

Question number	Answer	Mark
1(a)	B	(1)

Question number	Answer	Additional guidance	Mark
1(b)(i)	The time taken for the activity of a radioactive nuclide to halve (1)	accept for nuclide: isotope sample	(1)

Question number	Answer	Additional guidance	Mark
1(b)(ii)	<p>Determines number of half-lives and rounds (1) $263/87.7 = 3$</p> <p>Determines that 3 half-lives is $1/2 \times 1/2 \times 1/2 = 1/8$ (1)</p> <p>Determines mass of Pu-238 after 3 half-lives (1) $925/8 = 115.625$ (g)</p> <p>Determines average energy released per second (1) $115.625 \times 0.54 = 62.4$ (J)</p>	<p>allow repeated division by 2 allow ecf from step 2 for 1 mark (mass of Pu-238 after 1 half-life $925/2 = 462.5$ (g))</p> <p>allow ecf from 1 half-life or from step 3</p>	(4)

Question number	Answer	Mark
1(c)(i)	<p>An answer that combines the following points of application of knowledge and understanding to provide a logical description:</p> <ul style="list-style-type: none"> • proton number/atomic number decreases by 1 (1) • nucleon number/mass number remains unchanged (as p and n have same mass and mass of electron is (assumed) negligible) (1) 	(2)

Question number	Answer	Mark
1(c)(ii)	C	(1)

Question number	Answer	Additional guidance	Mark
2(a)(i)	<p>An explanation that combines identification – knowledge (1 mark) and reasoning/justification – knowledge (3 marks):</p> <ul style="list-style-type: none"> • causes 2 or 3 neutrons to be released (1) • (and) one or more of these (released) neutrons are absorbed by other (U) nuclei (1) • which cause further fission of U nuclei (1) • and release further neutrons that can be absorbed, causing a chain reaction (1) 	<p>ignore U nucleus 'splits up'/eq</p>	(4)

Question number	Answer	Mark
2(a)(ii)	<p>Idea that to get a chain reaction the particle that impacts the nucleus must be the same as the one released (1)</p>	(1)

Question number	Answer	Additional guidance	Mark
2(b)	<p>An explanation that combines identification – knowledge (1 mark) and reasoning/justification – knowledge (2 marks):</p> <ul style="list-style-type: none"> • reaction will slow down (1) • because there are fewer fissions (1) • because fission more likely with slow neutrons (1) 	<p>allow</p> <p>reactor shuts down/eq</p> <p>fission requires slow neutrons</p> <p>thermal neutrons for slow neutrons</p>	(3)

Question number	Answer	Mark
2(c)	<p>An answer that combines the following points of understanding to provide a logical description:</p> <ul style="list-style-type: none"> • the reactor is surrounded by a coolant (1) • the thermal energy release from the chain reaction heats the coolant (1) • the hot coolant is used to generate steam which is used to drive the turbine (1) 	(3)

Question Number	Answer	Acceptable answers	Mark
3(a)	P and M OR M and P OR N and Q OR Q and N	one mark for a pair	(1)

Question Number	Answer	Acceptable answers	Mark
3(b)	{atomic /proton} number drops by 2 and {mass/nucleon} number by 4 (1) (which is) alpha decay (1)	2 protons and 2 neutrons are lost 92 → 90 and 238 → 234 helium nucleus given off (which is) alpha particle	(2)

Question Number	Answer	Acceptable answers	Mark
3(c)	same {mass/nucleon} number but {atomic/proton} number increases by 1 (1) (negative) beta decay (1)	a neutron changes to a proton ignore GAINS a proton beta particle /electron given off	(2)

Question Number	Answer	Acceptable answers	Mark
3(d)(i)	alpha	Alpha ray, alpha particle, α Ignore capital letters	(1)

Question Number	Answer	Acceptable answers	Mark
3(d)(ii)	A description including two of one increases as other increases (1) rate of increase is in the range from 1.17 to 1.33 (cm/MeV) (1) range gradually increases more with energy (1)	the particles with higher energy travel further accept values quoted from graph not (quite) linear/not proportional /curves upwards accept values quoted from graph	(2)

Question Number	Answer	Acceptable answers	Mark
3(e)	<p>chain reaction needs a neutron from one fission to reach another uranium nucleus/atom (at the right speed) (1)</p> <p>(fission of 238) needs {fast/high(er) energy} neutrons (1)</p>	<p>idea of continuous nature of chain reaction</p> <p>the neutrons would be going too slowly /do not have enough energy / lose energy too fast</p>	(2)

Question Number	Answer	Acceptable answers	Mark
4(a)(i)	Any one from the following <ul style="list-style-type: none"> • living things (1) • space (1) • nuclear power stations/accidents (1) • hospitals (1) • industrial processes (1) 	Ignore radon gas from ... another radioactive rock a named radioactive substance eg uranium, radium, plutonium	(1)

Question Number	Answer	Acceptable answers	Mark
4(a)(ii)	statement 2 only		(1)

Question Number	Answer	Acceptable answers	Mark
4(a)(iii)	An explanation linking two of the following points <ul style="list-style-type: none"> • radon gas comes from rocks (1) • types of rocks vary in different parts of the UK (1) • where there is more (of this type of) rock, the reading is higher (1) 	may be explained in terms of specific places eg Cornwall	(2)

Question Number	Answer	Acceptable answers	Mark
4(b)	A description of a change including the following points <ul style="list-style-type: none"> • used to be thought beneficial (1) • now known to be extremely {dangerous/hazardous} (1) 	{was commonly used (without care)/dangers were not realised} now known to cause cancer now can be used safely {under controlled conditions/medical supervision}	(2)

Question Number		Indicative Content	Mark
QWC	*4(c)	<p>A discussion including some of the following points</p> <p>Appropriate type of radiation is chosen</p> <ul style="list-style-type: none"> - some passes through - – β and γ not α - significant change with thickness - – β <p>Half-life</p> <ul style="list-style-type: none"> - reference to half-life - not too long - too much material needed for activity - not too short – expense of replacing regularly - disposal problems <p>Safety issues</p> <ul style="list-style-type: none"> - shielding <ul style="list-style-type: none"> • type of radiation • linked to appropriate material and thickness - security <ul style="list-style-type: none"> • storage of spares • in use - safety procedures / precautions in use 	(6)
Level	0	No rewardable content	
1	1 - 2	<ul style="list-style-type: none"> • a limited discussion of one factor with no reasons e.g. (F) penetration / half-life/ safety. • the answer communicates ideas using simple language and uses limited scientific terminology • spelling, punctuation and grammar are used with limited accuracy 	
2	3 - 4	<ul style="list-style-type: none"> • a discussion linking some of one factor (F) with some reasoning (R) OR two factors e.g. (F) use a source which has a long/short half life (R) with suitable reason OR (F) use radiation which is affected by different thicknesses of paper and (F) mention of half-life. • the answer communicates ideas showing some evidence of clarity and organisation and uses scientific terminology appropriately • spelling, punctuation and grammar are used with some accuracy 	
3	5 - 6	<ul style="list-style-type: none"> • a detailed discussion of at least two factors with some reasons e.g. (F) use a (beta) radiation which is affected by thickness (R) because others will not penetrate at all (alpha) or will not be {affected / stopped} by paper (gamma) and (F) some discussion of half-life or safety. • the answer communicates ideas clearly and coherently uses a range of scientific terminology accurately • spelling, punctuation and grammar are used with few errors 	