

Nuclear Fission and Fusion

Mark Scheme



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1. Nuclear fission and fusion are spectacular nuclear reactions where atoms are either deliberately split or violently smashed together to release absolutely massive amounts of energy.

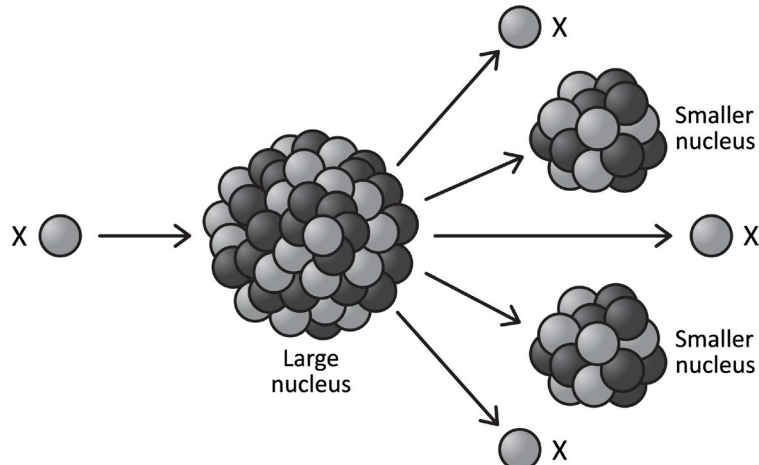
For each of the following questions **circle** the letter of the correct answer.

- a) Which of the following statements correctly describes the process of nuclear fusion?

B – is the only correct answer.	1 mark
	Total: 1 mark

- b) Look at the diagram showing a nuclear fission chain reaction.

What is the name of the particle labelled X that triggers the first reaction and is also released to start the next reactions?



C – is the only correct answer.	1 mark
	Total: 1 mark

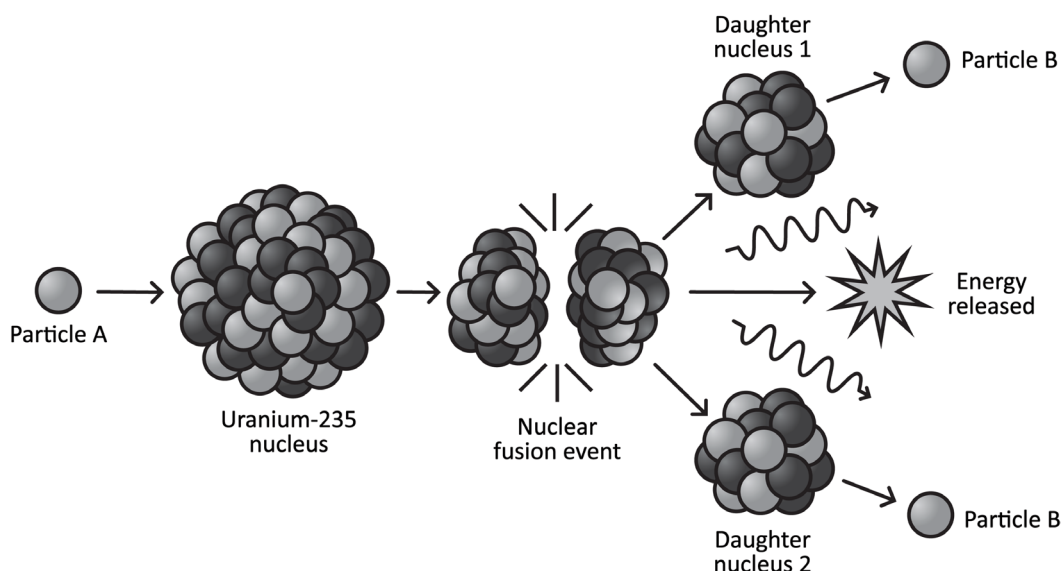
- c) Nuclear fusion is the process that powers the Sun and other stars.

Why is it so difficult for scientists to build nuclear fusion reactors to generate electricity on Earth?

A – is the only correct answer.	1 mark
	Total: 1 mark

(Total for Question 1 is 3 marks)

2. Nuclear power stations use the nuclear fission of Uranium-235 to generate electricity.



- a) Name the particle labelled A that is fired at the Uranium-235 nucleus to start the reaction.

Neutron.	1 mark
	Total: 1 mark

- b) Describe the process of nuclear fission as shown in the diagram.

In your answer, you should refer to what happens to the Uranium-235 nucleus.

A description to include the following:	
The Uranium-235 nucleus absorbs a neutron.	1 mark
Allow: 1 mark for absorbing a neutron (must state absorbs/takes in).	
The nucleus splits into two smaller (daughter) nuclei.	1 mark
Allow: 1 mark for splitting into two smaller nuclei/atoms.	
It also releases 2 or 3 neutrons AND energy.	1 mark
Allow: 1 mark for releasing neutrons and energy.	
	Total: 3 marks

- c) The particles labelled B are exactly the same as particle A.

Explain how the release of particles B can lead to a chain reaction.

An explanation to include:	
The released neutrons go on to hit / be absorbed by other Uranium nuclei.	1 mark
Allow: 1 mark for the neutrons hitting other Uranium nuclei.	
Causing those nuclei to undergo fission / split, which releases more neutrons (repeating the process).	1 mark
Allow: 1 mark for stating this causes further splitting/fission.	
	Total: 2 marks

- d) Inside a nuclear reactor, the chain reaction must be carefully controlled.

Explain how control rods are used to prevent the chain reaction from growing out of control and causing a meltdown.

Control rods <u>absorb</u> neutrons.	1 mark
This decreases the number of neutrons available to cause fission / decreases the rate of reaction.	1 mark
Allow: 1 mark for linking this to slowing down the reaction / stopping the chain reaction from accelerating.	
	Total: 2 marks

- e) A different part of the nuclear reactor is called the moderator. Its job is to slow down the neutrons released during fission.

Suggest why it is important to slow the neutrons down.

A suggestion to include one of the following:	
Fast-moving neutrons cannot easily be absorbed by Uranium-235 nuclei.	1 mark
Neutrons must be slow to cause fission.	1 mark
	Total: 1 mark

(Total for Question 2 is 10 marks)

3. Nuclear fission and nuclear fusion are two different types of nuclear reaction that both release massive amounts of energy.

Compare the processes of nuclear fission and nuclear fusion.

In your answer, you should include:

- what happens to the nuclei during each process
- the conditions required for each process to occur
- the waste products generated by each process.

Marking guidance		
Level	Marks	Descriptor
Level 1	1 - 2	Simple, fragmented statements. The student correctly identifies at least one or two isolated facts (e.g., "fission is splitting", "fusion happens in the Sun").
Level 2	3 - 4	A mostly correct description. The student describes the processes well but may omit the specific conditions or waste products for one or both of the reactions. May contain minor inaccuracies.
Level 3	5 - 6	A detailed, coherent, and logically structured comparison. The student correctly describes the process, conditions, and waste products for both fission and fusion.

Indicative content:	
What happens to the nuclei: • Fission: A large, heavy, unstable nucleus (like Uranium/Plutonium) is split into two smaller, lighter daughter nuclei. • Fusion: Two small, light nuclei (like Hydrogen) are joined / fused together to make a single, heavier nucleus. The conditions required: • Fission: Usually requires the heavy nucleus to absorb a slow-moving neutron to trigger the split. (Occurs in nuclear reactors). • Fusion: Requires extremely high temperatures and extremely high pressures. This is needed to overcome the electrostatic repulsion between the positively charged nuclei. (Occurs naturally in stars). The waste products: • Fission: Produces highly radioactive daughter nuclei / nuclear waste which has a very long half-life and is dangerous to store. • Fusion: Produces stable, non-radioactive products (like Helium). It does not produce long-lived radioactive nuclear waste.	
	Total: 6 marks

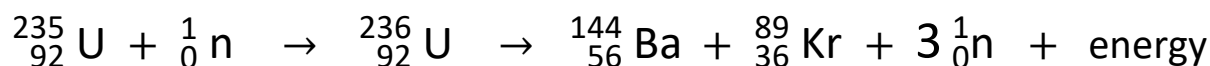
(Total for Question 3 is 6 marks)

4. This question is about nuclear fission.

a) State where nuclear fission takes place on earth.

Nuclear reactors / nuclear power stations.	1 mark
	Total: 1 mark

b) The nuclear equation below shows the fission of uranium-235.



Use the information in the equation to describe the process of nuclear fission.

A description to include the following:	
A Uranium(-235) nucleus absorbs a neutron.	1 mark
The nucleus becomes unstable and splits into two smaller (daughter) nuclei.	1 mark
It also releases three neutrons.	1 mark
It releases energy.	1 mark
	Total: 4 marks

c) The fission reaction must be carefully controlled to prevent a meltdown.

Explain how control rods are used to control the rate of the reaction.

An explanation to include the following:	
Control rods absorb (spare) neutrons.	1 mark
This decreases the number of neutrons available to cause fission / decreases the rate of the reaction.	1 mark
	Total: 2 marks

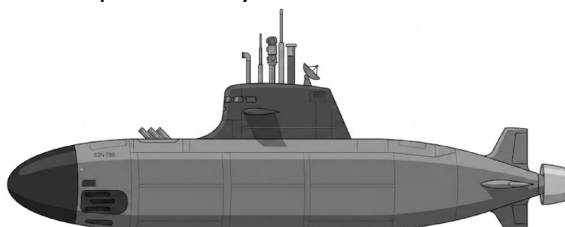
d) If you measured the particles before and after the reaction, the total mass of the products is slightly less than the total mass of the reactants.

State what happens to this 'missing' mass.

It is converted (directly) into energy.	1 mark
	Total: 1 mark

(Total for Question 4 is 8 marks)

5. A nuclear submarine uses a reactor powered by the fission of Plutonium-239 ($^{239}_{94}\text{Pu}$).



During one fission event, a Plutonium-239 nucleus absorbs a neutron. It splits into Tellurium-137 ($^{137}_{52}\text{Te}$), an unknown nucleus **X**, and three spare neutrons.

- a) Determine the mass number and atomic number of nucleus **X**.

Show your working.

Plutonium mass + the incoming neutron $239 + 1 = 240$	
Tellurium mass (137) + the three spare neutrons (3×1) $137 + 3 = 140$	1 mark
$240 - 140 = 100$ Mass number of X = 100	1 mark
$94 - 52 = 42$	1 mark
Mass number of X = 100 Atomic number of X = 42	
	Total: 3 marks

- b) A single fission of a Plutonium-239 nucleus releases 3.0×10^{-11} J of energy.

The submarine's reactor has a useful power output of **12 MW**. The reactor has an efficiency of **40%**.

Calculate the total number of fission reactions that must occur in the reactor in **one minute**.

Calculate total power required: Total Power = $12 \text{ MW} \div 0.40 = 30 \text{ MW}$	1 mark
Convert to watts: 30,000,000 W	1 mark
Calculate total energy in one minute: (Time = 60 seconds) $E = P \times t$ $E = 30,000,000 \times 60$ $E = 1,800,000,000 \text{ J or } 1.8 \times 10^9$	1 mark
Calculate number of reactions: Reactions = Total Energy $\div$ Energy per reaction $\text{Reactions} = 1.8 \times 10^9 \div 3.0 \times 10^{-11}$ $\text{Reactions} = 60,000,000,000,000,000$	1 mark
Convert to standard form: Reactions = 6.0×10^{19}	1 mark
	Total: 3 marks

(Total for Question 5 is 8 marks)