5	**C is the only correct answer** A is not the correct answer, as this does not make the process spontaneous B is not the correct answer, as this does not make the process spontaneous D is not the correct answer, as this does not make the process spontaneous	(1)

4	**B is the correct answer (P is the least stable and Q is the most stable)** A is not correct because Q is more stable than R C is not correct because Q is the most stable and P the least stable D is not correct because P is less stable than Q	1

5	**D is the only correct answer (we cannot predict when a decay will take place)** A is not the correct answer, as "natural" is not the same as "random" B is not the correct answer, as "spontaneous" is not the same as "random" C is not the correct answer, as this defines "spontaneous"	1

7	**The only correct answer is C (0.13 I_0)** A is not correct because the absorption calculation assumes a linear absorption B is not correct because this would be the intensity with 5 cm of absorber D is not correct because this would be the intensity with 10 cm of absorber	1

7	**C is the correct answer** A is not correct, as the longer the count time the larger the count B is not correct, as background count rate varies from place to place D is not correct, as different detectors have different sensitivities	(1)

3	**D is the only correct answer** A is not the correct answer, as B.E./nucleon has a maximum for ^{56}Fe B is not the correct answer, as B.E./nucleon has a maximum for ^{56}Fe C is not the correct answer, as B.E./nucleon has a maximum for ^{56}Fe	(1)

3	**The only correct answer is D (B.E. / nucleon increases in fission and fusion)** A is not correct because B.E. / nucleon increases for both fusion and fission B is not correct because B.E. / nucleon increases for fusion C is not correct because B.E. / nucleon increases for fission	1

3	**C is the only correct answer,** as the mass-energy equivalent is calculated by converting the mass to kg and then using $\Delta E = c^2\Delta m$	(1)

Question Number	Answer	Mark
1	**A is the only correct answer** B is not the correct answer, as temperature must be high for fusion C is not the correct answer, as density must be high for fusion D is not the correct answer, as temperature and density must be high for fusion	(1)
8	**B is the only correct answer** A is not the correct answer, as penetration is high C is not the correct answer, as ionising power is low and penetration is high D is not the correct answer, as ionising power is low	(1)

Question Number	Answer		Mark
11(a)	Top line correct	(1)	
	Bottom line correct	(1)	2
	<u>Example of calculation</u>		
	${}^{187}_{75}\text{Re} \rightarrow {}^{187}_{76}\text{Os} + {}^{0}_{-1}\beta^{-} + {}^{0}_{0}\bar{\nu}$		
11(b)	Use of 1 eV = 1.6×10^{-19} J [4.16×10^{-16}]	(1)	
	Use of $E_k = \frac{1}{2}mv^2$ [Allow use of the mass of an proton]	(1)	
	$v = 3.0 \times 10^{7}$ m s^{-1}	(1)	3
	<u>Example of calculation</u>		
	$2.6 \times 10^3 \times 1.6 \times 10^{-19}\ \text{J} = \frac{1}{2} \times 9.11 \times 10^{-31}\ \text{kg} \times v^2$		
	$\therefore v = \sqrt{\frac{2 \times 4.16 \times 10^{-16}\ \text{J}}{9.11 \times 10^{-31}\ \text{kg}}} = 3.02 \times 10^{7}\ \text{m s}^{-1}$		

Question Number	Answer		Mark
21(a)(i)	The paper will absorb some of the beta radiation **Or** beta radiation will pass through the paper	(1)	
	(So) the count rate will vary as the thickness of the paper varies	(1)	2
21(a)(ii)	Top line correct	(1)	
	Bottom line correct	(1)	2
	<u>Example of equation</u>		
	${}^{147}_{61}\text{Pm} \rightarrow {}^{147}_{62}\text{Sm} + {}^{0}_{-1}\beta^{-} + {}^{0}_{0}\bar{\nu}_e$		
21(a)(iii)	Use of $\lambda = \frac{\ln 2}{t_{1/2}}$	(1)	
	Use of 0.75%	(1)	
	Use of $A = A_0 e^{-\lambda t}$	(1)	
	t = 18.5 year [5.83 × 108 s]	(1)	4
	<u>Example of calculation</u>		
	$\lambda = \frac{\ln 2}{2.62\ \text{year}} = 0.265\ \text{year}^{-1}$		
	$\frac{0.75}{100} = e^{-0.262\ \text{year}^{-1}\ t}$		
	$t = \frac{\ln(7.5 \times 10^{-3})}{-0.265\ \text{year}^{-1}} = 18.46\ \text{year}$		

21(b)	Use of $1\ \text{u} = 1.66 \times 10^{-27}$ kg [to convert mass of nucleus or mass of neutrons] Use of $\Delta E = c^2 \Delta m$ [must substitute a mass difference] Conversion from J to (M)eV $\text{B.E./nucleon} = 7.6\ \text{MeV}$ Example of calculation $\text{mass defect} = (61 \times 1.67 \times 10^{-27}\ \text{kg}) + (84 \times 1.00867 \times 1.66 \times 10^{-27}\ \text{kg})) - (144.913 \times 1.66 \times 10^{-27}\ \text{kg})$ $\therefore \text{mass defect} = 1.963 \times 10^{-27}$ kg $\text{B.E.} = 1.963 \times 10^{-27}\ \text{kg} \times (3.00 \times 10^{8}\ \text{m s}^{-1})^2 = 1.767 \times 10^{-10}\ \text{J}$ $\therefore \text{B.E.} = \frac{1.767 \times 10^{-10}\ \text{J}}{1.60 \times 10^{-19}\ \text{J eV}^{-1}} = 1.10 \times 10^{9}\ \text{eV}$ $\therefore \text{B.E./nucleon} = \frac{1.10 \times 10^{3}\ \text{MeV}}{145} = 7.617\ \text{MeV}$	(1) (1) (1) (1)	4
	Total for question 21		**12**

Question Number	Answer		Mark
19(a)	A large nucleus splits (into two nuclei plus neutrons) The binding energy increases, (so energy is released) [Accept binding energy per nucleon increases] **Or** There is a decrease in (total) mass, (so energy is released)	(1) (1)	2

19(b)	Binding energy per nucleon read from graph for before and after fission Binding energy before and after fission calculated **Or** Binding energy increase calculated Energy released ≈ 240 (MeV) Example of calculation Increase in binding energy per nucleon = (8.5 – 7.5) MeV = 1.0 MeV Increase in binding energy ≈ 238 × 1.0 MeV Energy released ≈ 240 MeV	(1) (1) (1)	3

19(c)(i)	Top line correct Bottom line correct Example of completed equation $^{90}_{38}\text{Sr} \rightarrow {}^{90}_{39}\text{Y} + {}^{0}_{-1}\beta^{-} + {}^{0}_{0}\bar{\nu}_e$	(1) (1)	2

19(c)(ii)	Calculates total energy released Conversion between eV and J $P = 110$ (W) Example of calculation $P = 1295 \times 10^{12}\ \text{s}^{-1} \times 0.546 \times 10^{6}\text{eV} \times 1.6 \times 10^{-19}\ \text{J eV}^{-1} = 113\ \text{W}$	(1) (1) (1)	3

19(c)(iii)	Use of $\lambda = \frac{\ln 2}{t_{½}}$ Use of $A = A_0 e^{-\lambda t}$ t = 44 (years) ≠ 50 (years), so claim inaccurate **Or** (After 50 years), $A = 1.1 \times 10^{15}$ (Bq) ≠ 1.295×10^{15} (Bq) so claim inaccurate **Or** (If A 1.295×10^{15} Bq), $A_0 = 4.3 \times 10^{15}$ (Bq) ≠ 3.7×10^{15} (Bq) so claim inaccurate Example of calculation $\lambda = \frac{\ln 2}{28.8} = 0.0241\ \text{years}^{-1}$ $1295\ \text{TBq} = 3700\ \text{TBq} \times e^{-0.0241\ \text{years}^{-1} \times t}$ $t = \frac{\ln\left({}^{1295\ \text{TBq}}/_{3700\ \text{TBq}}\right)}{-0.0241\ \text{years}^{-1}} = 43.6\ \text{years}$	(1) (1) (1)	 3
	Total for question 19		**13**