Question	Answer	Marks
1 a	B	1
1 b	B	1
1 c	D	1
1 d	D	1
2 a	$\gamma = \frac{1}{\sqrt{1-0.5^2}}$ = 1.15… = 1.2 (2 s.f.)	1 1
2 b	Momentum = γmv = 1.15… × 9.11 × 10^{-31} × 1.5 × 10^8 = 1.6 × 10^{-22} kg m s^{-1}	1 1
3	$\gamma = 2 = \frac{\text{total energy}}{\text{rest energy}} = 1 + \frac{\text{kinetic energy}}{\text{rest energy}}$ Kinetic energy = 0.51 MeV. Therefore p.d. = 0.51 MV	1 1
4	$\lambda = \frac{h}{\sqrt{2me}}$ = 1.2 × 10^{-13}	1 1
5 a	$r = \frac{9\times10^9 \times 1.6\times10^{-19} \times 2\times1.6\times10^{-19} \times 92}{5.4\times10^6 \times 1.6\times10^{-19}}$ = 4.9 × 10^{-14} m	1 1
5 b	No change as proton number is the same.	1
6 a	$\gamma = \frac{\text{total energy}}{\text{rest energy}} = 1 + \frac{7\times10^{12}}{9.6\times10^8}$ 7300 (2 s.f.)	1 1
6 b	Speed of proton = 2.99… × 10^8 m s^{-1} This is very close to the speed of light—indeed it is equal to the speed of light to eight significant figures.	1 1
7	Energy released = Δmc^2 = (1.6749 – 1.6726 – 0.0009) × 10^{-27} × 9.0 × 10^8 = 1.26 × 10^{-13} J	1 1
8	$\frac{r_h}{\sqrt[3]{4}} = \frac{r_u}{\sqrt[3]{238}}$ r_u = 7.4 × 10^{-15} m	1 1
9 a	Diagram showing six possible transitions.	1
9 b	Lowest frequency equates to photon energy of 0.6 eV Frequency = 1.4(5) × 10^{-14} Hz	1 1
9 c	Highest frequency equates to photon energy of 12.7 eV Frequency = 3.1 × 10^{15} Hz	1 1
9 d	The free electron raises the hydrogen atom from the ground state to an energy of –3.4 eV. The free electron transers 10.2 eV to the atom 11.5 eV–10.2 eV = 1.3 eV	1 1
10 a	$\frac{h^2}{m^2v^2} = \lambda^2 \therefore m^2v^2 = \frac{h^2}{\lambda^2}$ worked through to required equation	1
10 b	n = 2: λ = 2 × 10^{-10} m energy = 6 × 10^{-18} J n = 3: λ = 1.3 × 10^{-10} m energy = 1.4 × 10^{-17} J	1 1 1 1

10 c	The kinetic energy of the electron is of lower magnitude than its negative potential energy so its total energy is negative.	1 1
11 a i	$N = \frac{7\times10^4\times9.2\times10^8}{\ln 2}$ $= 9.3 \times 10^{13}$	1 1
11 a ii	Minimum figure as it assumes all beta particles released are accounted for.	1
11 b i	0.11 to 0.12 MeV	1
11 b ii	(Graph shows that) beta particles have a range of energies. Energy is conserved in the emission process so remaining energy taken away by other particles.	1 1 1
11 c	$\gamma = \frac{0.511+0.45}{0.511}$ $= 1.88$ $1.88 = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$ $v = 2.54 \times 10^8$ m s^{-1}	1 1 1 1
12 a i	Greater proportion deflected as there is a greater chance of close approach to the nucleus.	1 1
12 a ii	Smaller proportion deflected as less time spent near nuclei.	1 1
12 b i	5 MeV	1
12 b ii	8×10^{-13} J	1
12 b iii	$r = \frac{2\times79\times1.6\times10^{-19}\times9\times10^9}{8\times10^{-13}}$ $= 4.55 \times 10^{-14}$ m	1 1
12 c	ratio of volumes = $(6 \times 10^{-5})^3$ $= 2.16 \times 10^{-13}$ density = $\frac{1.9\times10^4}{2.16\times10^{-3}} = 9 \times 10^{16}$ kg m^{-3} Assumption: e.g. all mass in nucleus or no volume between gold atoms.	1 1 1