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* $\lambda = 0.693 / T_{½} = 0.693 / (4.47 \times 10^9)$ ($= 1.55 \times 10^{-10}$ 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* C1
Cs 8.4 MeV

Total binding energies: U 235 × 7.4 (1739)
Rb 94 × 8.6 (808) B2
Cs 142 × 8.4 (1193)

Total energy released = 808 + 1193 – 1739 A1
= 262 MeV
allow 8.6 + 8.4 – 7.4 = 9.4 MeV for 1 mark only

[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) 1
(but initial mtm. not zero)

(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.

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

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]