $m\,u$ (and v = u / 5)

(b) (i) initial k.e. = final k.e. + (gain of) p.e. (1) — 1

(ii) k.e. = ½ $m\,v^2$ (1)
total k.e. = ½ × 3 $m\,u^2$ + ½ × 2 $m\,u^2$ (= 2.5 $m\,u^2$) (1)
= 2.5 × 1.67 × 10^{-27} u^2 (= 4.18 × 10^{-27} u^2) (1) — 3
allow m = 1.66 × 10^{-27} kg for full credit

(iii) gain of p.e. = initial k.e. – final k.e.

$$\frac{(1.6\times10^{-19})^2}{(4\pi\times8.85\times10^{-12}\times1.5\times10^{-15})} = 4.18\times10^{-27}\,u^2 - 4.18\times10^{-27}\,(u/5)^2 \ (2)$$

1.53 × 10^{-13} = 4.01 × 10^{-27} u^2 (1) *algebra*
u = 6.18 × 10^6 m s^{-1} (1) — 4

omits - 4.18 × 10^{-27} $(u/5)^2$, gets u = 6. 06 × 10^6 m s^{-1}: 1/2, 1, 1 = 3/4

[11]

8. (a) $^{239}_{92}U \rightarrow {}^{239}_{93}Np + {}^{0}_{-1}\beta$ / $^{0}_{-1}e + \bar{\nu}$ (1)
allow $^{238}_{92}U + {}^{1}_{0}n$ on LHS

$^{239}_{93}Np \rightarrow {}^{239}_{94}Pu + {}^{0}_{-1}\beta$ / $^{0}_{-1}e + \bar{\nu}$ (1) 2

allow neutrino instead of antineutrino
omits neutrino altogether - gets 1/2

(b) straight line starts from zero and reaches 1.08×10^{13} at
$t = 6.0 \times 10^5$ s or equivalent (1) 1

(c) (i) rate of decay increases with time; (1)
because rate of decay increases with / is proportional to
number of nuclei; (1) 2

(ii) (eventually) rate of decay (of $^{239}_{93}Np$) = rate of formation (1) 1

(iii) $dN/dt = (–)\ \lambda N$ *equation* (1)
$\lambda = 0.693 / T½$
so $N = (dN/dt) / \lambda = 1.8 \times 10^7 / (0.693 / [2.04 \times 10^5])$ *subs.* (1)
$= 5.3 \times 10^{12}$ *ans.* (1) 3
calculation of λ gets 1/3

(iv) correctly curved from zero to (5.3×10^{12}) or less (1) 1

[10]

9. (i) 3 points plotted; any point incorrect loses this mark 1

(ii) curve through 3 points and heads down towards zero; (1)
line peaks between Br and origin; (1) 2

(iii) BE per *nucleus* of $^{235}_{92}U$ = 7.60×235 (= 1786 MeV)
BE of products = $8.20 \times 146 + 8.60 \times 87$ both lines (1)
(= 1197 + 748 MeV)
so energy released = (1197 + 748) – 1786 (1)
= 159 MeV (1)
omits multiplication by nucleon number to get 9.2 MeV gets 0,1,0 = 1 3

[6]