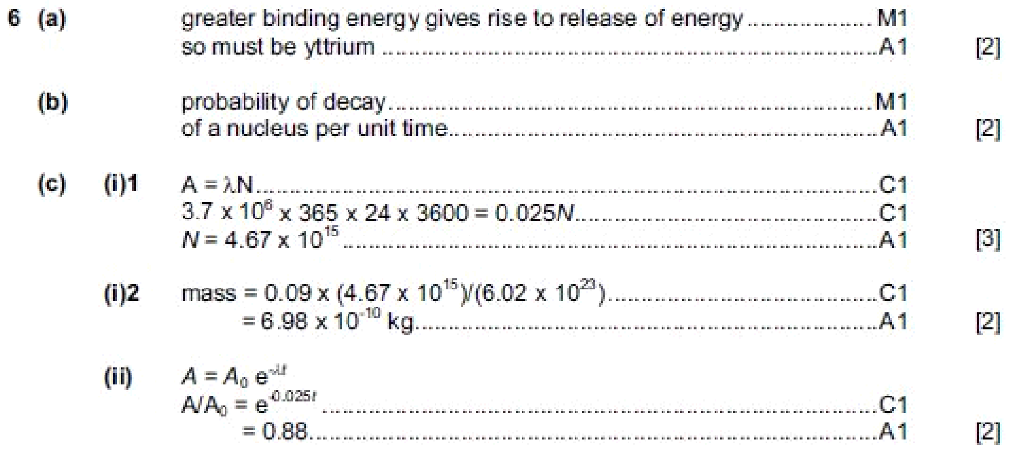
Q1.



6 **(a)** greater binding energy gives rise to release of energy M1
so must be yttrium .... A1 [2]

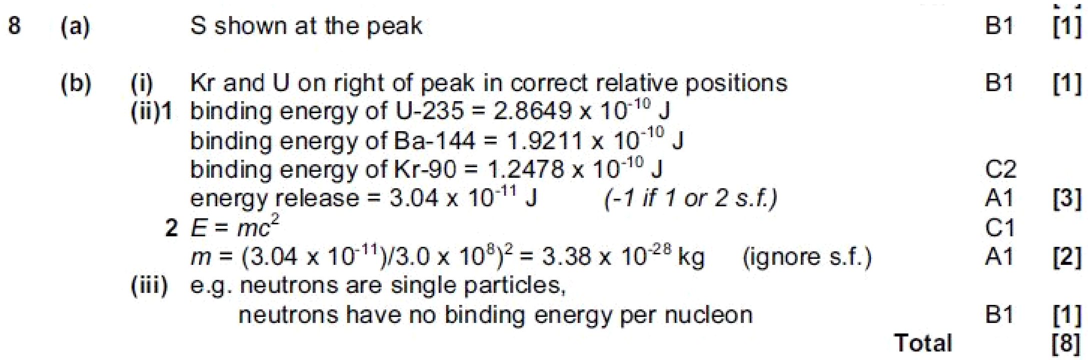
(b) probability of decay M1
of a nucleus per unit time .... A1 [2]

(c) **(i)1** $A = \lambda N$ C1
$3.7 \times 10^6 \times 365 \times 24 \times 3600 = 0.025N$ C1
$N = 4.67 \times 10^{15}$ .... A1 [3]

(i)2 mass = $0.09 \times (4.67 \times 10^{15})/(6.02 \times 10^{23})$ C1
$= 6.98 \times 10^{-10}$ kg .... A1 [2]

(ii) $A = A_0 \, e^{-\lambda t}$
$A/A_0 = e^{-0.025t}$ C1
$= 0.88$ .... A1 [2]

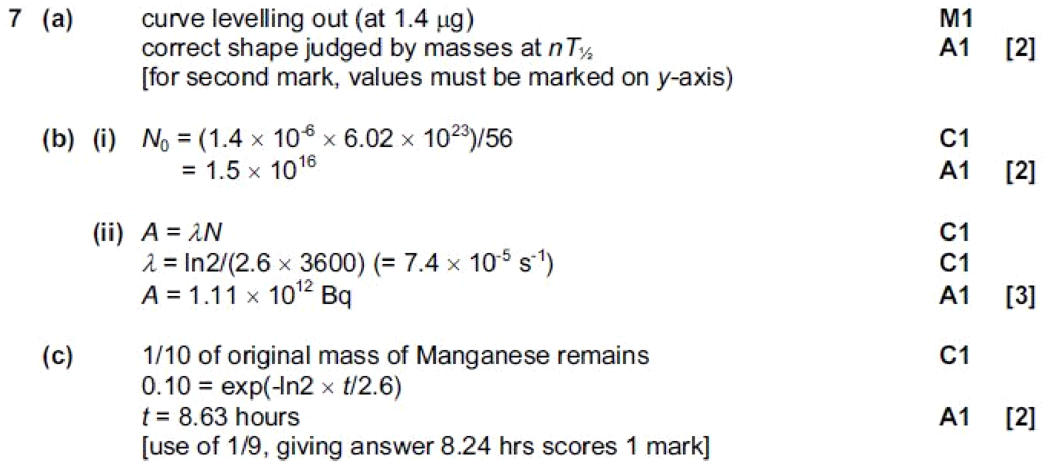
Q2.



8 (a) S shown at the peak B1 [1]

(b) (i) Kr and U on right of peak in correct relative positions B1 [1]
(ii)1 binding energy of U-235 = 2.8649×10^{-10} J
binding energy of Ba-144 = 1.9211×10^{-10} J
binding energy of Kr-90 = 1.2478×10^{-10} J C2
energy release = 3.04×10^{-11} J *(-1 if 1 or 2 s.f.)* A1 [3]
2 $E = mc^2$ C1
$m = (3.04 \times 10^{-11})/3.0 \times 10^8)^2 = 3.38 \times 10^{-28}$ kg (ignore s.f.) A1 [2]
(iii) e.g. neutrons are single particles,
neutrons have no binding energy per nucleon B1 [1]
Total [8]

Q3.



7 (a) curve levelling out (at 1.4 μg) **M1**
correct shape judged by masses at $nT_{½}$ **A1** [2]
[for second mark, values must be marked on y-axis)

(b) (i) $N_0 = (1.4 \times 10^{-6} \times 6.02 \times 10^{23})/56$ **C1**
$= 1.5 \times 10^{16}$ **A1** [2]

(ii) $A = \lambda N$ **C1**
$\lambda = \ln 2/(2.6 \times 3600)$ (= 7.4×10^{-5} s^{-1}) **C1**
$A = 1.11 \times 10^{12}$ Bq **A1** [3]

(c) 1/10 of original mass of Manganese remains **C1**
$0.10 = \exp(-\ln 2 \times t/2.6)$
$t = 8.63$ hours **A1** [2]
[use of 1/9, giving answer 8.24 hrs scores 1 mark]

Q4.

6 **(a)** probability of decay	M1	
of a nucleus per unit time	A1	[2]
(allow 1 mark for $A = \lambda N$, with symbols explained)		
(b) **(i)** $\lambda = \ln 2/(28 \times 365 \times 24 \times 3600)$	C1	
$= 7.85 \times 10^{-10}\ \mathrm{s^{-1}}$	A1	[2]
(ii) $A = (-)\lambda N$		
$N = (6.4 \times 10^{9})/(7.85 \times 10^{-10})$	C1	
$= 8.15 \times 10^{18}$	C1	
mass $= (8.15 \times 10^{18} \times 90)/(6.02 \times 10^{23})$ (e.c.f. for value of N)	C1	
$= 1.22 \times 10^{-3}$ g	A1	[4]
(iii) volume $= (1.22 \times 10^{-3}/2.54 =)\ 4.8 \times 10^{-4}\ \mathrm{cm^3}$	A1	[1]
(c) *either* very small volume of Strontium-90 has high activity		
or dust can be highly radioactive	B1	
breathing in dust presents health hazard	B1	[2]

Q5.

8 **(a)** since momentum before combining is zero	B1	
momenta must be equal and opposite after	B1	
<u>equal momenta so</u> photon energies equal	B1	[3]
(b) $E = mc^2$	C1	
$= 9.1 \times 10^{-31} \times (3.0 \times 10^{8})^2$		
$= 8.19 \times 10^{-14}$ (J)	C1	
$= (8.19 \times 10^{-14}) / (1.6 \times 10^{-13})$		
$= 0.51$ MeV	A1	[3]

Q6.

9 **(a)** **(i)** $\Delta N / \Delta t$ (ignore any sign)	B1	[1]
(ii) $\Delta N / N$ (ignore any sign)	B1	[1]
(b) source must decay by 8%	C1	
$A = A_0 \exp(-\ln 2\ t / T_{½})$ *or* $A/A_0 = 1 / (2^{t/T})$	C1	
$0.92 = \exp(-\ln 2 \times t / 5.27)$ *or* $0.92 = 1 / (2^{t/5.27})$	C1	
$t = 0.634$ years		
$= 230$ days	A1	[4]
(allow 2 marks for $A/A_0 = 0.08$, answer 7010 days		
allow 1 mark for $A/A_0 = 0.12$, answer 5880 days)		

Q7.

8	(a)		momentum conservation hence momenta of photons are equal (but opposite)	M1	
			same momentum so same energy	A1	[2]
	(b)	(i)	$(\Delta)E = (\Delta)mc^2$	C1	
			$= 1.2 \times 10^{-28} \times (3.0 \times 10^8)^2$		
			$= 1.08 \times 10^{-11}$ J	A1	[2]
		(ii)	$E = hc / \lambda$		
			$\lambda = (6.63 \times 10^{-34} \times 3.0 \times 10^8) / (1.08 \times 10^{-11})$	C1	
			$= 1.84 \times 10^{-14}$ m	A1	[2]
		(iii)	$\lambda = h / p$		
			$p = (6.63 \times 10^{-34}) / (1.84 \times 10^{-14})$	C1	
			$= 3.6 \times 10^{-20}$ N s	A1	[2]

Q8.

8	(a)	(i)	number $= (5.1 \times 10^{-6} \times 6.02 \times 10^{23}) / 241$	C1	
			$= 1.27 \times 10^{16}$	A1	[2]
		(ii)	$A = \lambda N$	C1	
			$5.9 \times 10^5 = \lambda \times 1.27 \times 10^{16}$		
			$\lambda = 4.65 \times 10^{-11}\ \mathrm{s}^{-1}$	A1	[2]
		(iii)	$4.65 \times 10^{-11} \times t_{½} = \ln 2$	C1	
			$t_{½} = 1.49 \times 10^{10}$ s		
			= 470 years	A1	[2]
	(b)		sample / activity would decay appreciably whilst measurements are being made	B1	[1]

Q9.

8	(a)	(i)	Fe shown near peak	A1	[1]
		(ii)	Zr shown about half-way along plateau	A1	[1]
		(iii)	H shown at less than 0.4 of maximum height	A1	[1]
	(b)	(i)	heavy / large nucleus breaks up / splits	M1	
			into two nuclei / fragments of approximately equal mass	A1	[2]
		(ii)	binding energy of nucleus = $B_E \times A$	B1	
			binding energy of parent nucleus is less than sum of binding energies of fragments	B1	[2]

Q10.

8 (a)	energy required to separate nucleons in a nucleus	M1	
	to infinity	A1	[2]
(b)	$1\text{u} = 1.66 \times 10^{-27}$ kg		
	$E = mc^2$	C1	
	$= 1.66 \times 10^{-27} \times (3.0 \times 10^8)^2$	M1	
	$= 1.49 \times 10^{-10}$ J		
	$= (1.49 \times 10^{-10}) / (1.6 \times 10^{-13})$	M1	
	= 930 MeV	A0	[3]
(c) (i)	$\Delta m = 2.0141\text{u} - (1.0073 + 1.0087)\text{u}$		
	$= -1.9 \times 10^{-3}\text{u}$	C1	
	binding energy $= 1.9 \times 10^{-3} \times 930$		
	= 1.8 MeV	A1	[2]
(ii)	$\Delta m = (57 \times 1.0087\text{u}) + (40 \times 1.0073\text{u}) - 97.0980\text{u}$	C1	
	= (–)0.69 u		
	binding energy per nucleon = (0.69 × 930) / 97	C1	
	= 6.61 MeV	A1	[3]

Q11.

9 (a) (i)	*either* probability of decay (of a nucleus)	M1	
	per unit time	A1	[2]
	or $\lambda = (-)(\text{d}N/\text{d}t) / N$	(M1)	
	(–)dN/dt and N explained	(A1)	
(ii)	in time $t_{½}$, number of nuclei changes from N_0 to $½N_0$	B1	
	$½ = \exp(-\lambda t_{½})$ *or* $2 = \exp(\lambda t_{½})$	B1	
	$\ln(½) = -\lambda t_{½}$ and $\ln(½) = -0.693$ *or* $\ln 2 = \lambda t_{½}$ and $\ln 2 = 0.693$	B1	
	$0.693 = \lambda t_{½}$	A0	[3]
(b)	$228 = 538 \exp(-8\lambda)$	C1	
	$\lambda = 0.107$ (hours^{-1})	C1	
	$t_{½} = 6.5$ hours *(do not allow 3 or more SF)*	A1	[3]
(c)	e.g. random nature of decay background radiation daughter product is radioactive *(any two sensible suggestions, 1 each)*	B2	[2]

Q12.

8 (a) <u>nuclei</u> having same number of protons/proton (atomic) number B1
different numbers of neutrons/neutron number B1 [2]
(allow second mark for nucleons/nucleon number/mass number/atomic mass if made clear that same number of protons/proton number)

(b) probability of decay per unit time is the decay constant C1
$\lambda = \ln 2 / t_{½}$
$= 0.693 / (52 \times 24 \times 3600)$ C1
$= 1.54 \times 10^{-7}\,\text{s}^{-1}$ A1 [3]

(c) (i) $A = A_0 \exp(-\lambda t)$
$7.4 \times 10^6 = A_0 \exp(-1.54 \times 10^{-7} \times 21 \times 24 \times 3600)$ C1
$A_0 = 9.8 \times 10^6$ Bq A1 [2]
(*alternative method uses 21 days as 0.404 half-lives*)

(ii) $A = \lambda N$ and mass $= N \times 89 / N_A$ C1
mass $= (9.8 \times 10^6 \times 89) / (1.54 \times 10^{-7} \times 6.02 \times 10^{23})$
$= 9.4 \times 10^{-9}$ g A1 [2]

Q13.

8 (a) two (light) nuclei combine M1
to form a more massive nucleus A1 [2]

(b) (i) $\Delta m = (2.01410\,\text{u} + 1.00728\,\text{u}) - 3.01605\,\text{u}$
$= 5.33 \times 10^{-3}$ u C1
energy $= c^2 \times \Delta m$ C1
$= 5.33 \times 10^{-3} \times 1.66 \times 10^{-27} \times (3.00 \times 10^8)^2$
$= 8.0 \times 10^{-13}$ J A1 [3]

(ii) speed/kinetic energy of proton and deuterium must be very large B1
so that the nuclei can overcome electrostatic repulsion B1 [2]

Q14.

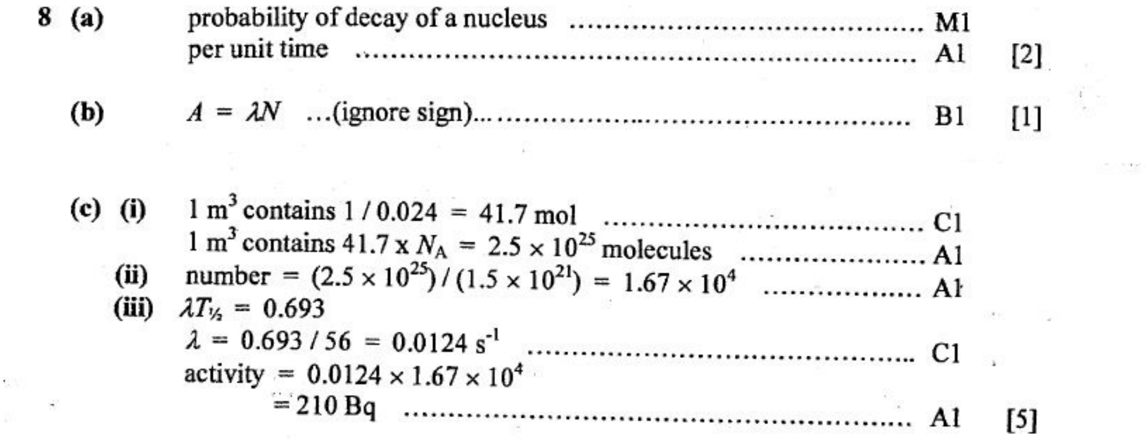
8 (a) energy is given out / released on formation of the α-particle (or reverse argument) M1
either $E = mc^2$ so mass is less
or reference to mass-energy equivalence A1 [2]

(b) (i) mass change = 18.00567 u – 18.00641 u C1
$= 7.4 \times 10^{-4}$ u *(sign not required)* A1 [2]

(ii) energy $= c^2 \Delta m$
$= (3.0 \times 10^8)^2 \times 7.4 \times 10^{-4} \times 1.66 \times 10^{-27}$ C1
$= 1.1 \times 10^{-13}$ J A1 [2]
(*allow use of* u $= 1.67 \times 10^{-27}$ kg*)*
(*allow method based on* 1u *equivalent to* 930 MeV *to* 933 MeV*)*

(iii) *either* mass of products greater than mass of reactants M1
this mass/energy provided as kinetic energy of the helium-4 nucleus A1
or both nuclei positively charged (M1)
energy required to overcome electrostatic repulsion (A1) [2]

Q15.

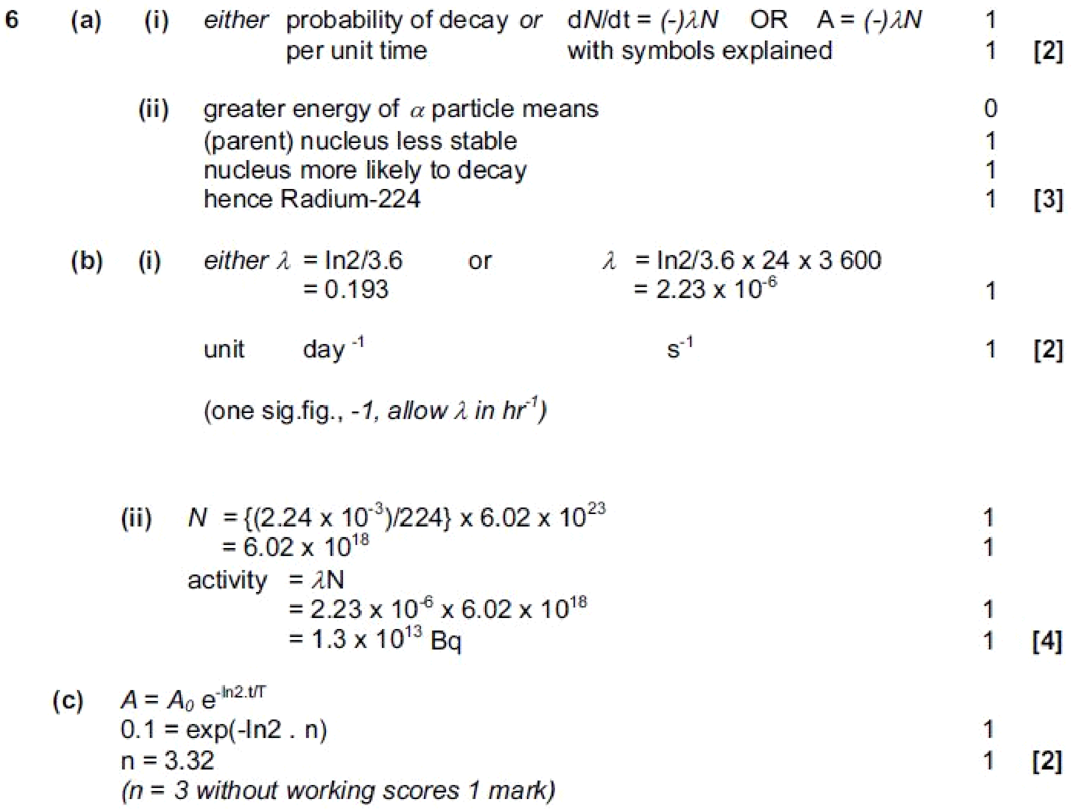


8 (a) probability of decay of a nucleus M1
per unit time .... A1 [2]

(b) $A = \lambda N$ …(ignore sign)…... B1 [1]

(c) (i) 1 m^3 contains 1 / 0.024 = 41.7 mol C1
1 m^3 contains 41.7 x N_A = 2.5×10^{25} molecules A1
(ii) number = $(2.5 \times 10^{25}) / (1.5 \times 10^{21})$ = 1.67×10^4 .... A1
(iii) $\lambda T_{½} = 0.693$
$\lambda = 0.693 / 56 = 0.0124\ s^{-1}$ C1
activity = $0.0124 \times 1.67 \times 10^4$
= 210 Bq .... A1 [5]

Q16.



6 (a) (i) *either* probability of decay *or* d*N*/dt = *(-)*λN OR A = *(-)*λN 1
per unit time with symbols explained 1 **[2]**

(ii) greater energy of α particle means 0
(parent) nucleus less stable 1
nucleus more likely to decay 1
hence Radium-224 1 **[3]**

(b) (i) *either* λ = ln2/3.6 or λ = ln2/3.6 x 24 x 3 600
= 0.193 = 2.23×10^{-6} 1

unit day $^{-1}$ s^{-1} 1 **[2]**

(one sig.fig., *-1, allow* λ *in* hr^{-1}*)*

(ii) *N* = $\{(2.24 \times 10^{-3})/224\} \times 6.02 \times 10^{23}$ 1
= 6.02×10^{18} 1
activity = λN
= $2.23 \times 10^{-6} \times 6.02 \times 10^{18}$ 1
= 1.3×10^{13} Bq 1 **[4]**

(c) $A = A_0\, e^{-\ln 2 . t/T}$
0.1 = exp(-ln2 . n) 1
n = 3.32 1 **[2]**
(n = 3 without working scores 1 mark)

Q17.

7	**(a)(i)**	energy required to separate the nucleons in a nucleus ……………….. nucleons separated to infinity / completely ……………..……………….	M1 A1	**[2]**
	(ii)	S shown at peak ……………………………………………………………	B1	**[1]**
	(b)(i)	4 …………………………………………………………………………	A1	**[1]**
	(ii) 1.	idea of energy as product of *A* and energy per nucleon ……………	C1	
		energy $= (8.37 \times 142 + 8.72 \times 90) - 235 \times 7.59$ $= 1189\ +785\ -\ 178$ $= 190$ MeV ………(–1 for each a.e.) …………………………	A2	**[3]**
	2.	energy $= mc^2$ …………………………………………………………	C1	
		1 MeV $= 1.6 \times 10^{-13}$ J ………………………………………………..	C1	
		energy $= (190 \times 1.6 \times 10^{-13}) / (3.0 \times 10^8)^2$ $= 3.4 \times 10^{-28}$ kg …………………………………………………	A1	**[3]**

Q18.

8 (a)	**(i)**	*either* number $= 6.02 \times 10^{23} \times (\{2.65 \times 10^{-6}\}/234)$ *or* number $= (2.65 \times 10^{-9})/(234 \times 1.66 \times 10^{-27})$	C1	
		$= 6.82 \times 10^{15}$	A1	[2]
	(ii)	$A = \lambda N$	C1	
		$604 = \lambda \times 6.82 \times 10^{15}$ $\lambda = 8.86 \times 10^{-14}\ \text{s}^{-1}$	A1	[2]
	(iii)	$T_{½} = \ln 2/\lambda$ $= 7.82 \times 10^{12}$ s	C1	
		$= 2.48 \times 10^5$ years	A1	[2]
(b)		half-life is (very) long (compared with time of counting)	B1	[1]
(c)		there would be appreciable decay of source during the taking of measurements	B1	[1]

Q19.

7 **(a)** energy required to (completely) separate the nucleons (in a nucleus) .... B1 [1]

(b) **(i)** U labelled near right-hand end of line B1
Ba and Kr in approximately correct positions .... B1 [2]

(ii) binding energy is $A \times E_B$ B1
either binding energy of U < binding energy of (Ba + Kr)
or E_B of U < E_B of (Ba + Kr) .... B1 [2]

(c) Krypton-92 reduced to 1/8 in 9 s M1
in 9 s, very little decay of Barium-141 .... M1
so, approximately 9 s .... A1 [3]
OR
$\lambda_{Kr} = 0.231$ or $\lambda_{Ba} = 6.42 \times 10^{-4}$ (M1)
$8 = e^{-\lambda B \times t}/e^{-\lambda K \times t}$ (C1)
$t = 9.0$ s (A1)

Q20.

8 **(a)** neutron is a single nucleon / particle .... B1 [1]

(b) binding energy = $4 \times 7.07 \times 1.6 \times 10^{-13}$ C1
$= 4.52 \times 10^{-12}$ J
binding energy = $c^2 \Delta m$ C1
$4.52 \times 10^{-12} = (3.0 \times 10^8)^2 \times \Delta m$
$\Delta m = 5.03 \times 10^{-29}$ kg .... A1 [3]

(c) **(i)** fusion ……(*do not allow fussion*) .... B1 [1]

(ii) $(2 \times 1.12) + 3x = 28.28$ C1
…… -17.7 .... C1
$x = 2.78$ MeV per nucleon .... A1 [3]
(*use of +17.7 gives x = 14.6 MeV, allow 1 mark only*)

[Total: 8]

Q21.

8 (a) (constant) probability of decay M1
per unit time .... A1 [2]
(*reference to decay of isotope / mass / sample / nuclide, allow max 1 mark*)

(b) *either* when time $= t_{½}$, $N = ½N_0$
or $½N_0 = N\exp(-\lambda t_{½})\ t_{½}$ M1
either $2 = \exp(\lambda t_{½})$
or $½ = \exp(-\lambda t_{½})$ M1
(taking logs), $\underline{\ln 2 = 0.693 = \lambda t_{½}}$ .... A1 [3]

(c) $A = \lambda N$
$1.8 \times 10^5 = N \times (0.693 / \{1.66 \times 10^8\})$ C1
$N = 4.3 \times 10^{13}$
mass $= 60 \times (N / N_A)$ or $60 \times N \times u$ C1
$= (60 \times 4.3 \times 10^{11}) / (6.02 \times 10^{23})$
$= 4.3 \times 10^{-9}$ g .... A1 [3]

[Total: 8]

Q22.

8 (a) splitting of a heavy nucleus (*not atom/nuclide*) M1
into two (lighter) nuclei of approximately same mass A1 [2]

(b) ${}^{1}_{0}\text{n}$
${}^{4}_{2}\text{He}$ (*allow* ${}^{4}_{2}\alpha$) M2
${}^{7}_{3}\text{Li}$ A1 [3]

(c) emitted particles have kinetic energy B1
range of particles in the control rods is short / particles stopped in rods / lose kinetic energy in rods B1
kinetic energy of particles converted to thermal energy B1 [3]

Q23.

8 (a) (i) time for initial number of nuclei/activity M1
to reduce to one half of its initial value A1 [2]

(ii) $\lambda = \ln 2/(24.8 \times 24 \times 3600)$ M1
$= 3.23 \times 10^{-7}\ \text{s}^{-1}$ A0 [1]

(b) (i) $A = \lambda N$ C1
$3.76 \times 10^6 = 3.23 \times 10^{-7} \times N$
$N = 1.15 \times 10^{13}$ A1 [2]

(ii) $N = N_0 e^{-\lambda t}$
$= 1.15 \times 10^{13} \times \exp(-\{\ln 2 \times 30\}/24.8)$ C1
$= 4.97 \times 10^{12}$ A1 [2]

(c) ratio $= (4.97 \times 10^{12})/(1.15 \times 10^{13} - 4.97 \times 10^{12})$ C1
$= 0.76$ A1 [2]

Q24.

8	(a)	(i)	probability of decay (of a nucleus)	M1	
			per unit time	A1	[2]
		(ii)	$\lambda t_{\frac{1}{2}} = \ln 2$		
			$\lambda = \ln 2/(3.82 \times 24 \times 3600)$	M1	
			$= 2.1 \times 10^{-6}\ \text{s}^{-1}$	A0	[1]
	(b)		$A = \lambda N$	C1	
			$200 = 2.1 \times 10^{-6} \times N$	C1	
			$N = 9.5 \times 10^{7}$		
			ratio $= (2.5 \times 10^{25})/(9.5 \times 10^{7})$		
			$= 2.6 \times 10^{17}$	A1	[3]

Q25.

8	(a)	(i)	$x = 2$	A1	[1]
		(ii)	*either* beta particle *or* electron	B1	[1]
	(b)	(i)	mass of separate nucleons = $\{(92 \times 1.007) + (143 \times 1.009)\}$ u	C1	
			= 236.931 u	C1	
			binding energy = 236.931 u – 235.123 u		
			= 1.808 u	A1	[3]
		(ii)	$E = mc^2$	C1	
			energy = $1.808 \times 1.66 \times 10^{-27} \times (3.0 \times 10^{8})^2$		
			$= 2.7 \times 10^{-10}$ J	C1	
			binding energy per nucleon = $(2.7 \times 10^{-10}) / (235 \times 1.6 \times 10^{-13})$	M1	
			= 7.18 MeV	A0	[3]
	(c)		energy released = $(95 \times 8.09) + (139 \times 7.92) - (235 \times 7.18)$	C1	
			= 1869.43 – 1687.3		
			= 182 MeV	A1	[2]
			(*allow calculation using mass difference between products and reactants*)		

Q26.

8	(a)		energy to separate nucleons (in a nucleus)	M1	
			separate to infinity	A1	[2]
	(b)	(i)	fission	B1	[1]
		(ii)	**1.** U: near right-hand end of line	B1	[1]
			2. Mo: to right of peak, less than 1/3 distance from peak to U	B1	[1]
			3. La: 0.4 → 0.6 of distance from peak to U	B1	[1]

(iii) **1.** right-hand side, mass = 235.922 u C1
mass change = 0.210 u A1 [2]

2. energy = mc^2 C1
$= 0.210 \times 1.66 \times 10^{-27} \times (3.0 \times 10^8)^2$
$= 3.1374 \times 10^{-11}$ J C1
= 196 MeV (*<u>need 3 s.f.</u>*) A1 [3]
(*use of 1 u = 934 MeV, allow 3/3; use of 1 u = 930 MeV or 932 MeV, allow 2/3*)
(*use of 1.67×10^{-27} not 1.66×10^{-27} scores max. 2/3*)

Q27.

8 **(a)** probability of decay (of a nucleus)/fraction of number of nuclei in sample that decay M1
per unit time A1 [2]
(*allow λ =(dN / dt) / N with symbols explained – (M1), (A1)*)

(b) **(i)** number $= (1.2 \times 6.02 \times 10^{23}) / 235$ C1
$= 3.1 \times 10^{21}$ A1 [2]

(ii) $N = N_0\,e^{-\lambda t}$
negligible activity from the krypton B1
for barium, $N = (3.1 \times 10^{21}) \exp(-6.4 \times 10^{-4} \times 3600)$
$= 3.1 \times 10^{20}$ C1
activity $= \lambda N$
$= 6.4 \times 10^{-4} \times 3.1 \times 10^{20}$ C1
$= 2.0 \times 10^{17}$ Bq A1 [4]

Q28.

10 **(a)** energy required to separate the nucleons (in a nucleus) M1
to infinity A1 [2]
(*allow reverse statement*)

(b) **(i)** $\Delta m = (2 \times 1.00867) + 1.00728 - 3.01551$ C1
$= 9.11 \times 10^{-3}$ u C1
binding energy $= 9.11 \times 10^{-3} \times 930$
$= 8.47$ MeV A1 [3]
(*allow 930 to 934 MeV so answer could be in range 8.47 to 8.51 MeV*)
(*allow 2 s.f.*)

(ii) $\Delta m = 211.70394 - 209.93722$
$= 1.76672$ u C1
binding energy per nucleon $= (1.76672 \times 930)/210$ C1
$= 7.82$ MeV A1 [3]
(*allow 930 to 934 MeV so answer could be in range 7.82 to 7.86 MeV*)
(*allow 2 s.f.*)

(c) <u>total</u> binding energy of barium and krypton M1
is greater than binding energy of uranium A1 [2]

Q29.

9 **(a)** time for number of atoms / nuclei / activity (of the isotope) M1
to be reduced to one half (of its initial value) A1 [2]

(b) **(i)** $A = \lambda N$ C1
$460 = N \times \ln 2/(8.1 \times 24 \times 60 \times 60)$ C1
$N = 4.6 \times 10^{8}$ A1 [3]

(ii) number of water molecules in 1.0 kg $= (6.02 \times 10^{23})/(18 \times 10^{-3})$ C1
$= 3.3 \times 10^{25}$
ratio $= (3.3 \times 10^{25})/(4.6 \times 10^{8})$
$= 7.2\ (7.3) \times 10^{16}$ A1 [2]

(c) $A = A_0 e^{-\lambda t}$ <u>and</u> $\lambda t_{½} = \ln 2$ C1
$170 = 460 \exp(-\{\ln 2\ t\}/8.1)$ C1
$t = 11.6$ days (*allow 2 s.f.*) A1 [3]

Q30.

9	**(a)**	'light' nuclei combine to form 'heavier' nuclei	B1	[1]
	(b) (i)	*either* energy = $c^2\Delta m$		
		or energy = $(3.00 \times 10^8)^2 \times 1.66 \times 10^{-27}$	C1	
		energy = 1.494×10^{-10} J	C1	
		= $(1.494 \times 10^{-10})/(1.60 \times 10^{-13})$		
		= 934 MeV (*3 s.f.*)	A1	[3]
	(ii)	Δm = (2.01356 + 3.01551) – (4.00151 + 1.00867)		
		= 5.02907 – 5.01018		
		= 0.01889 u	C1	
		energy = 0.01889×934		
		= 17.6 MeV (*allow 2 s.f.*)	A1	[2]
	(iii)	high temperature means high speeds / <u>kinetic</u> energy of nuclei	B1	
		D and T nuclei collide despite repelling one another	B1	[2]

Q31.

9	**(a)**	activity = $(1.7 \times 10^{14})/(2.5 \times 10^6)$		
		= 6.8×10^7 Bq kg^{-1}	A1	[1]
	(b) (i)	energy released per second in 1.0 kg of steel		
		= $6.8 \times 10^7 \times 0.067 \times 1.6 \times 10^{-13}$		
		= 7.3×10^{-7} J	B1	[1]

(ii)	this is a very small quantity of energy so steel will not be warm	B1	[1]
(iii)	$A = A_0 e^{-\lambda t}$ <u>and</u> $\lambda t_{½} = \ln 2$	C1	
	$400 = (6.8 \times 10^7) \exp(-[\ln 2 \times t]/92)$	C1	
	t = 1600 years	A1	
	or		
	$A = A_0/2^n$	(C1)	
	n = 17.4	(C1)	
	$t = 17.4 \times 92$ = 1600 years	(A1)	[3]