7.2 Fission and fusion

Name: _____ Class: _____ Date: _____ **Total: 21 marks**

KEY WORDS nuclear fission • chain reaction

Objective

Build the skills to answer exam questions on **nuclear fission and fusion** : fission of uranium-235 and plutonium-239, chain reactions, control rods, nuclear waste, and fusion in stars.

You must be able to:

- describe nuclear fission and a chain reaction
- explain how a nuclear reactor is controlled and what happens to its waste
- describe nuclear fusion and why it needs a very high temperature
- compare fission and fusion as ways to release energy

1 Key knowledge and worked examples

■ Fission and fusion

idea	equation or rule
fission	a uranium-235 or plutonium-239 nucleus absorbs a neutron and splits into two smaller nuclei, 2 or 3 neutrons and energy (gamma and kinetic energy)
chain reaction	the new neutrons cause more fissions; in a reactor one neutron from each fission goes on to cause another
control rods	absorb neutrons (boron); lower them to slow the reaction, raise them to speed it up
moderator and coolant	the moderator (water or graphite) slows neutrons; the coolant carries the heat away to make steam
waste	used fuel stays radioactive for thousands of years; it is stored deep underground, shielded and cooled
fusion	two light nuclei join to make a heavier nucleus and release energy; it powers stars; it needs very high temperature and pressure

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Worked example 1: neutrons in a chain. Each fission makes 3 neutrons. If every neutron causes a new fission, how many fissions are there in the third step, starting with one?

1. Known: step 1 has 1 fission, giving 3 neutrons.
2. Rule: each neutron causes one fission.
3. Numbers: step 2: 3; step 3: 3×3.
4. Result: 9 **fissions** (the reaction grows very fast).

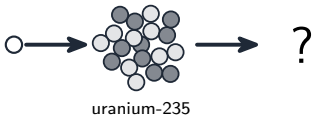
Worked example 2: the number of fissions. One fission of uranium-235 releases 3.2×10^{-11} J. How many fissions release 1.0 J?

1. Known: energy per fission 3.2×10^{-11} J.
2. Rule: number = total energy $\div$ energy per fission.
3. Numbers: $1.0 \div (3.2 \times 10^{-11})$.
4. Result: 3.1×10^{10} **fissions**.

Answer shapes: say what absorbs the neutron and what is released; fusion joins, fission splits.

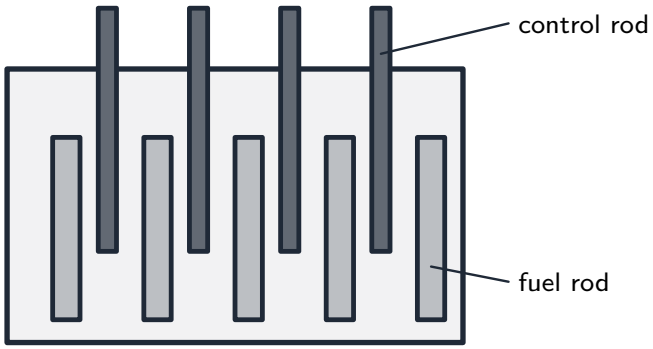
2 Practice

2.1 A neutron is absorbed by a uranium-235 nucleus. Name the products of the fission, apart from energy. [2]



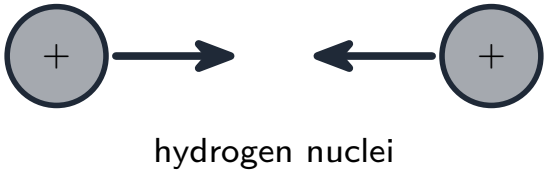
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2.2 The diagram shows the core of a nuclear reactor. What do the control rods do? What happens to the reaction when the rods are pushed further in? [2]



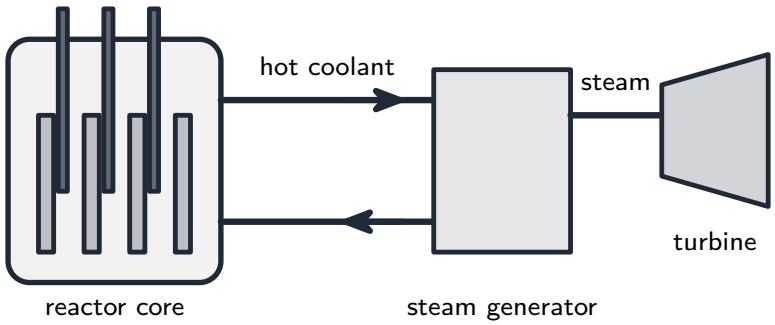
3 Exam-style questions

3.1 Two hydrogen nuclei must get very close to fuse. Explain why fusion only happens at a very high temperature and pressure. [3]



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3.2 The diagram shows a nuclear power station. Fission in the core heats the coolant, which makes steam to turn the turbine.



(a) Describe how a chain reaction happens in the fuel. [3]

(b) The power station must give out less power at night. Explain what the operators do. [2]

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(c) The reactor core releases 3.0×10^9 J every second. One fission releases 3.2×10^{-11} J. Calculate the number of fissions each second. [3]

(d) Scientists are trying to build fusion power stations. Compare fission and fusion as ways to generate electricity. [6]

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Solutions

Marking: **M1** a correct method, **A1** the correct answer, **B1** an independent mark.

Each answer shows the steps, then the **result**.

2.1

- two smaller (daughter) nuclei; two or three neutrons

2.2

- they absorb neutrons; fewer fissions happen, so the reaction slows down

3.1

- both nuclei are positive, so they repel each other
- at a very high temperature they move very fast, so they can get close enough to join
- high pressure (density) means they collide often enough for fusion to keep going

3.2

(a) a uranium-235 nucleus absorbs a neutron and splits; it releases 2 or 3 neutrons; these are absorbed by other uranium-235 nuclei, which split and release more neutrons

(b) they lower the control rods further into the core; the rods absorb more neutrons, so there are fewer fissions each second and less heat

(c) number $= \frac{3.0\times10^{9}}{3.2\times10^{-11}}$; $= 9.4 \times 10^{19}$; fissions each second, with the power in J/s

(d) points to include:

- fission splits heavy nuclei (uranium, plutonium); fusion joins light nuclei (hydrogen)
- both release a lot of energy from a small mass of fuel and give out no carbon dioxide
- fission is used in power stations now; fusion is still being developed
- fusion needs a very high temperature and pressure, which is hard to make and hold
- fission makes radioactive waste that lasts thousands of years; fusion makes much less, and its fuel comes from water

Levels: **5–6** a full, logical answer with correct physics and correct terms; **3–4** several correct points, partly linked; **1–2** one or two relevant points.

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