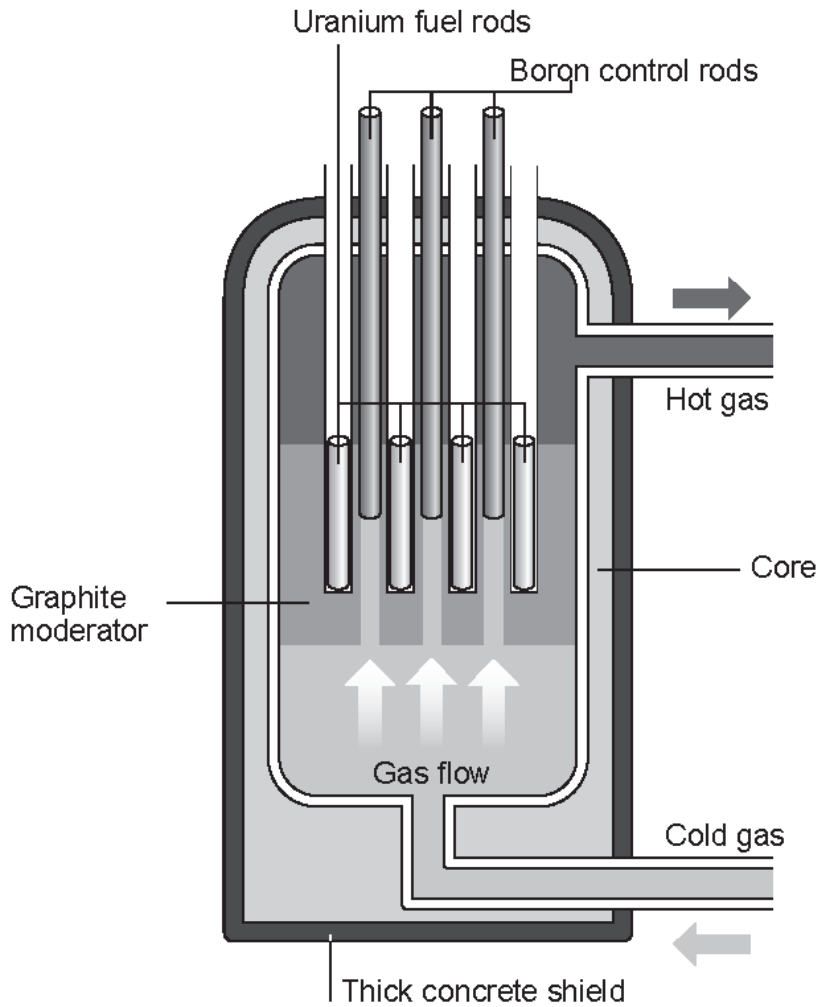
My Question Paper

1.

Read the information in the passage and study the diagram before answering the questions that follow.

In the reactor, energy is released by fission and is the result of a controlled chain reaction. Fuel rods are made of uranium. The graphite moderator surrounds the fuel rods. The boron control rods can be raised and lowered.

The diagram shows the important parts in the core of a gas-cooled nuclear reactor.



(a) (i) Describe the process of fission of a single uranium nucleus in a gas-cooled reactor. [2]

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(ii) Explain the purpose of the graphite moderator. [2]

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(iii) Explain why raising the boron control rods increases the energy released in the reactor. [2]

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(b) The table below shows different isotopes of uranium (U).

Isotope	Nuclear symbol
U-230	$^{230}_{92}U$
U-234	$^{234}_{92}U$
U-235	$^{235}_{92}U$
U-238	$^{238}_{92}U$

(i) Tick (✓) the boxes next to **three** correct statements about the isotopes shown in the table. [3]

All the isotopes have nuclei which contain 92 neutrons ☐

A nucleus of U-230 contains the least number of neutrons ☐

A nucleus of U-235 contains 143 neutrons ☐

A nucleus of U-234 contains 92 protons ☐

A nucleus of U-238 contains 238 protons ☐

(ii) Complete the following nuclear equations which show the decay of two of the uranium isotopes listed in the table above. [2]

$$^{238}_{92}U \rightarrow {}^{4}_{2}He + {}^{.....}_{90}Th$$

$$..... \rightarrow {}^{4}_{2}He + {}^{230}_{90}Th$$

11

2. Complete the following paragraph about a nuclear reactor by **underlining** the correct word or words in each of the brackets. [5]

The absorption of **(slow protons / slow neutrons / slow electrons)** can cause a **(fusion / fission / chemical)** reaction in uranium nuclei. The particles are slowed down by **(a moderator / control rods / concrete shielding)**. The emission of **(protons / neutrons / electrons)** in this reaction can cause a chain reaction. An uncontrolled chain reaction is prevented by using **(a moderator / control rods / concrete shielding)**.

5

3.

Nuclear fission and nuclear fusion are examples of nuclear reactions. Typical nuclear fission and nuclear fusion reactions are shown below.

(a) (i) Complete the equation for the first reaction. [2]

$$^{235}_{92}\mathrm{U} + {}^{1}_{0}\mathrm{n} \rightarrow {}^{90}_{\ldots\ldots}\mathrm{Sr} + {}^{144}_{54}\mathrm{Xe} + \ldots\ldots\ {}^{1}_{0}\mathrm{n}$$

$$^{2}_{1}\mathrm{H} + {}^{3}_{1}\mathrm{H} \rightarrow {}^{4}_{2}\mathrm{He} + {}^{1}_{0}\mathrm{n}$$

(ii) Explain how the first reaction could lead to an uncontrolled chain reaction. [2]

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(b) $^{2}_{1}\mathrm{H}$ and $^{3}_{1}\mathrm{H}$ are both isotopes of hydrogen.

Compare the structure of the **nuclei** of these two isotopes. [2]

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(c) Nuclear fission and nuclear fusion both produce heat energy. Describe and compare nuclear fission and nuclear fusion reactions. [6 QWC]

Include in your answer:

- what happens in each of the reactions;
- the problems associated with each reaction.

(You are **not** required to include any detail on moderators or control rods.)

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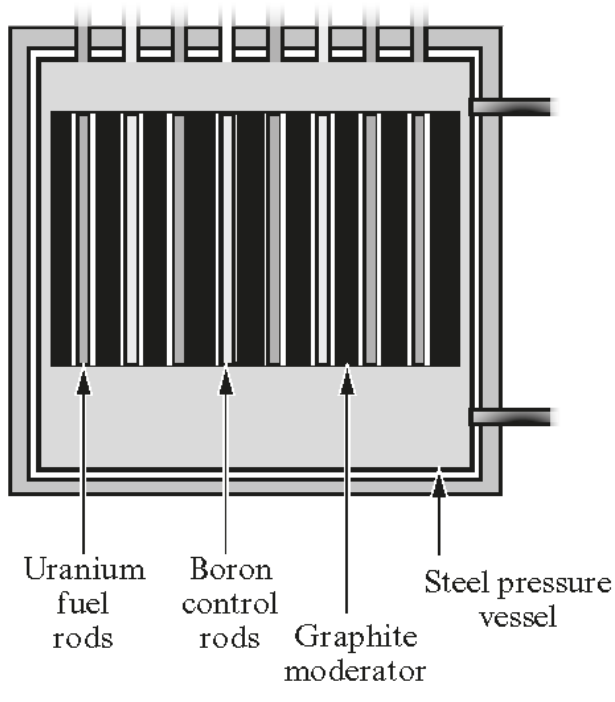
4. The diagram shows a nuclear fission reactor.



(a) (i) State which labelled part of the reactor slows down neutrons. [1]

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(ii) Give a reason why the neutrons need to be slowed down. [1]

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(b) (i) State which labelled part of the reactor absorbs neutrons. [1]

.....

(ii) Give a reason why neutrons need to be absorbed. [1]

.....

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(c) The reaction in this type of reactor is shown below.

$$^{235}_{92}U + {}^{1}_{0}n \longrightarrow {}^{142}_{56}Ba + {}^{91}_{36}Kr + 3{}^{1}_{0}n$$

Use the information in the equation to answer the questions below.

(i) State the nucleon number of uranium (U). ..... [1]

(ii) State the proton number of krypton (Kr). ..... [1]

(iii) Calculate the number of neutrons in an atom of krypton. .....[1]

(d) One of the products, barium (Ba), has other isotopes.
Circle the correct symbol of an isotope of barium in the following list. [1]

$^{142}_{57}Ba$ $^{136}_{56}Ba$ $^{136}_{51}Ba$

(e) The other product krypton, decays into rubidium (Rb) by emitting beta particles.
Complete the decay equation shown below. [2]

$$^{91}_{36}Kr \longrightarrow {}^{\ldots\ldots}_{\ldots\ldots}Rb + {}^{\ldots\ldots}_{-1}e$$

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5. The table below gives information about some elements.

Element	Symbol	Nucleon number (A)	Proton number (Z)	Number of neutrons in a nucleus
Hydrogen	H	1	1	0
Helium	He	4	2	.....
Iron	Fe	.....	26	30
Lead	Pb	207	82	125
Krypton	Kr	90	36	54
Barium	Ba	144	56	88
Uranium	U	235	92	143

(a) **Complete** the table. [2]

(b) Tritium has a proton number of 1 and a nucleon number of 3.
Tritium is an isotope of one of the elements in the table above. Which one? [1]

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(c) The **nuclear** symbol for uranium is written as $^{235}_{92}\mathrm{U}$.

Use information in the table above to answer the following questions.

(i) Complete the nuclear symbol for lead. $^{\ldots\ldots}_{\ldots\ldots}\mathrm{Pb}$ [1]

(ii) In a nuclear reactor, uranium undergoes fission by absorbing a neutron ($^{1}_{0}\mathrm{n}$).
The products of this reaction are **krypton**, **barium** and **two neutrons**.

Complete the equation below for this reaction. [2]

$$^{235}_{92}\mathrm{U} + {}^{1}_{0}\mathrm{n} \longrightarrow \ldots\ldots + \ldots\ldots + \ldots\ldots\,{}^{1}_{0}\mathrm{n}$$

(d) Complete the sentences below by **underlining** the correct word(s) in the brackets. [2]

(i) In a nuclear reactor the moderator (**slows down / speeds up / absorbs**) neutrons.

(ii) In a nuclear reactor the control rods (**slow down / speed up / absorb**) neutrons.

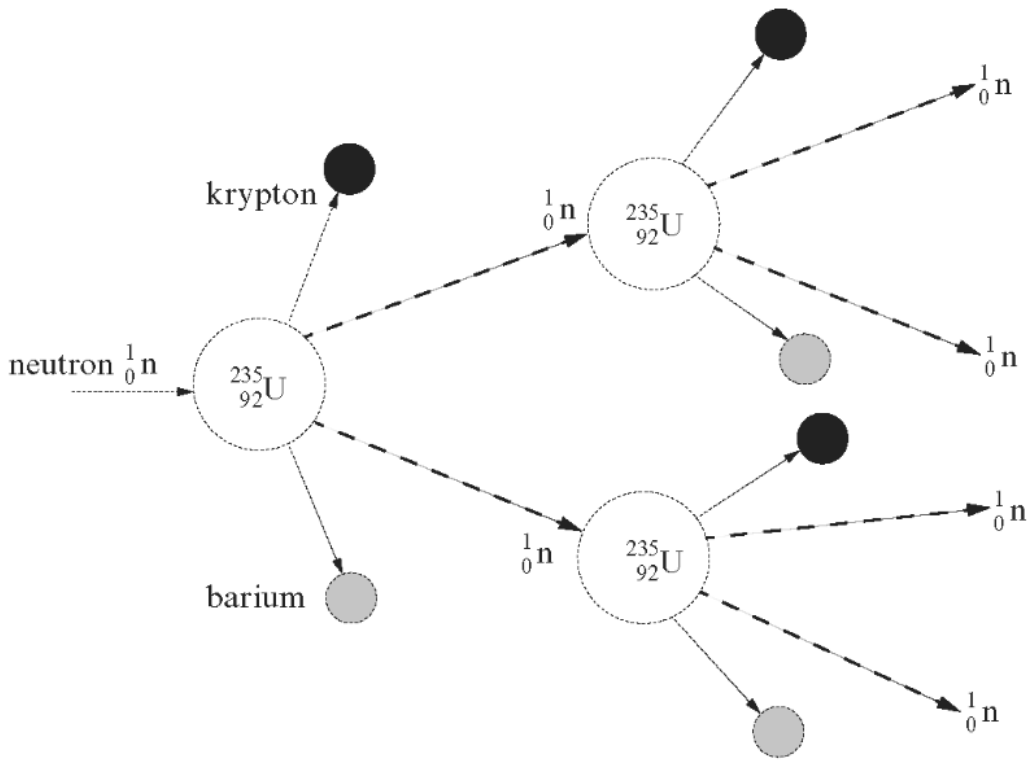
8

6.

(a) Draw a line from **each** of the four boxes on the left to a **box on the right**. [3]

Part of nuclear reactor	Its function
Control rods	Provides atoms for fission to occur
Moderator	Absorb neutrons
Steel and concrete container	Slow down neutrons
Uranium	Absorb radiation

(b) A nuclear reaction that takes place in a nuclear reactor is shown below. Use the diagram to help you answer the questions that follow.



(i) Write down the name of this type of reaction. ..... [1]

(ii) Name **one** waste product of this reaction. ..... [1]

(c) State **two** reasons why waste radioactive materials from nuclear reactors need to be stored **safely** for a **long period** of time. [2]

1. .....

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2. .....

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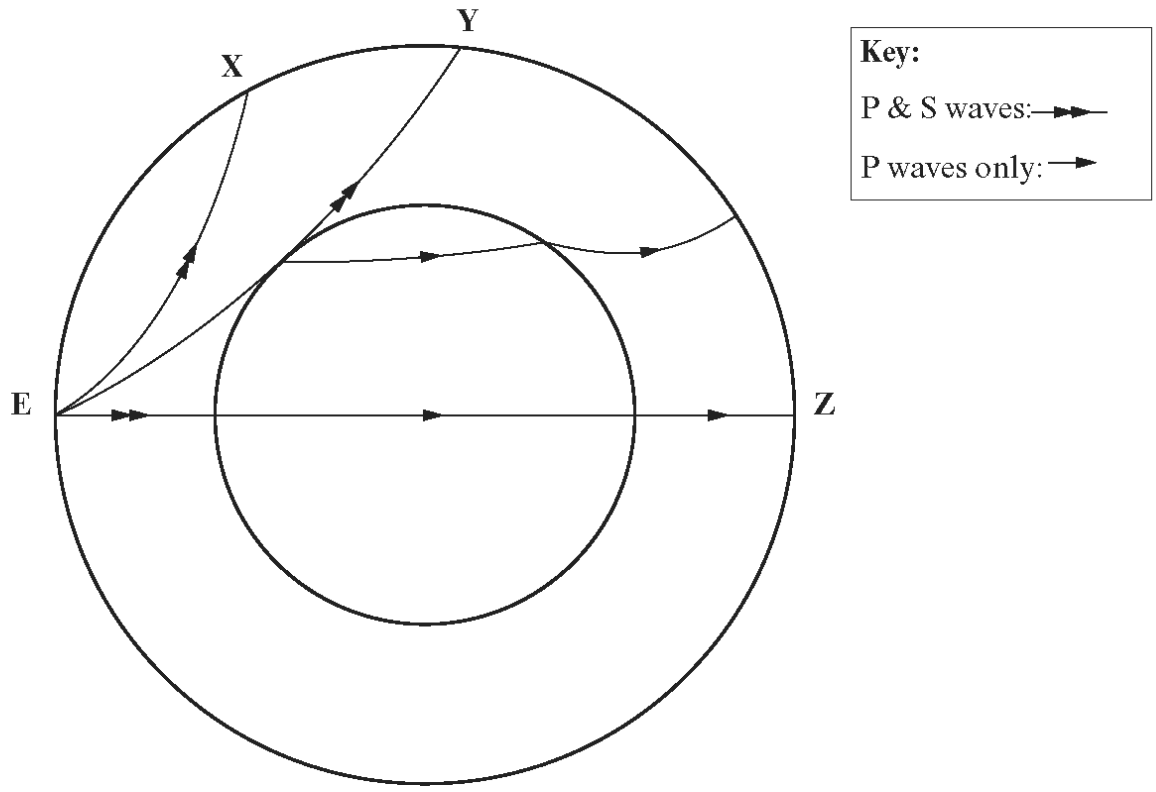
7.

The diagram shows the path of P and S waves from an earthquake at **E**. Surface waves are not shown on this diagram. **X**, **Y** and **Z** are stations that detect seismic waves.



(a) (i) State the difference between surface waves and P and S waves. [1]

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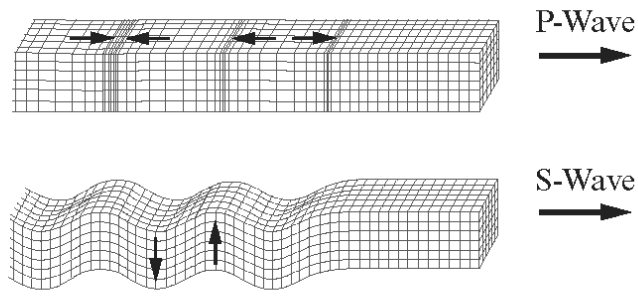
(ii) Use the diagram below to help you explain the difference between how the particles move in P and S waves. [2]



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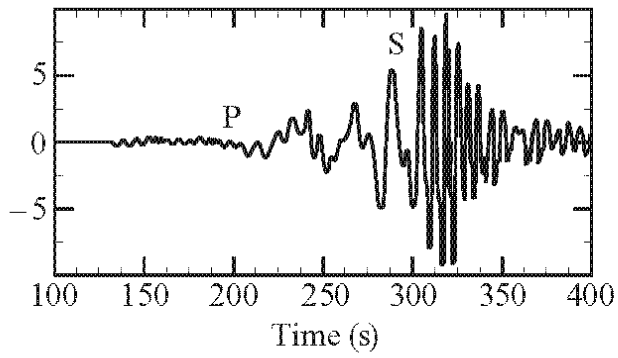
(b) The signals 1, 2 and 3 below were detected at either stations **X**, **Y** or **Z**.

1



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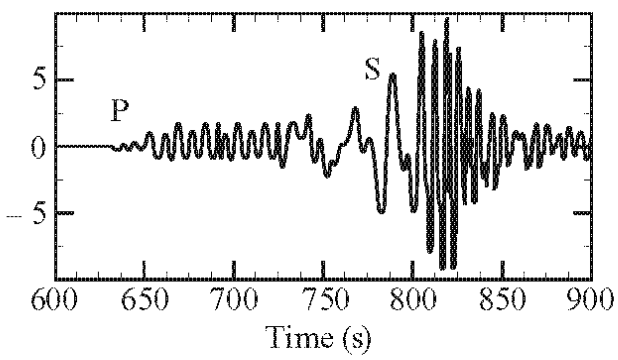

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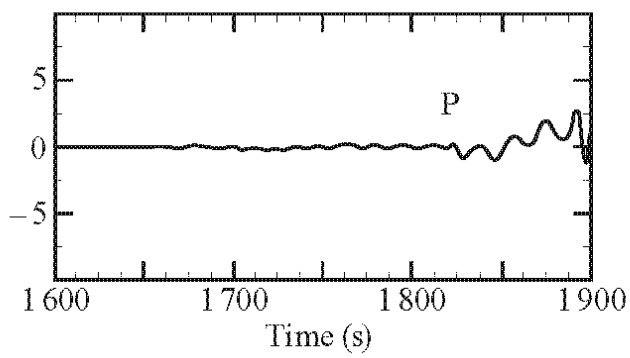

(i) State which signal **1**, **2** or **3** was detected at station **Z**. ..... [1]
Give a reason for your answer. [1]

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(ii) State which signal **1**, **2** or **3** was detected at station **Y**. ..... [1]
Explain your choice. [2]

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8. The Sun is in a stable state in the main sequence stage of its "life".

(a) (i) Name the forces acting on the Sun. [1]

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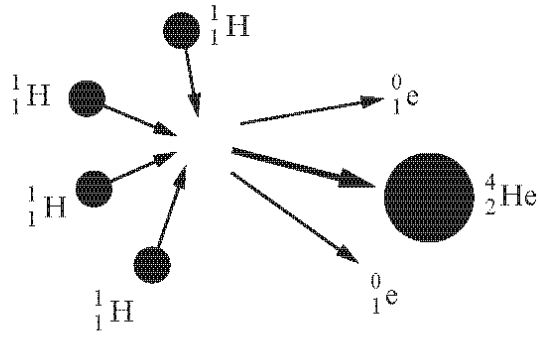
(ii) State why the Sun is in a stable state at present. [1]

.....

(b) The Sun generates most of its energy by the nuclear reaction shown in the diagram.



(i) Write the nuclear equation for this reaction. [1]

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(ii) Describe this reaction, naming the particles involved. [3]

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(c) State what happens when a particle $^{0}_{1}e$ collides with a particle $^{0}_{-1}e$. [1]

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9.

The Sun is in a stable state in the main sequence stage of its "life".

(a) (i) Name the forces acting on the Sun. [1]

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(ii) State why the Sun is in a stable state at present. [1]

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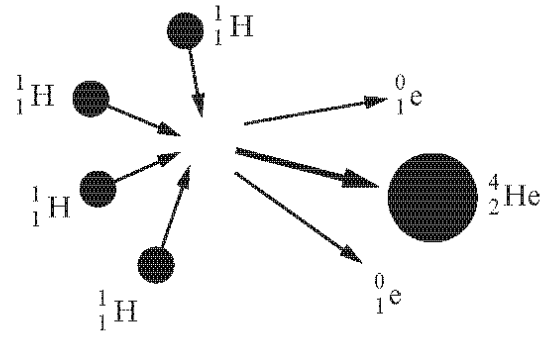
(b) The Sun generates most of its energy by the nuclear reaction shown in the diagram.



(i) Write the nuclear equation for this reaction. [1]

(ii) Describe this reaction, naming the particles involved. [3]

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(iii) Use the information below and an equation from page 2 to calculate the energy produced by this reaction. [4]

mass of a proton ($^{1}_{1}\mathrm{H}$ nucleus) = 1.00728 u

nuclear mass of $^{4}_{2}\mathrm{He}$ = 4.00151 u

1 u = 1.66×10^{-27} kg

$c = 3 \times 10^{8}$ m/s

ignore the mass of $^{0}_{1}\mathrm{e}$

energy = ... J

(c) State what happens when a particle $^{0}_{1}\mathrm{e}$ collides with a particle $^{0}_{-1}\mathrm{e}$. [1]

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10. In nuclear reactors, uranium $^{235}_{92}U$ undergoes fission when a neutron ($^{1}_{0}n$) is absorbed. Products of this include krypton (Kr) and barium (Ba). The particles in the nuclei of these substances are shown below.

Element	Number of protons in the nucleus	Number of neutrons in the nucleus
Uranium	92	143
Krypton	36	54
Barium	56	88

Write a balanced **nuclear equation** for this reaction and explain how a controlled chain reaction is achieved inside the nuclear reactor. [6 QWC]

Equation:

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11.

(a) Deuterium, $^{2}_{1}H$, is an isotope of hydrogen.
Explain what the term "isotope" means. [2]

(b) A fusion reaction can occur when two deuterium nuclei, $^{2}_{1}H$, collide at high speed to produce a helium nucleus (He) and release a neutron.

Explain the importance of this reaction along with its benefits and the difficulties in achieving it in a controlled manner. Your answer should include a balanced nuclear equation. [6 QWC]

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12.

(a) The Sun produces energy by nuclear fusion. One of the nuclear fusion reactions that takes place in the Sun is shown in the equation below. Complete the equation. [2]

$$\underset{\ldots\ldots}{\overset{\ldots\ldots}{\ldots\ldots}}\mathrm{H} + \underset{\ldots\ldots}{\overset{\ldots\ldots}{\ldots\ldots}}\mathrm{H} \longrightarrow {}^{3}_{2}\mathrm{He} + \gamma$$

(b) Another nuclear fusion reaction in the Sun is shown below.

$${}^{3}_{2}\mathrm{He} + {}^{3}_{2}\mathrm{He} \longrightarrow {}^{4}_{2}\mathrm{He} + 2\,{}^{1}_{1}\mathrm{p}$$

(i) Use the information below to calculate the difference between the mass of the products and the reactants (i.e. the mass lost in the reaction in atomic mass units u). [2]

Nuclear mass of ${}^{3}_{2}\mathrm{He}$ = 3.014932 u

Nuclear mass of ${}^{4}_{2}\mathrm{He}$ = 4.00151 u

Mass of a proton = 1.00728 u

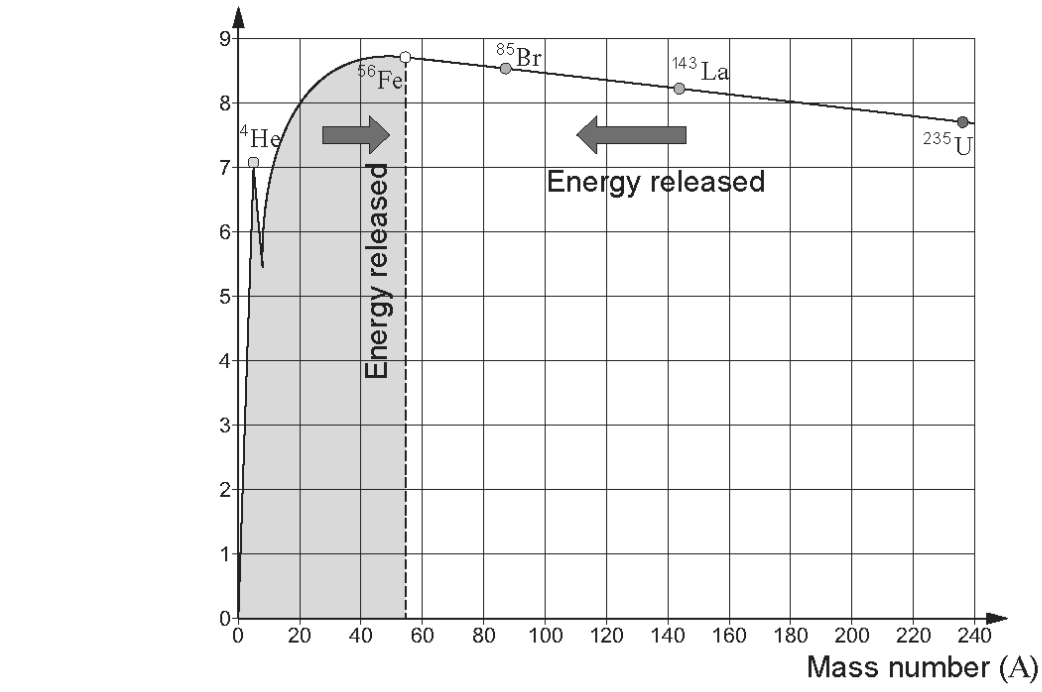
mass loss = ... u

(ii) Use an equation from page 2 and your answer to (i) to calculate the energy released in this reaction. [2]

$1\,\mathrm{u} = 1.66 \times 10^{-27}$ kg
$c = 3 \times 10^{8}$ m/s

energy released = ... J

(c) Use the graph below to explain why energy is released in both nuclear fission **and** nuclear fusion. [6 QWC]



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13.

Nuclear fission and nuclear fusion are examples of nuclear reactions. Typical nuclear fission and nuclear fusion reactions are shown below.

(a) (i) Complete the equation for the first reaction. [2]

$$^{235}_{92}\mathrm{U} + {}^{1}_{0}\mathrm{n} \rightarrow {}^{90}_{\ldots\ldots}\mathrm{Sr} + {}^{144}_{54}\mathrm{Xe} + \ldots\ldots\ {}^{1}_{0}\mathrm{n}$$

$$^{2}_{1}\mathrm{H} + {}^{3}_{1}\mathrm{H} \rightarrow {}^{4}_{2}\mathrm{He} + {}^{1}_{0}\mathrm{n}$$

(ii) Explain how the first reaction could lead to an uncontrolled chain reaction. [2]

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(b) $^{2}_{1}\mathrm{H}$ and $^{3}_{1}\mathrm{H}$ are both isotopes of hydrogen.

Compare the structure of the **nuclei** of these two isotopes. [2]

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(c) Nuclear fission and nuclear fusion both produce heat energy. Describe and compare nuclear fission and nuclear fusion reactions. [6 QWC]

Include in your answer:

- what happens in each of the reactions;
- the problems associated with each reaction.

(You are **not** required to include any detail on moderators or control rods.)

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14. The table below shows information about different nuclei involved in the process of nuclear fission.

Nucleus	Symbol	Number of protons	Number of neutrons
Plutonium	Pu	94	145
Yttrium	Y	39	50
Caesium	Cs	55	93

(a) A nucleus of plutonium undergoes fission when bombarded with a **slow moving** neutron (n) splitting into the daughter nuclei yttrium and caesium.

(i) How are slow moving neutrons achieved in a nuclear reactor? [1]

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(ii) Produce the balanced nuclear equation for this fission reaction. [4]

..... + ... ⟶ ..... + ... + ...

(b) Caesium has 40 known isotopes. Describe how these isotopes are similar to and different from each other. [2]

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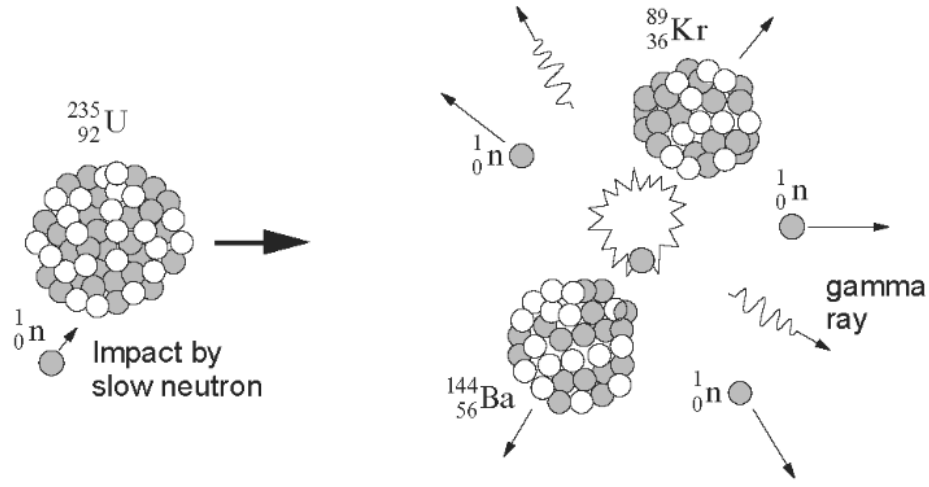
15. The diagram below shows an example of a nuclear fission reaction in which a neutron strikes an atom of $^{235}_{92}U$.



The neutrons that are released in the reaction (3 in this case) have high energies and move very fast.

(a) State which part of the nuclear reactor core is designed to reduce the neutrons' high energies and explain why the reduction in energy is **necessary**. [3]

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(b) (i) Only 1 of the 3 neutrons that are released is needed to maintain a controlled chain reaction. Describe how the others are stopped inside the reactor. [2]

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(ii) Describe how the fission reactions inside a nuclear reactor can be shut down completely. [2]

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(c) (i) Write a balanced nuclear equation for the reaction shown opposite. [2]

(ii) If the barium nucleus in the diagram opposite is released with the same **kinetic energy** as a neutron, explain why the size of its velocity would only be **one twelfth** ($\frac{1}{12}$) of the velocity of a neutron. [2]

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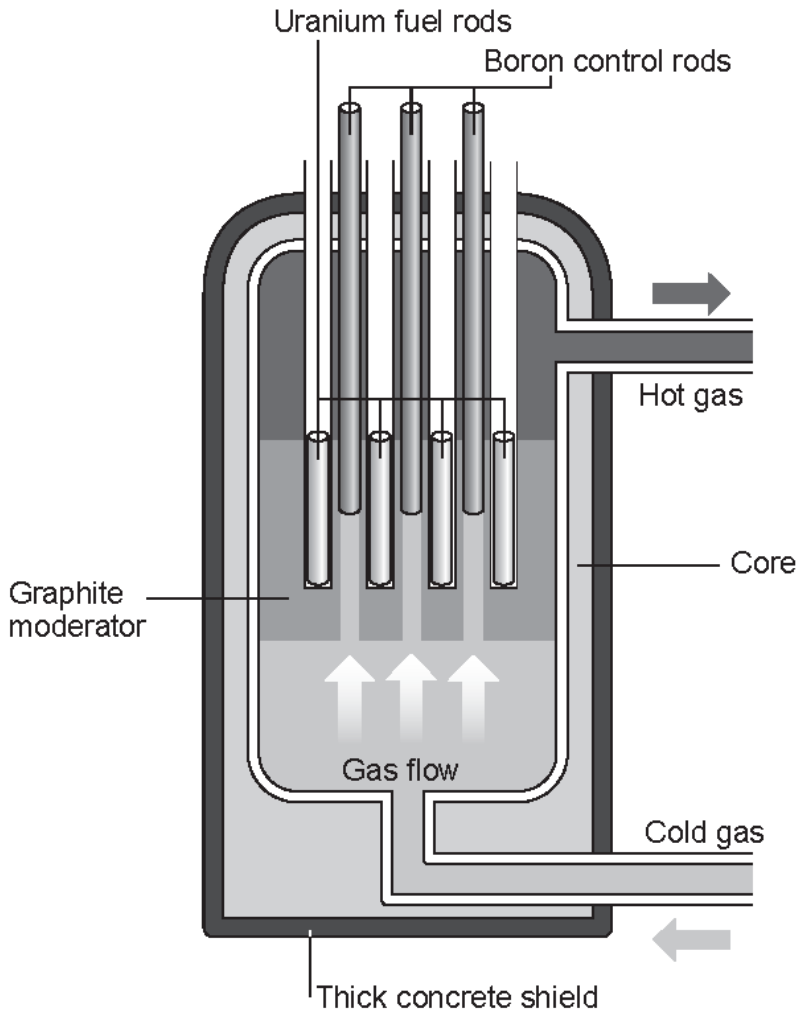
16.

Read the information in the passage and study the diagram before answering the questions that follow.

In the reactor, energy is released by fission and is the result of a controlled chain reaction. Fuel rods are made of uranium. The graphite moderator surrounds the fuel rods. The boron control rods can be raised and lowered.

The diagram shows the important parts in the core of a gas-cooled nuclear reactor.



(a) (i) Describe the process of fission of a single uranium nucleus in a gas-cooled reactor. [2]

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(ii) Explain the purpose of the graphite moderator. [2]

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(iii) Explain why raising the boron control rods increases the energy released in the reactor. [2]

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(b) The table below shows different isotopes of uranium (U).

Isotope	Nuclear symbol
U-230	$^{230}_{92}U$
U-234	$^{234}_{92}U$
U-235	$^{235}_{92}U$
U-238	$^{238}_{92}U$

(i) Tick (✓) the boxes next to **three** correct statements about the isotopes shown in the table. [3]

All the isotopes have nuclei which contain 92 neutrons ☐

A nucleus of U-230 contains the least number of neutrons ☐

A nucleus of U-235 contains 143 neutrons ☐

A nucleus of U-234 contains 92 protons ☐

A nucleus of U-238 contains 238 protons ☐

(ii) Complete the following nuclear equations which show the decay of two of the uranium isotopes listed in the table above. [2]

$$^{238}_{92}U \rightarrow {}^{4}_{2}He + {}^{.....}_{90}Th$$

$$..... \rightarrow {}^{4}_{2}He + {}^{230}_{90}Th$$

11

Marking Scheme

1.

Question Number									
FT	HT	Sub-section			Mark	Answer	Accept	Neutral answer	Do not accept
5		(a)	(i)		2	Uranium [nucleus] / it absorbs neutron[s] (1) splits into 2 [smaller] nuclei and neutrons [are released] (1)	Atoms Neutron capture Named elements		Force of impact shatters nucleus. Don't accept collides.
			(ii)		2	Slows down the neutrons (1) **so** they can be absorbed / captured by uranium [nuclei] (1) **The 2nd mark can only be awarded if it is linked to the 1st mark.**	For 2nd mark: Split uranium nuclei **or** they cause fission of uranium **or** the reaction of uranium		
			(iii)		2	Fewer or no neutrons absorbed (1) **so** increase [in rate of] fission [of uranium nuclei] (1) **The 2nd mark can only be awarded if it is linked to the 1st mark.**	For 1st mark: So more neutrons available for fission		Taken out / removed / more energy released
		(b)	(i)		3	Ticks in the 2nd, 3rd and 4th boxes A nucleus of U-230 least number of neutrons (1) ✓ A nucleus of U-235 contains 143 neutrons (1) ✓ A nucleus of U-234 contains 92 protons (1) ✓			Extra tick attracts -1
			(ii)		2	234 (1) $^{234}_{92}U$ (1) as shown here			
		Total Mark			11				

2.

Question			Marking details	Marks
2.			slow neutrons (1) fission (1) moderator (1) neutrons (1) control rods (1) **Question total**	5 **[5]**

3.

Question				Marking details	Marks
7.	(a)	(i)		38 (1) 2 (1)	2
		(ii)		Neutrons produced [go on to] cause more reactions **or** collisions **or** bombards (1), number of neutrons doubles (accept increase / multiply / triple) [each time] (1) Treat reference to fast neutrons as neutral. N.B. reference to 3 neutrons could arise from the equation above. **To award both marks both statements must be linked.**	2
	(b)			They contain same number of protons / 1 proton (1) but different number of neutrons / 1 neutron and the other has 2 neutrons (1) Reference to electrons loses 1 mark. **Don't accept** nucleons / mass number / atomic number	2
	(c)			**Indicative content:** In fission a heavy element such as [U 235] absorbs a neutron and splits into lighter nuclei [releasing energy]. In fusion, light elements [such as hydrogen isotopes] collide [in high energy collisions and join together] to produce a heavier element, [also releasing energy]. The main problem with nuclear fission is that it produces waste products which are highly radioactive for a long time. The main problem with nuclear fusion is that it requires very high temperatures and pressures which need lots of energy so it is not yet easily contained. **5 – 6 marks** The candidate constructs an articulate, integrated account correctly linking relevant points, such as those in the indicative content, which shows sequential reasoning. The answer fully addresses the question with no irrelevant inclusions or significant omissions. The candidate uses appropriate scientific terminology and accurate spelling, punctuation and grammar. **3 – 4 marks** The candidate constructs an account correctly linking some relevant points, such as those in the indicative content, showing some reasoning. The answer addresses the question with some omissions. The candidate uses mainly appropriate scientific terminology and some accurate spelling, punctuation and grammar. **1 – 2 marks** The candidate makes some relevant points, such as those in the indicative content, showing limited reasoning. The answer addresses the question with significant omissions. The candidate uses limited scientific terminology and inaccuracies in spelling, punctuation and grammar. **0 marks** The candidate does not make any attempt or give a relevant answer worthy of credit. **Question total**	6 **[12]**
				Foundation tier paper total	**[60]**

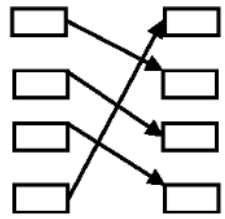
4.

Question			Answer / Explanatory Notes	Marks Available
4.	*(a)*	(i)	graphite / moderator	1
		(ii)	to cause [fission / chain] reactions / if too quick, reaction won't work	1
	(b)	(i)	boron / control rods	1
		(ii)	to prevent an uncontrolled chain reaction / control the chain reaction / prevent overheating or meltdown / Don't accept "to stop fission" only must be qualified.	1
	(c)	(i)	235	1
		(ii)	36	1
		(iii)	[91 – 36] = 55 (No ecf for 91 – (ii))	1
	(d)		$^{136}_{56}$Ba circled	1
	(e)		37 (1) 0 (1)	2
			Question total	**[10]**

5.

Question			Marking details	Marks
4.	(a)		[He] 2 (1) [Fe] 56 (1)	2
	(b)		H or hydrogen	1
	(c)	(i)	$^{207}_{82}Pb$	1
		(ii)	$^{90}_{36}Kr$ + $^{144}_{56}Ba$ (1) $2^{1}_{0}n$ (1) **Do not accept** krypton and barium written in full **Do not accept** Kr^{90}_{36} or Ba^{144}_{56}	2
	(d)	(i)	slows down	
		(ii)	absorb	2
			Question total	**[8]**

6.

Question			Marking details	Mark
1.	(a)		All correct - 3 marks 2 or 3 correct – 2 marks 1 correct – 1 mark 	3
	(b)	(i)	fission OR chain [reaction]	1
		(ii)	krypton or barium (accept Kr or Ba)	1
	(c)		Any 2 x (1): - they have <u>long half- lives</u> - <u>highly/very</u> <u>radioactive</u> - prevents leaks / getting into the environment or food chain or water supply - <u>harmful/poisonous/toxic/dangerous to living things</u> or <u>ionises cells / mutates cells</u> or <u>risk to health/cancer</u> - prevent theft/use as weapons/use by terrorists If 2 correct answers given on 1 line only then award 2 marks. If 2 correct answers given on 1 line and then on the 2nd line an incorrect answer is given award 1 mark only. If 1 correct answer and 1 incorrect answer are given on the same line then no mark awarded.	2
			Question total	[7]

7.

Question			Marking details	Mark
4.	(a)		1	1
	(b)		positron / antiparticle of electron / antielectron	1
	(c)		it is negative (accept different charge or opposite charge) **don't accept** it is positive	1
	(d)		annihilate / cancel each other out / destroy each other (1) **don't accept** fuse or neutralise and release energy / creates heat (1) any reference to 2 electrons don't award the 1st mark	2
			Question total	**[5]**

8.

Question Number									
FT	HT	Sub-section			Mark	Answer	Accept	Neutral answer	Do not accept
6		(a)	(i)		1	Gravity **and** radiation / pressure			
			(ii)		1	Forces are balanced / they are balanced	Equal and opposite / forces cancel each other out		The same / equal / because it has a supply of hydrogen / its balanced
		(b)	(i)		1	$^{1}_{1}\mathrm{H} + {}^{1}_{1}\mathrm{H} + {}^{1}_{1}\mathrm{H} + {}^{1}_{1}\mathrm{H} \rightarrow {}^{4}_{2}\mathrm{He} + {}^{0}_{1}\mathrm{e} + {}^{0}_{1}\mathrm{e}$	$4\,{}^{1}_{1}\mathrm{H} \rightarrow {}^{4}_{2}\mathrm{He} + 2\,{}^{0}_{1}\mathrm{e}$		
			(ii)		3	Four hydrogen [nuclei] / protons join / fuse (1) to form a helium [nucleus] (1) and two positrons (1)	Antielectron instead of positron		Positive electron / react / bond / collide / alpha particle
		(c)			1	Energy / gamma is released	They annihilate / destroy each other / cancel each other out	An explosion takes place	They neutralise each other
		Total Mark			7				

9.

Question Number									
FT	HT	Sub-section			Mark	Answer	Accept	Neutral answer	Do not accept
	2	(a)	(i)		1	Gravity **and** radiation / pressure			
			(ii)		1	Forces are balanced / they are balanced	Equal and opposite / forces cancel each other out		The same / equal / because it has a supply of hydrogen / its balanced
		(b)	(i)		1	$^{1}_{1}\mathrm{H} + {}^{1}_{1}\mathrm{H} + {}^{1}_{1}\mathrm{H} + {}^{1}_{1}\mathrm{H} \rightarrow {}^{4}_{2}\mathrm{He} + {}^{0}_{1}\mathrm{e} + {}^{0}_{1}\mathrm{e}$	$4\,{}^{1}_{1}\mathrm{H} \rightarrow {}^{4}_{2}\mathrm{He} + 2\,{}^{0}_{1}\mathrm{e}$		
			(ii)		3	Four hydrogen [nuclei] / protons join / fuse (1) to form a helium [nucleus] (1) and two positrons (1)	Antielectron instead of positron		Positive electron / react / bond / collide / alpha particle
			(iii)		3	Mass on left hand side = 4 × 1.00728 = 4.02912 (1) [Mass on right hand side = 4.00151] Mass defect = 4.02912 **ecf** – 4.00151 = 0.02761 [u] (1) $E = mc^2$ =0.02761 **ecf** × 1.66×10^{-27} = 4.58326×10^{-29} [kg] (1) × $(3 \times 10^{8})^2 = 4.12 \times 10^{-12}$ [J] (1) **Alternative solution:** LHS: 4 × 1.00728 = 4.02912 (1) 4.02912 **ecf** × $1.66 \times 10^{-27} = 6.6883392 \times 10^{-27}$ [kg] **and** RHS: $4.00151 \times 1.66 \times 10^{-27} = 6.6425066 \times 10^{-27}$ [kg] (1) LHS: 6.6883392 **ecf** × $(3 \times 10^{8})^2 = 6.01950528 \times 10^{-10}$ [J] **and** RHS: 6.6425066 × $(3 \times 10^{8})^2 = 5.97825594 \times 10^{-10}$ [J] (1) Energy loss = $(6.01950528 - 5.97825594) \times 10^{-10}$ J = 4.12×10^{-12} [J] (1)			
		(c)			1	Energy / gamma is released	They annihilate / destroy each other / cancel each other out	An explosion takes place	They neutralise each other
		Total Mark			11				

10.

Question			Marking details	Marks
6.			$^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{90}_{36}Kr + {}^{144}_{56}Ba + 2{}^{1}_{0}n$ **Indicative content:** This nuclear reaction only occurs with slow neutrons and so it is the job of the moderator, usually graphite or water, to slow down the neutrons that cause the reaction and those that are released. A controlled chain reaction is achieved by using control rods, usually of boron steel, being used to absorb some of the neutrons that are released in the reaction. Other neutrons are allowed to go on to fission other uranium nuclei. **5 – 6 marks** The candidate constructs an articulate, integrated account correctly linking relevant points, such as those in the indicative content, which shows sequential reasoning. The answer fully addresses the question with no irrelevant inclusions or significant omissions. The candidate uses appropriate scientific terminology and accurate spelling, punctuation and grammar. **3 – 4 marks** The candidate constructs an account correctly linking some relevant points, such as those in the indicative content, showing some reasoning. The answer addresses the question with some omissions. The candidate uses mainly appropriate scientific terminology and some accurate spelling, punctuation and grammar. **1 – 2 marks** The candidate makes some relevant points, such as those in the indicative content, showing limited reasoning. The answer addresses the question with significant omissions. The candidate uses limited scientific terminology and inaccuracies in spelling, punctuation and grammar. **0 marks** The candidate does not make any attempt or give a relevant answer worthy of credit. **Question total**	6 **[6]**
			HIGHER TIER PAPER TOTAL	**[60]**

11.

6.	*(a)*		The same atomic / proton number (1) but different mass / nucleon / neutron numbers (1) (Reference to electrons treat as neutral).	2
	(b)		Indicative content: $^{2}_{1}\mathrm{H} + {}^{2}_{1}\mathrm{H} \rightarrow {}^{3}_{2}\mathrm{He} + {}^{1}_{0}\mathrm{n}$ (LHS correct with He and n written on RHS, correct nucleon and proton numbers for He, correct nucleon and proton numbers for n.) The collision releases a large amount of energy. Containment is very difficult because of the high pressure needed and in maintaining high temperatures. Difficulty in keeping the plasma away from the container - can be achieved magnetically. Virtually unlimited availability of deuterium from water in the oceans. It releases a large amount of energy per unit mass and no radioactive waste. However the neutrons that are released interact with container causing radiation emissions. 5 - 6 marks The candidate constructs an articulate, integrated account correctly linking relevant points, such as those in the indicative content, which shows sequential reasoning. The answer fully addresses the question with no irrelevant inclusions or significant omissions. The candidate uses appropriate scientific terminology and accurate spelling, punctuation and grammar. 3 – 4 marks The candidate constructs an account correctly linking some relevant points, such as those in the indicative content, showing some reasoning. The answer addresses the question with some omissions. The candidate uses mainly appropriate scientific terminology and some accurate spelling, punctuation and grammar. 1 – 2 marks The candidate makes some relevant points, such as those in the indicative content, showing limited reasoning. The answer addresses the question with significant omissions. The candidate uses limited scientific terminology and inaccuracies in spelling, punctuation and grammar. 0 marks The candidate does not make any attempt or give a relevant answer worthy of credit.	6
			Question total	**[8]**

12.

Question			Marking details	Mark
6.	(a)		$^{2}_{1}H$ (1) $^{1}_{1}H$ (1)	2
	(b)	(i)	mass of reactants = (2 × 3.014932) = 6.029864 [u] (1) mass of products = 4.00151 u + (2 × 1.00728) = 6.01607 [u] (1) [mass difference = 0.013794 u] N.B. for 1 proton: mass of products = 5.00879 [u] and [mass difference = 1.021074 u]	2
		(ii)	conversion to kg = 0.013794 (**ecf**) × 1.66×10^{-27} = 2.29×10^{-29} kg(1) energy calculation to give answer = 2.06×10^{-12} [J] (1) N.B. for 1 proton: conversion to kg = 1.69498×10^{-27} kg energy = 1.52548×10^{-10} [J]	2
	(c)		**Indicative content:** The relationship $E = mc^2$ states the equivalence of mass and energy. Binding energy is the energy equivalent of the mass difference between a whole nucleus and its individual constituent protons and neutrons. As the graph above shows, fusion of light nuclei into heavier nuclei causes an increase in binding energy per nucleon. The product is more stable. In fission heavy nuclei split into lighter nuclei with a higher binding energy per nucleon. The fragments are more stable. In a fusion/fission reaction, the mass difference is converted to energy. **5 – 6 marks** The candidate constructs an articulate, integrated account correctly linking relevant points, such as those in the indicative content, which shows sequential reasoning. The answer fully addresses the question with no irrelevant inclusions or significant omissions. The candidate uses appropriate scientific terminology and accurate spelling, punctuation and grammar. **3 – 4 marks** The candidate constructs an account correctly linking some relevant points, such as those in the indicative content, showing some reasoning. The answer addresses the question with some omissions. The candidate uses mainly appropriate scientific terminology and some accurate spelling, punctuation and grammar. **1 – 2 marks** The candidate makes some relevant points, such as those in the indicative content, showing limited reasoning. The answer addresses the question with significant omissions. The candidate uses limited scientific terminology and inaccuracies in spelling, punctuation and grammar. **0 marks** The candidate does not make any attempt or give a relevant answer worthy of credit. **Question total**	6 **[12]**
			Higher tier paper total	**[60]**

13.

Question				Marking details	Marks
2.	(a)	(i)		38 (1) 2 (1)	2
		(ii)		Neutrons produced [go on to] cause more reactions **or** collisions **or** bombards (1), number of neutrons doubles (accept increase / multiply / triple) [each time] (1) Treat reference to fast neutrons as neutral. N.B. reference to 3 neutrons could arise from the equation above. **To award both marks both statements must be linked.**	2
	(b)			They contain same number of protons / 1 proton (1) but different number of neutrons / 1 neutron and the other has 2 neutrons (1) Reference to electrons loses 1 mark. **Don't accept** nucleons / mass number / atomic number	2
	(c)			**Indicative content:** In fission a heavy element such as [U 235] absorbs a neutron and splits into lighter nuclei [releasing energy]. In fusion, light elements [such as hydrogen isotopes] collide [in high energy collisions and join together] to produce a heavier element, [also releasing energy]. The main problem with nuclear fission is that it produces waste products which are highly radioactive for a long time. The main problem with nuclear fusion is that it requires very high temperatures and pressures which need lots of energy so it is not yet easily contained. **5 – 6 marks** The candidate constructs an articulate, integrated account correctly linking relevant points, such as those in the indicative content, which shows sequential reasoning. The answer fully addresses the question with no irrelevant inclusions or significant omissions. The candidate uses appropriate scientific terminology and accurate spelling, punctuation and grammar. **3 – 4 marks** The candidate constructs an account correctly linking some relevant points, such as those in the indicative content, showing some reasoning. The answer addresses the question with some omissions. The candidate uses mainly appropriate scientific terminology and some accurate spelling, punctuation and grammar. **1 – 2 marks** The candidate makes some relevant points, such as those in the indicative content, showing limited reasoning. The answer addresses the question with significant omissions. The candidate uses limited scientific terminology and inaccuracies in spelling, punctuation and grammar. **0 marks** The candidate does not make any attempt or give a relevant answer worthy of credit.	6
				Question total	**[12]**

14.

Question			Marking details	Mark
4.	(a)	(i)	By using a moderator / graphite / water. Accept graphite rods / graphite monitor. BUT moderator + control rods (0) graphite and boron (0).	1
		(ii)	$^{239}_{94}Pu + {}^{1}_{0}n \rightarrow {}^{89}_{39}Y + {}^{148}_{55}Cs + 3\ {}^{1}_{0}n$ LHS: Correct symbol for a neutron $^{1}_{0}n$ NOT N (1), correct nuclear symbol for plutonium $^{239}_{94}Pu$ (1), RHS: correct nuclear symbols for Yttrium $^{89}_{39}Y$ and Caesium $^{148}_{55}Cs$ (1), 3 neutrons 3 $^{1}_{0}n$ (1). Accept Y^{89}_{39} Accept 3 $^{1}_{0}N$ or 3n	4
	(b)		Same/equal number (accept amount) of protons/atomic number/55 protons (1) different number (accept amount) of neutrons/mass number/nucleon number (1) Electrons are not awarded but regard as neutral. HOWEVER 'same number of electrons in neutral atoms' (1).	2
			Question total	[7]

15.

Question			Marking details	Marks
5.	(a)		Moderator / water / graphite (1) slows down the neutrons (1) so to allow capture by uranium / absorption by uranium / fission or split of uranium (1) Do not accept (for 3rd mark) reacts with uranium or impacts with uranium. **The second and third marks can be awarded even if the first mark is withheld.**	3
	(b)	(i)	Control rods (1) [completely] absorb the [other] neutrons (1)	2
		(ii)	Dropping / putting / letting in [all of] the control rods [into the reactor] (1) absorbs all (1) neutrons.	2
	(c)	(i)	$^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{89}_{36}Kr + {}^{144}_{56}Ba + 3{}^{1}_{0}n$ (+ γ treat as neutral) (1 for symbol equation correct, 1 for 3 neutrons on RHS)	2
		(ii)	Since $(\frac{1}{2}mv^2)\text{Ba} = (\frac{1}{2}mv^2)\text{n}$ (1) (or by implication) Then $144v^2(\text{Ba}) = 1v^2(\text{n})$ $v_{\text{Ba}} = \frac{1}{12}v_{\text{n}}$ (1) Accept $m_{\text{Ba}} = 144\ m_{\text{n}}$ OR that Ba has a bigger mass, so needs less speed for the same kinetic energy [as the neutron] OR recognition of square root for the 1st mark. **Either mark can be awarded on its own but only award 2 marks if they are linked.**	2
			Question total	[11]

16.

Question Number									
FT	HT	Sub-section			Mark	Answer	Accept	Neutral answer	Do not accept
	1	(a)	(i)		2	Uranium [nucleus] / it absorbs neutron[s] (1) splits into 2 [smaller] nuclei and neutrons [are released] (1)	Atoms Neutron capture Named elements		Force of impact shatters nucleus. Don't accept collides.
			(ii)		2	Slows down the neutrons (1) **so** they can be absorbed / captured by uranium [nuclei] (1) **The 2nd mark can only be awarded if it is linked to the 1st mark.**	For 2nd mark: Split uranium nuclei **or** they cause fission of uranium **or** the reaction of uranium		
			(iii)		2	Fewer or no neutrons absorbed (1) **so** increase [in rate of] fission [of uranium nuclei] (1) **The 2nd mark can only be awarded if it is linked to the 1st mark.**	For 1st mark: So more neutrons available for fission		Taken out / removed / more energy released
		(b)	(i)		3	Ticks in the 2nd, 3rd and 4th boxes A nucleus of U-230 least number of neutrons (1) ✓ A nucleus of U-235 contains 143 neutrons (1) ✓ A nucleus of U-234 contains 92 protons (1) ✓			Extra tick attracts -1
			(ii)		2	234 (1) $^{234}_{92}U$ (1) as shown here			
		Total Mark			11				