Question Number	Answer	Acceptable answers	Mark
1(a)(i)	**A** nuclear reactor		**(1)**

Question Number	Answer	Acceptable answers	Mark
1(a)(ii)	**D** generator		**(1)**

Question Number	Answer	Acceptable answers	Mark
1(b)	A description including any four from: (there are) 89 particles in the nucleus (1) protons (1) (there are) 36 (protons) (1) neutrons (1) (there are) 53 (neutrons) (1) i.e. 36 protons and 53 neutrons gains four marks	ignore all references to electrons (its) {mass/nucleon} number / RAM / A_r / A <u>is 89</u> {atomic/proton} number / positive charge / Z <u>= 36</u> Numbers must be correctly linked to gain credit e.g. 36 neutrons gets 1 mark (for neutrons) 53 protons and 36 neutrons gains two marks (for protons and neutrons) 89 protons and neutrons gets 3 marks (altogether there are) 89 protons and neutrons. 36 are protons gains 4 marks	**(4)**

Question Number	Answer	Acceptable answers	Mark
1(c)	nucleus (1) neutron (1)	**Answers in this order only**	**(2)**

Question Number	Answer	Acceptable answers	Mark
1(d)	An explanation linking two of the following: control rods absorb neutrons (1) control rods moved into / inserted (into reactor core) (1) to capture <u>more</u> neutrons / increase (surface) area (of control rods) (1) (and so) fewer neutrons left (to cause fission) (1)	Ignore 'to control/reduce the reaction(s)' as paraphrase of stem accept control rods take in/soak up neutrons ignore slow down neutrons accept lowered/pushed down (into reactor) NOT move(d) up AND down accept {stops / reduces number (of)} neutrons colliding (with uranium nuclei)	**(2)**

Total for Question 3 = 10 marks

Question Number	Answer	Acceptable answers	Mark
2(ai)	**B** 1 proton only **(1)**		**(1)**

Question Number	Answer	Acceptable answers	Mark
2(aii)	Same number of protons (as hydrogen) or same atomic number(as hydrogen) **(1)**	Same proton number(as hydrogen) / (they all) have one proton / (their) proton number is 1 accept bottom number is 1/the same NOT same mass / nucleon number NOT same atomic mass ignore references to electrons / neutrons	**(1)**

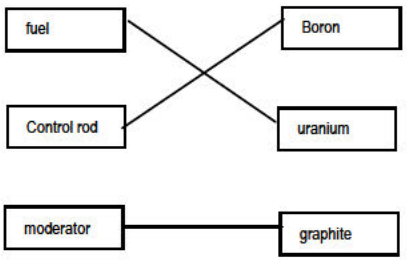
Question Number	Answer	Acceptable answers	Mark
2(b)(i)	Helium (nucleus has) positive/+ (charge) **(1)** Neutron has no/zero/0 (charge) **(1)**	helium is +(any number >0 and <5) helium has a larger/bigger charge neutron is neutral /neutrally charged/uncharged ignore references to nuclear fusion or masses	**(2)**

Question Number	Answer	Acceptable answers	Mark
2(b)(ii)	An explanation linking (Nuclear fusion/it) occurs in the Sun (1) (The Sun / Fusion provides) energy/heat/light (needed for life on Earth) (1)	 (nuclear fusion/it) is the Sun's energy source OR (it) occurs in stars any valid use of fusion in Sun or stars e.g. • without heat (from Sun) Earth would freeze/have no life • new/heavier elements are made (by fusion/ in stars) eg creates helium	**(2)**

Question Number		Indicative Content	Mark
QWC	***2(c)**	A description including some of the following points Stages involved in a chain reaction: o (neutrons released go on to) collide with other nuclei o causes nuclei to become unstable o (nuclei) split/fission (into daughter nuclei) o releases **more** neutrons o releases energy Control: -Action of the moderator o neutrons need to be slowed down/turned into thermal neutrons o to increase chance of collision o this is achieved with a moderator o carbon/graphite/water/heavy water can be used -Action of control rods o number of neutrons available for collision needs to be controlled o so that reaction proceeds at a steady rate / does not increase o this is achieved by control rods absorbing neutrons o boron / silver/indium/cadmium can be used. Many candidates repeat parts of the question Do NOT give credit for these statements eg neutrons are released during fission	**(6)**

Level		No rewardable content
1	**1 - 2**	• A limited description which gives one relevant fact e.g. (neutrons) cause atoms to split. OR (during fission of uranium atom) neutrons collide with atoms OR (nuclear fission) releases energy OR (3) neutrons are released and two of them are absorbed/taken away • 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 simple description, giving more than one fact, about a chain reaction or control OR at least one fact about both. e.g. a neutron collides with (uranium) atoms and causes them to split (into daughter nuclei) OR atoms split releasing **more** neutrons OR an atom splits and releases energy OR (neutrons) cause atoms to split and there are (control) rods to control the neutrons. OR control rods can be lowered into the reactor to absorb neutrons • 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 description involving:- • more than two stages of the chain reaction • OR a description involving more than one stage of the chain reaction AND at least one detail about control. • OR a description involving more than one detail about control AND at least one detail about the chain reaction. e.g. Neutrons are slowed down by graphite/water. This makes them more likely to collide with other nuclei. OR neutrons collide with other nuclei and cause them to split releasing more neutrons AND these neutrons hit another nuclei causing it to split OR neutrons collide with other nuclei and cause them to split releasing more neutrons AND there are (control) rods to control the neutrons OR neutrons collide with uranium nuclei causing them to split and release more neutrons. Control rods of boron absorb some of the neutrons. • the answer communicates ideas clearly and coherently uses a range of scientific terminology accurately. uses nuclei split and not atoms split. • spelling, punctuation and grammar are used with few errors.

(Total for Question 6 =12 marks)

Question Number	Answer	Acceptable answers	Mark
3 (a) (i)		All three correct for 2 marks One or two only correct for 1 mark Reject any box with more than one line	**(2)**

Question Number	Answer	Acceptable answers	Mark
3(a) (ii)	A suggestion to include Neutrons do not need to be captured (by another nucleus) / do not play a part in the fusion process	 Fusion does not use neutrons No chain reaction	**(1)**

Question Number	Answer	Acceptable answers	Mark
3 (b)	A description to include Thermal energy used to create steam / boil water(1) (Steam used to drive) turbine (1) (Turbine used to turn) generator (1)	Ignore detail of fission process.	**(3)**

Question Number		Indicative Content	Mark
QWC	*	An explanation including some of the following points • Description of the problem - Nuclei have positive charge - Repel each other - Reduces possibility of suitable collisions - Rate of fusion too small to be useful • Description of how this can be overcome o Very high temperature (of fuel) o Very high KE / speed of nuclei o High KE can overcome repulsion o Very high density / pressure o Increases possibility of suitable collisions	**(6)**
Level		No rewardable content	
1	**1 - 2**	A limited explanation e.g. The fuel has to be at a high temperature to start the reaction/to make particles collide. Or The fuel has to be at a very high temperature and pressure. • 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 simple explanation. e.g. We need to overcome repulsion of nuclei to make them collide. This is achieved by having a high temperature and pressure. • 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 explanation • e.g. The nuclei repel each other. To overcome this they need very high kinetic energy which is achieved by generating high temperature and pressure. • the answer communicates ideas clearly and coherently uses a range of scientific terminology accurately • spelling, punctuation and grammar are used with few errors	

(Total for Question 5 = 12 marks)

Question Number	Answer		Mark
4(a)(i)	does not emit (ionising) radiation / no (radioactive) decay	it is not radioactive	**(1)**

Question Number	Answer	Acceptable answers	Mark
4 (a)(ii)	☒ **B** 5		**(1)**

Question Number	Answer	Acceptable answers	Mark
4 (a)(iii)	$^{8}_{4}Be$ ☒ A		**(1)**

Question Number	Answer	Acceptable answers	Mark
4(b)(i)	helium beryllium (1) (1) helium	daughter in right hand boxes daughter	**(2)**

Question Number	Answer	Acceptable answers	Mark
4(b)(ii)	a comparison which describes any **three** of the following: similarities: • produce (more) neutrons (1) • produce 'daughter' (nuclei) (1) • release energy (1) • split a (bigger) nucleus (1) • (triggered by) a neutron coming in (1) • nucleus becomes unstable (before splitting) (1) differences: • uranium daughters are different from each other/ beryllium daughters are the same (1) • uranium daughters are heavier than beryllium daughters (1)	different elements / smaller nuclei for daughters do not accept split an atom neutron is absorbed	**(3)**

Question Number	Answer	Acceptable answers	Mark
4(b)(iii)	a description including: neutron(s) (from first fission) (1) (go on to) cause another fission (1)	collide with another nucleus /atom	**(2)**