1. Nuclear power today is generated by nuclear fission.

Some scientists believe that in the future, nuclear **fusion** will be a major source of energy.

Use the structure of the atom to explain the process of nuclear fusion.

You may use the blank space to draw a diagram to help your explanation.

The quality of written communication will be assessed in your answer.

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[6]

2. A nuclear reaction takes place in the Sun releasing a lot of energy.

Hydrogen nuclei join together to produce helium.

What is the name of this process?

Put a (ring) around the correct answer.

fission **fusion** **half-life** **radioactivity**

[1]

3. Nina researches how the Sun releases energy. She finds this information in a textbook.

> The Sun releases energy by nuclear fusion. The Sun emits about 4×10^{26} J of energy every second. As a result, its mass falls by about 4 billion kilograms every second.

Explain why nuclear fusion causes the mass of the Sun to decrease.

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[1]

4. Stars produce a great deal of energy.

Describe the nuclear reaction producing energy in the Sun.

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[3]

5. At the beginning of the 20th century, scientists could not explain how the Sun produced its energy.

However, the development of Einstein's equation $E = mc^2$ showed that energy could be released when mass is lost during nuclear fusion, where $c = 3 \times 10^8$ m/s.

The luminosity of the Sun is about 3.90×10^{26} J/s.

(i) Use Einstein's equation to calculate the amount of mass lost each second by the Sun.

mass loss per second = _____ kg/s **[3]**

(ii) The Sun will be on the main sequence for about 10 billion (10^{10}) years.

Assume that the only loss of mass from the Sun is due to the fusion of hydrogen.

How much mass will the Sun lose while it is on the main sequence?

mass loss = _____ kg **[2]**

6. Some scientists believe that nuclear fusion will be a major source of energy.

Currently, nuclear power stations use nuclear **fission** to generate electricity.

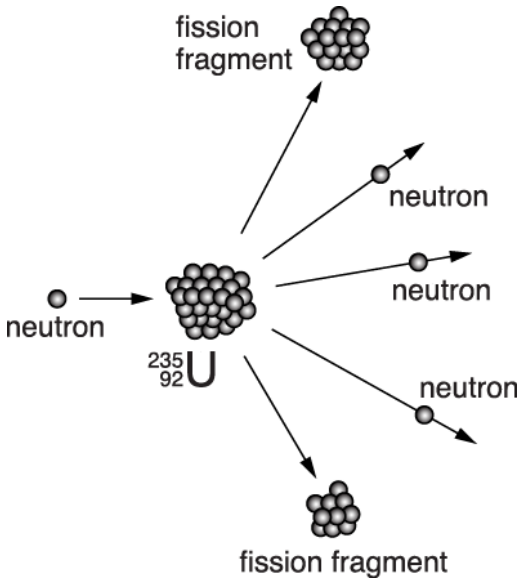
- Fission of uranium-235 releases $3.2 \times 10^{?11}$ J per event.
- Fusion of hydrogen-1 releases $2.8 \times 10^{?12}$ J per event.

Compare how nuclear fusion and nuclear fission release energy.

The quality of written communication will be assessed in your answer.

[6]

7. The diagram represents nuclear fission that takes place in the fuel rods of a reactor at a nuclear power station.



A nucleus of uranium-235 absorbs a neutron and then splits into two parts and releases a number of neutrons.

(i) How does this process produce a **chain reaction**?

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[1]

(ii) How do the **control rods** in the reactor control the speed of the chain reaction?

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[1]

8.

(i) Energy in a power station is produced by the fission of uranium.
Complete this nuclear equation for a fission reaction in the power station

$$ {}_{0}^{1}n + {}_{92}^{235}U \rightarrow {}_{40}^{98}Zr + {}_{\ldots\ldots}^{\ldots\ldots}Te + 3\,{}_{0}^{1}n $$

[2]

(ii) Explain how the nuclear fission reaction is controlled in a nuclear power station.
Include the following in your answer:
chain reaction, fuel rod, control rod, coolant.

[4]

9. Nina researches how the Sun releases energy. She finds this information in a textbook.

The Sun releases energy by nuclear fusion. The Sun emits about 4×10^{26} J of energy every second. As a result, its mass falls by about 4 billion kilograms every second.

Explain why nuclear fusion causes the mass of the Sun to decrease.

[1]

END OF QUESTION PAPER

Question			Answer/Indicative content	Marks	Guidance
1			**Level 3** A description of the nucleus that includes at least two features **AND** a description of fusion that includes high temperature or energy release as one of at least two features. Quality of written communication does not impede communication of the science at this level. **(5–6 marks)** **Level 2** A description of the nucleus that includes at least two features **OR** a description of fusion that includes at least two features **OR** a simple description of the nucleus **AND** a simple description of fusion. Quality of written communication partly impedes communication of the science at this level. (**3–4 marks**) **Level 1** a simple description of the nucleus or atom **or** a simple description of fusion **or** a simple description of fission Quality of written communication impedes communication of the science at this level. **(1–2 marks)** **Level 0** Insufficient or irrelevant science. Answer not worthy of credit. **(0 marks)**	6	**This question is targeted at grades up to D** **Indicative scientific points:** **Discussion of nuclear fusion:** • hydrogen / small nuclei • brought close to each other • fuse (owtte) • to make larger nuclei • lots of energy released. • large energy required to bring nuclei together • (even larger) amounts of energy released • need for magnetic containment • due to high temperatures • ionising radiation. **Description of what nuclei are:** • the centre of atoms • protons • neutrons • the electrons are round the outside. correct description of fission for level 1 information from diagram **ignore** chemical reaction ideas where atoms join and energy is released. **Use the L1, L2, L3 annotations in Scoris; do not use ticks.** **Examiner's Comments** This was the first six-mark extended writing question. Candidates were expected to use the model of the atom to explain the phenomenon of nuclear fusion. This question proved to be very challenging to candidates at this level with quite a few candidates making no attempt at an answer. Only the strongest candidates could either recall and label an atom or describe fusion in the simplest terms of hydrogen nuclei joining to make helium. Very few candidates were able to blend both aspects of the explanation. There was

Question			Answer/Indicative content	Marks	Guidance
					general confusion between fusion and fission and also with chemical reactions.
			Total	6	
2			fusion (2nd answer)	1	Examiner's Comments The majority of candidates correctly identified the name of the process generating helium in the Sun.
			Total	1	
3			mass is converted into energy (of radiation) ✓	1 (AO 1.1)	e.g. quoting $E = mc^2$ **ALLOW** mass is lost in the form of energy **ALLOW** mass is transferred/turned into energy Examiner's Comments Most candidates were unable to recall that during fusion reactions mass is converted to energy. This is from a different part of the specification than the previous two parts of this question.
			Total	1	
4			Fusion Hydrogen To Helium	3	**Maximum 2 marks** if refers to atoms rather than nuclei. Examiner's Comments There is some confusion among candidates between "fission" and "fusion" as well as knowing that Helium is a product of the reaction and not a reactant.
			Total	3	

Question			Answer/Indicative content	Marks	Guidance
5		i	substitution: energy = 3.90×10^{26} (1) rearrange: $m = E/c^2$ OR $m = 3.90 \times 10^{26} / (3 \times 10^8)^2$ (1) 4.3×10^9 (kg/s) (1)	3	3 marks for correct answer Examiner's Comments Very few candidates clearly laid out their working meaning that 'method marks' were often not awarded. Since a high number of candidates were not able to give the correct final answer, this was significant. The most common errors were; not identifying what the numbers they were using represented and despite regularly rearranging the equation correctly, many failed to square 'c' in the calculation. Many students seemed unhappy handling standard form. Correct responses were often expressed as 4333333333.
		ii	time = $60 \times 60 \times 24 \times 365.25 \times 10^{10} = 3.2 \times 10^{17}$ seconds (1) time × answer to (ai) 1.4×10^{27} kg (1)	2	**allow** 365 days which gives 3.15×10^{17} ecf from (i) **accept** correct answer which when rounded is 1.4 or ecf Examiner's Comments The most common error was to simply take their answer in ai and multiply by 10^{10}. Those who showed their working nearly always got something for calculating the seconds in a year. Many got one power out presumably because they did not know how to put 10^{10} into their calculator properly.
			Total	5	

Question			Answer/Indicative content	Marks	Guidance
6			**(Level 3)** Discussions of both fusion and fission are correct, with some additional correct detail provided. Quality of written communication does not impede communication of the science at this level. (5–6 marks) **(Level 2)** Brief Discussion of fission and fusion **or** a discussion of one of these in greater detail. No significant errors in science. Quality of written communication partly impedes communication of the science at this level. (3–4 marks) **(Level 1)** Brief discussion of fission or fusion. Quality of written communication impedes communication of the science at this level. (1–2 marks) **Level 0** Insufficient or irrelevant science. Answer not worthy of credit. (0 marks)	6	**This question is targeted at grades up to A*** **Relevant points include:** **Nuclear fission:** • a neutron • is absorbed by a nucleus • making it unstable • splits a large nucleus • into smaller parts (e.g. barium and krypton) • releasing more neutrons • can lead to a chain reaction • elements involved: uranium / plutonium. **Nuclear fusion:** • hydrogen / small nuclei collide • at high temperatures / speeds / KE • and pressures • fuse (owtte) • to make larger nuclei • e.g Helium. **Energy (as possible additional detail):** • reference to $E = mc^2$ • m is mass lost • comparison of energy released per event in fission and fusion e.g. more in fission • energy released as KE of fragments. **Accept:** • energy released greater than that released by a chemical reaction with a similar mass of material. **Use the L1, L2, L3 annotations in Scoris; do not use ticks.** **Examiner's Comments** This was a challenging six-mark extended writing question. Consequently, only the strongest candidates successfully accessed the higher levels of marks on this question. The best responses were

Question			Answer/Indicative content	Marks	Guidance
					logically presented, with a clear discussion of the process of fission separated from a clear discussion of the process of fusion before comparative statements relating the amount of energy released from each. Such answers were relatively rare. Many candidates recognised that fusion involved the joining of small nuclei and fission involved the splitting of a larger nucleus into smaller fragments. Many candidates then added confusing and often incorrect detail involving electrons being released in fission, ionisation of nuclei to split them apart etc. Only a minority of candidates discussed each idea separately before drawing comparisons.
			Total	6	
7		i	these neutrons trigger further (fission) reactions that produce more neutrons	1	Examiner's Comments Many candidates showed an understanding of the term ‘chain reaction’ but failed to achieve the mark as their answers were too general about the process repeating and they did not state that more neutrons are produced.
		ii	absorb / stop neutrons	1	**allow** soak up as AW for absorb **ignore** move rods in / out Examiner's Comments The action of the control rods was not well known. Some incorrect answers were about temperature control or changing the seed of the neutrons.
			Total	2	

Question			Answer/Indicative content	Marks	Guidance
8		i	135 (1) 52 (1)	2	Examiner's Comments This question produced the greatest number of 'no responses' with no attempt made by the candidate for either answer. More candidates successfully gave the proton number, 52, for Te than the mass number, 135. A common incorrect answer for the latter was 137, due to missing the 3 in front of the neutron.
		ii	chain reaction - produces energy in the fuel rod / correct description of chain reaction (1) fuel rod - contains the **nuclear** fuel / it's where fission takes place (1) control rod - absorbs neutrons (1) coolant - absorbs heat from the reaction / transfers heat (1)	4	**allow** contains uranium / plutonium **ignore** prevent overheating / cooling Examiner's Comments The majority of candidates' responses failed to be awarded any marks. In many responses candidates did not use scientific terminology and ideas in explaining how fission reactions are controlled. They tried using everyday terms such as 'the coolant cools' or 'the coolant prevents an explosion' and 'the control rods control'. Many attempted to describe what a chain reaction is, but did not know that the particles released were neutrons; protons, electrons and atoms were mentioned. The function of the fuel rods was generally not known.
			Total	6	

Question			Answer/Indicative content	Marks	Guidance
9			mass is converted into energy (of radiation) ✓	1 (AO 1.1)	e.g. quoting $E = mc^2$ **ALLOW** mass is lost in the form of energy **ALLOW** mass is transferred/turned into energy Examiner's Comments Only the most able candidates were able to explain that the Sun's mass is converted to energy or state the relationship: $E = mc^2$. Many candidates repeated information from the text box or gave descriptions of the process of nuclear fusion.
			Total	1	