


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 \times 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
- Explanation of how results identify the source
- (2 marks possible)
- Allowance for background (max 2)
- (allow for distance expt to a max 2)
- B1
B2

[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 = $\frac{1}{2} \times$ 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* $\lambda = 0.693 / T_{1/2} = 0.693 / (4.47 \times 10^9)$ ($= 1.55 \times 10^{-10} \text{ y}^{-1}$) 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 $t = 2.61 \times 10^9 \text{ y}$ ans. (1) 3

or $N/N_0 = (\frac{1}{2})^x$ so $0.667 = (\frac{1}{2})^x$ and $\ln(0.667) = x \ln(0.5)$
 and $x = 0.584$ then $t = x T_{1/2} = 0.584 \times 4.47 \times 10^9 = 2.61 \times 10^9 \text{ y}$

(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 $5m v = m u$ (and $v = u / 5$)
- (b) (i) initial k.e. = final k.e. + (gain of) p.e. (1) 1
- (ii) k.e. = $\frac{1}{2} m v^2$ (1)
 total k.e. = $\frac{1}{2} \times 3 m u^2 + \frac{1}{2} \times 2 m u^2$ (= $2.5 m u^2$) (1)
 = $2.5 \times 1.67 \times 10^{-27} u^2$ (= $4.18 \times 10^{-27} u^2$) (1) 3
 allow $m = 1.66 \times 10^{-27}$ kg for full credit
- (iii) gain of p.e. = initial k.e. – final k.e.

$$\frac{(1.6 \times 10^{-19})^2}{(4\pi \times 8.85 \times 10^{-12} \times 1.5 \times 10^{-15})} = 4.18 \times 10^{-27} u^2 - 4.18 \times 10^{-27} (u/5)^2$$
 (2)
 $1.53 \times 10^{-13} = 4.01 \times 10^{-27} u^2$ (1) *algebra*
 $u = 6.18 \times 10^6 \text{ m s}^{-1}$ (1) 4
 omits - $4.18 \times 10^{-27} (u/5)^2$, gets $u = 6.06 \times 10^6 \text{ m s}^{-1}$: 1/2, 1, 1 = 3/4

[11]

8. (a) ${}^{239}_{92}\text{U} \rightarrow {}^{239}_{93}\text{Np} + {}^0_{-1}\beta / {}^0_{-1}\text{e} + \bar{\nu}$ (1)
 allow ${}^{238}_{92}\text{U} + {}^1_0\text{n}$ on LHS
 ${}^{239}_{93}\text{Np} \rightarrow {}^{239}_{94}\text{Pu} + {}^0_{-1}\beta / {}^0_{-1}\text{e} + \bar{\nu}$ (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 ${}^{239}_{93}\text{Np}$) = rate of formation (1) 1
- (iii) $dN/dt = (-) \lambda N$ equation (1)
 $\lambda = 0.693 / T_{1/2}$
 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
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 ${}^{235}_{92}\text{U} = 7.60 \times 235 (= 1786 \text{ MeV})$
 BE of products $= 8.20 \times 146 + 8.60 \times 87$ both lines (1)
 $(= 1197 + 748 \text{ MeV})$
 so energy released $= (1197 + 748) - 1786$ (1)
 $= 159 \text{ MeV}$ (1)
 omits multiplication by nucleon number to get 9.2 MeV gets 0,1,0 = 1 3

[10]

[6]