

4.7 Nuclear fission and fusion

Name: _____ Class: _____ Date: _____

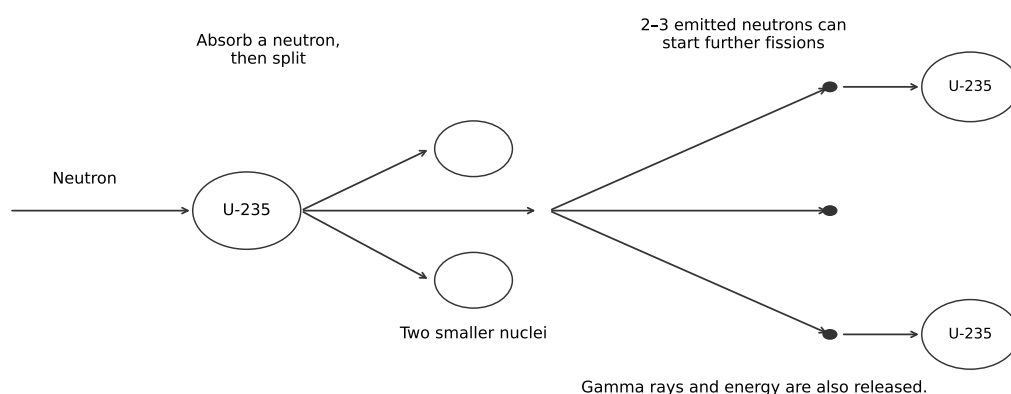
Total: 21 marks

KEY WORDS fission • fusion

Objective

Describe nuclear fission including the chain reaction, and nuclear fusion, and interpret the credited diagrams. Physics only. Original questions for spec statements 4.4.4.1–4.4.4.2.

1 Key knowledge and worked examples



Each released neutron can split another nucleus: a chain reaction.

Fission – the splitting of a **large, unstable** nucleus (uranium-235, plutonium-239):

1. spontaneous fission is rare – the nucleus usually **absorbs a neutron** first;
2. it splits into **two smaller nuclei, roughly equal in size**;
3. it releases **two or three neutrons** plus **gamma rays**; **energy is released**;
4. all the products (fragments, neutrons) carry **kinetic energy**;
5. the released neutrons may split further nuclei – a **chain reaction**.

Context	Chain reaction
nuclear reactor	controlled – control rods absorb neutrons to set the energy release rate
nuclear weapon	uncontrolled – it grows rapidly, releasing energy in an explosion

You must draw or interpret the chain diagram: neutron in $\rightarrow$ fragments + 2–3 neutrons out $\rightarrow$ each new neutron aimed at another large nucleus.

Fusion – **two light nuclei join** to form a heavier nucleus:

- some of the mass is **converted into the energy of radiation**;
- does not produce fission fragments, but a fusion system must not be assumed to create no radioactive material;
- needs extreme temperature and pressure to force nuclei together – why working fusion power is hard.

2 Practice

2.1 State the two fuel nuclei named by the spec for fission. [1]

2.2 List the products of one fission event (other than energy). [3]

2.3 State what fusion is and what happens to some of the mass. [2]

3 Exam-style questions

3.1 A uranium-235 nucleus absorbs a neutron and undergoes fission.

(a) Describe the products of this event. [3]

(b) Explain how a chain reaction can follow. [2]

(c) Explain how a reactor keeps the chain reaction controlled. [2]

3.2 Nuclear power stations do not generate electricity every day of the year; one station generated for 92% of a year (365 days). Calculate the number of generating days. [2]

3.3 Compare fission and fusion: their fuel nuclei, how energy is released, and radioactive material produced. [6]

Solutions

2.1 Uranium-235 and plutonium-239.

2.2 Two smaller nuclei roughly equal in size; two or three neutrons; gamma rays.

2.3 Fusion is the joining of two light nuclei to form a heavier nucleus; some of the mass is converted into the energy of the radiation.

3.1 (a) Two smaller nuclei of roughly equal size; two or three neutrons; gamma rays, with energy released and all products carrying kinetic energy. (b) The released neutrons can be absorbed by other U-235 nuclei; each causes another fission, so the number of fissions multiplies – a chain reaction. (c) Control rods (neutron-absorbing material) are lowered into the reactor; they absorb neutrons, setting how many continue the chain and so controlling the energy released.

3.2

$$\text{days} = \frac{92}{100} \times 365 = \mathbf{336} \text{ days (accept 335 or 336)}$$

(fraction C1, answer A1)

3.3 Indicative content – fission uses heavy nuclei such as uranium-235/plutonium-239; fusion joins light nuclei such as hydrogen isotopes. Fission splits a large nucleus after neutron absorption, releasing energy and neutrons that may continue a chain reaction; fusion joins light nuclei and converts some mass into the energy of radiation. Fission produces radioactive fragments needing secure management; fusion does not produce fission fragments, but radioactive fuel or activated materials may still need management. Do not claim that all fusion systems are waste-free. Level 2 (4–6): both processes compared on all three axes with accurate physics. Level 1 (1–3): some correct points on one or two axes.