7.2 Fission and fusion

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

Objective

Build the skills to answer exam questions on **fission and fusion** : how a uranium nucleus splits, chain reactions, the parts of a nuclear reactor, and fusion in stars.

You must be able to:

- describe nuclear fission of uranium-235
- explain a chain reaction and how it is controlled
- describe the roles of the moderator, control rods and shielding
- compare fission and fusion

1 Key knowledge and worked examples

■ Fission and fusion

idea	rule
fission	a slow neutron is absorbed by a uranium-235 nucleus, which splits into two smaller nuclei, 2 or 3 neutrons and energy
chain reaction	the neutrons released cause more fissions
moderator (graphite or water)	slows the neutrons so they can be absorbed
control rods (boron)	absorb neutrons to control the rate of fission
shielding (thick concrete)	absorbs radiation so it cannot escape
fusion	two light nuclei join to make a heavier nucleus and release energy; needs very high temperature and pressure

Worked example 1: neutrons in a chain. Each fission releases 3 neutrons. If every neutron causes a new fission, how many fissions happen in the next two steps?

1. Known: 3 neutrons from each fission.

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2. Rule: each neutron can cause one new fission.
3. Numbers: $1 \to 3 \to 9$.
4. Result: 3 **fissions, then** 9**, so the reaction grows**.

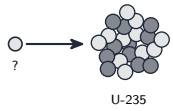
Worked example 2: balancing fission. ${}^{235}_{92}\mathrm{U} + {}^{1}_{0}\mathrm{n} \to {}^{141}_{56}\mathrm{Ba} + {}^{92}_{36}\mathrm{Kr} + x\,{}^{1}_{0}\mathrm{n}$. Find x.

1. Known: top numbers $235 + 1$ on the left.
2. Rule: nucleon numbers balance.
3. Numbers: $236 = 141 + 92 + x$.
4. Result: $x = 3$.

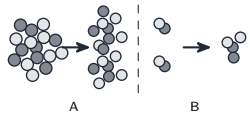
Answer shapes: in a steady reactor, on average one neutron from each fission causes another fission.

2 Practice

2.1 Name the particle that must be absorbed by a uranium-235 nucleus to start fission, and give **two** products of the fission. [2]



2.2 Give **one** similarity and **one** difference between fission and fusion. [2]



3 Exam-style questions

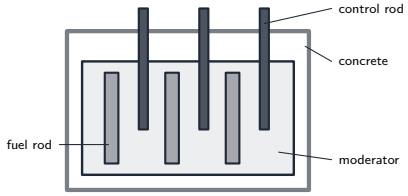
3.1 Explain why fusion happens in the Sun but is very hard to make happen on Earth. [3]



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3.2 The diagram shows the core of a nuclear reactor.

(a) Explain what is meant by a chain reaction. [2]



(b) Describe the job of the moderator, and explain why it is needed. [3]

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(c) The reactor must produce more power. Explain what the operators do with the control rods, and why. [3]

(d) Describe how a nuclear power station produces electricity, starting from fission, and explain how its waste is handled safely. [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

- a (slow) neutron
- two of: two smaller (daughter) nuclei; 2 or 3 neutrons; energy

2.2

- both release energy
- fission splits a heavy nucleus; fusion joins two light nuclei

3.1

- nuclei are positive, so they repel each other
- they only join if they move very fast, which needs a very high temperature and pressure
- the Sun's core has these conditions; on Earth they are very hard to make and contain

3.2

(a) neutrons released by one fission; go on to cause more fissions, and so on

(b) it slows down the fast neutrons from fission; slow neutrons are more likely to be absorbed by uranium-235; so fissions keep happening

(c) they raise (pull out) the control rods; fewer neutrons are absorbed; so more fissions happen each second, releasing more energy

(d) points to include:

- fission releases energy, which heats the reactor core (K)
- a coolant carries the thermal energy to a heat exchanger and boils water (K)
- the steam turns a turbine, which turns a generator (K)
- thick concrete shielding absorbs radiation from the core (App)
- spent fuel is very radioactive with long half-lives (An)
- it is cooled, sealed in containers and stored deep underground for a very long time (App)

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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