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)	Determines number of half-lives and rounds (1) 263/87.7 = 3 Determines that 3 half-lives is 1/2 × 1/2 × 1/2 = 1/8 (1) Determines mass of Pu-238 after 3 half-lives (1) 925/8 = 115.625 (g) Determines average energy released per second (1) 115.625 × 0.54 = 62.4 (J)	 allow repeated division by 2 allow ecf from step 2 for 1 mark (mass of Pu-238 after1 half-life 925/2 = 462.5 (g)) allow ecf from 1 half-life or from step 3	(4)

Question number	Answer	Mark
1(c)(i)	An answer that combines the following points of application of knowledge and understanding to provide a logical description: • 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)	An explanation that combines identification – knowledge (1 mark) and reasoning/justification – knowledge (3 marks): • 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)	ignore U nucleus 'splits up'/eq	**(4)**

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

Question number	Answer	Additional guidance	Mark
2(b)	An explanation that combines identification – knowledge (1 mark) and reasoning/justification – knowledge (2 marks): • reaction will slow down (1) • because there are fewer fissions (1) • because fission more likely with slow neutrons (1)	allow reactor shuts down/eq fission requires slow neutrons thermal neutrons for slow neutrons	**(3)**

Question number	Answer	Mark
2(c)	An answer that combines the following points of understanding to provide a logical description: • 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)	chain reaction needs a neutron from one fission to reach another uranium nucleus/atom (at the right speed) (1) (fission of 238) needs {fast/high(er) energy} neutrons (1)	idea of continuous nature of chain reaction the neutrons would be going too slowly /do not have enough energy / lose energy too fast	**(2)**

Question Number	Answer	Acceptable answers	Mark
4(a)(i)	Any **one** from the following • 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 • 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 • 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)**	A discussion including some of the following points Appropriate type of radiation is chosen - some passes through - – β and γ not α - significant change with thickness - - β Half-life - reference to half-life - not too long - too much material needed for activity - not too short – expense of replacing regularly - disposal problems Safety issues - shielding • type of radiation • linked to appropriate material and thickness - security • storage of spares • in use - safety procedures / precautions in use	**(6)**
Level	**0**	No rewardable content	
1	**1 - 2**	• 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**	• 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**	• a detailed discussion of at least two factors with some reasons e.g. (F) se 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	