Mark Scheme

Q1.

Question Number	Answer	Acceptable answers	Mark
	An explanation linking two of the following: control rods absorb neutrons (1) control rods moved into / inserted (into reactor core) (1) to capture more 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)**

Q2.

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

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

Q3.

	Answer	**Acceptable answers**	**Mark**
	An explanation linking any two of the following points		

	• a neutron(s)(1) • hits nucleus/nuclei (1) • uranium/nucleus splits (1) • (producing) neutrons /daughter nuclei/ energy / Kr and Ba (1)	collides/is absorbed breaks/divides accept chain reaction for 1 mark if no other mark awarded accept a correctly labelled diagram	**(2)**

Q4.

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

Q5.

	Answer	**Acceptable answers**	**Mark**
	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)**

Q6.

	Answer	**Acceptable answers**	**Mark**
	An explanation linking any two of the following points • heats/boils water (1) • to produce steam (1) • to run/turn/spin turbines (1) • to turn/power generators (1)	labelled diagram that indicates process (not just parts). heats boiler turns a coil in a magnet	**(2)**

Q7.

	Answer	Acceptable answers	Mark
	An explanation linking two of the following points • absorb (1) • neutrons (1) • (influences) chain reaction / rate of reaction (1)	Accept reverse arguments collects/removes/takes away slows down/changes	**(2)**

Q8.

Question Number	Answer	Additional guidance	Mark
(i)	a description referring to: fusion involves coming together / joining of particles / nuclei / atoms (1) fission involves (larger) particle(s) / nuclei /atoms breaking up (1)	 not just 'fuse together' that's just restating – more explanation needed particles etc. coming apart / separating no marks if just objects / things joining / coming apart	**(2)** AO 1 1

Question Number	Answer	Mark
(ii)	**D** protons **The only correct answer is D** *A 'beta particles' is incorrect, they are not found in nuclei to facilitate that repulsion* *B 'electrons' is incorrect, for the same reason as A* *C 'neutrons' is incorrect as they don't repel each other*	**(1)** AO 1 1

Q9.

Question Number	Answer	Additional guidance	Mark
(i)	Any two advantages from: no CO_2 produced / reduces global warming more energy (per kg) no cross-country pipelines no cross-country pipelines	 no harmful waste gases to atmosphere high energy density fuel IGNORE reference to unqualified non-pollution cost renewable efficiency sped of production	(2)

Question Number	Answer	Additional guidance	Mark
(ii)	Any **two** reasons for unpopularity from **mp1** public perception that radioactivity is dangerous **mp2** radiation leaks from plant **mp3** nuclear accidents **mp4** risks of terrorist attacks **mp5** production/storage of nuclear waste **mp6** (nuclear) waste radioactive for a long time		(2)

Q10.

Question Number	Answer	Additional guidance	Mark
(i)	substitution (1) $\frac{845\,000}{0.0394}$ evaluation (1) 21 000 000	answers that round to 21 000 000 $2.1(45) \times 10^7$ etc. award full marks for the correct answer without working	**(2)** AO 2 1

Question Number	Answer	Additional guidance	Mark
(ii)	any two from: • fusion power gives (many) more times the energy output (for the same mass used) • no greenhouse gases / CO_2 emissions (produced with the fusion alternative) • does not lead to global warming • no (radioactive) waste • does not deplete / use up a finite resource (e.g. oil)	may quote numbers here accept no or less pollution / no or less harmful gases etc. sustainable reference oil is running out ignore references to costs	**(2)** AO 1 1

Question Number	Answer	Additional guidance	Mark
(iii)	any two from: • problem of containment (the fusion gases / isotopes at high temperatures) • (maintaining) high temperature • (maintaining) high pressure		**(2)** AO 2 1

Q11.

		Indicative Content	
		an explanation which may include some of the followi <u>properties of nuclear waste</u> radioactivity is dangerous some isotopes in nuclear waste have long half-lives/ra thousands of years products of fission are warm identified radiation from nuclear waste e.g alpha, beta <u>problems caused by nuclear waste</u> leakage of radioactivity contamination of ground/sea water/lakes /rivers contamination of crops/fish/animals/drinking water harm to humans/cancer/radiation poisoning/ damage cells/mutation of cells or DNA difficulty in transporting safely/ stolen by terrorists fea people <u>solutions for dealing with nuclear waste safely</u> long term storage, underground /under the sea radiation shielding, lead/steel/concrete/ containers, se human safety, radiation suits, using tongs/lead jackets location, away from people/remote areas/sea cooling, information to persuade local people of safety	
Level	**0**	No rewardable content	
1	**1 - 2**	• a limited explanation mentioning at least one point, but without linking, e.g. radioactivity is dangerous ; nuclear waste should be stored underground ; terrorists might steal nuclear waste; • 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 mentioning two points with an appropriate linkage e.g. nuclear waste is dangerous and it must be stored underground ; the isotopes in nuclear waste have long half-lives so they must be stored for a long time; • 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 mentioning a range of points with appropriate linkages e.g. gamma rays from nuclear waste causes damage to cells so it must be stored away from where people live ; the isotopes in nuclear waste have long half-lives so they must be stored underground or in remote areas; • the answer communicates ideas clearly and coherently uses a range of scientific terminology accurately • spelling, punctuation and grammar are used with few errors	

Q12.

	Answer	Acceptable answers	Mark
(i)	helium beryllium (1) (1) helium	daughter in right hand boxes daughter	**(2)**
(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)**
(iii)	a description including: neutron(s) (from first fission) (1) (go on to) cause another fission (1)	 collide with another nucleus /atom	**(2)**

Q13.

	Answer	Acceptable answers	Mark
(a)(i)	does not emit (ionising) radiation / no (radioactive) decay	it is not radioactive	**(1)**
(a)(ii)	$^{8}_{4}Be$ **B** 5		**(1)**
(a)(iii)	$^{8}_{4}Be$ $^{8}_{4}Be$ A		**(1)**
(b)(i)	helium beryllium (1) (1) helium	daughter in right hand boxes daughter	**(2)**

(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)**
(b)(iii)	a description including: neutron(s) (from first fission) (1) (go on to) cause another fission (1)	 collide with another nucleus /atom	**(2)**

Q14.

	Answer	**Acceptable answers**	**Mark**
(a)	P and M OR M and P OR N and Q OR Q and N	one mark for a pair	**(1)**
(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)**
(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)**
(d)(i)	alpha	Alpha ray, alpha particle, α Ignore capital letters	**(1)**

(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)**
(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)**

Q15.

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

Question Number	Answer	Acceptable answers	Mark
(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
(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
(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	* (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	**0**	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 =12 marks)

Q16.

	Answer	**Acceptable answers**	**Mark**
(a)(i)	any one of X-ray (machines) / smoke alarms/ nuclear/ radioactive waste (1)	nuclear weapons (tests) nuclear power plants (medical) tracers/technetium	**(1)**
(a)(ii)	an explanation linking: comes from granite / rocks (1) none/ less of these (rocks) in some areas (1)	in some areas/Cornwall/Aberdeen the second mark is dependent on the first.	**(2)**
(b)(i)	suitable lines on graph to show halving after about 200 000 years (2) • horizontal line at 750 +or –50 Bq on y-axis to curve (1) • meeting (by eye) vertical line from x-axis between 190,000 years and 230,000 years (1)	use of data from graph to show halving after about 200 000 years 1500/2 =750(Bq) or 1600/2=800(Bq) gives a half-life of 210,000 +or- 20 000 (years)	**(2)**
(b)(ii)	any one of • penetrates/passes		**(1)**

	through the skin (1) • ionises (1) • damages tissue/ cells/DNA (1) • mutates cells/DNA(1) • causes cancer(1)		

Total marks for question = 12

		Indicative Content	
QWC	***(c)**	an explanation which may include some of the followi <u>properties of nuclear waste</u> radioactivity is dangerous some isotopes in nuclear waste have long half-lives/ra thousands of years products of fission are warm identified radiation from nuclear waste e.g alpha, beta <u>problems caused by nuclear waste</u> leakage of radioactivity contamination of ground/sea water/lakes /rivers contamination of crops/fish/animals/drinking water harm to humans/cancer/radiation poisoning/ damage cells/mutation of cells or DNA difficulty in transporting safely/ stolen by terrorists fea people <u>solutions for dealing with nuclear waste safely</u> long term storage, underground /under the sea radiation shielding, lead/steel/concrete/ containers, se human safety, radiation suits, using tongs/lead jackets location, away from people/remote areas/sea cooling, information to persuade local people of safety	

Level	**0**	No rewardable content
1	**1 - 2**	• a limited explanation mentioning at least one point, but without linking, e.g. radioactivity is dangerous ; nuclear waste should be stored underground ; terrorists might steal nuclear waste; • 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 mentioning two points with an appropriate linkage e.g. nuclear waste is dangerous and it must be stored underground ; the isotopes in nuclear waste have long half-lives so they must be stored for a long time; • 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 mentioning a range of points with appropriate linkages e.g. gamma rays from nuclear waste causes damage to cells so it must be stored away from where people live ; the isotopes in nuclear waste have long half-lives so they must be stored underground or in remote areas; • the answer communicates ideas clearly and coherently uses a range of scientific terminology accurately • spelling, punctuation and grammar are used with few errors