

Nuclear fission fusion and chain reactions

AQA GCSE Separate Physics 8463 only | Foundation and Higher | Paper 1

Estimated/untrialled: 35–40 min independent +15–20 review | 25 parts | 46 marks

Specification points covered

4.4.4.1: neutron-induced fission, products and controlled/uncontrolled chain reactions

4.4.4.2: fusion of light nuclei; qualitative conversion of mass into radiation energy

4.1.3: selected nuclear-energy resource evidence and environmental comparisons

An energy museum is commissioning exhibits about a fission reactor, an experimental fusion system and the Sun. Check the physics, test model predictions and correct the exhibit claims.

Complete all six sections. Use nuclei rather than atoms where appropriate. Show working for numerical answers. Diagrams are schematic; use the stated model assumptions, not measured sizes.

1 Checking the exhibit labels

Card A describes a large unstable nucleus splitting. Card B describes two light nuclei joining to form a heavier nucleus. The Sun exhibit describes hydrogen nuclei combining.

1(a) Name the nuclear process described by Card A and the process described by Card B. **[2 marks]**

1(b) A visitor says the Sun must use the same uranium chain reaction as a fission reactor because both release energy. Correct the visitor using the Sun exhibit. **[2 marks]**

1(c) The fission exhibit says, “Fission can never happen unless a neutron arrives first.” Is “never” justified? Explain. **[1 mark]**



2 Reading one fission event

Figure 1 shows a before-and-after model of one induced fission. Q groups two products; R groups three products. Symbols are not to scale and do not show individual protons or neutrons inside nuclei.

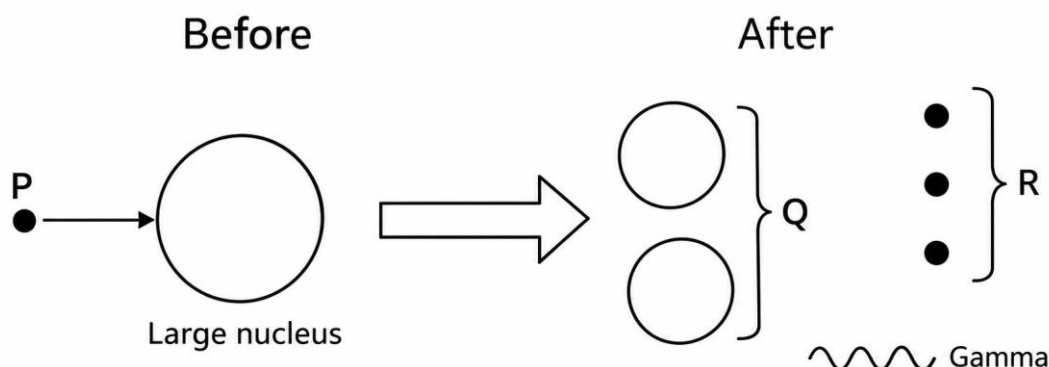


Figure 1

2(a) Identify the incoming particle P that can initiate this fission. **[1 mark]**

2(b) Identify the two objects grouped by Q and the three objects grouped by R. **[2 marks]**

2(c) A visitor calls the gamma symbol an electron leaving the nucleus. State the correct type of emission. **[1 mark]**

2(d) Another visitor says P breaks into the three R particles. Explain why this is not what the fission diagram represents. **[2 marks]**

2(e) A proposed label says all the released energy is carried by gamma radiation. Explain why this leaves out an important feature of the moving products. **[1 mark]**

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3 Following the next neutrons

Figure 2 traces only the three neutrons released by fission A; gamma rays and other products are omitted. An absorber captures a neutron without causing another fission. A neutron absorbed by the next fuel nucleus can trigger its fission.

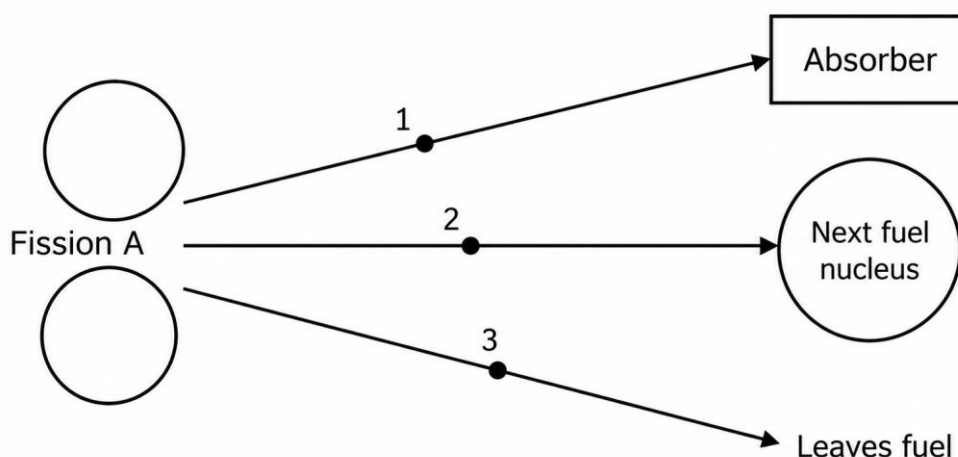


Figure 2

3(a) Which numbered path can continue the chain in Figure 2? Explain what must happen at the end of that path. **[2 marks]**

3(b) Only one of A's three neutrons causes another fission in this model. Explain how a chain can still continue rather than stopping after that next event. **[2 marks]**

3(c) An additional absorber intercepts path 2 as well. With no other neutron source, what happens to the next generation of this model chain? **[1 mark]**

3(d) In a different, idealised model, all three neutrons from each fission cause separate fresh nuclei to split. Starting with one fission A, calculate the number of fissions in the next generation and the generation after that. Do not include A in those totals. **[2 marks]**

3(e) The animator now labels every real fission "exactly three neutrons". Explain why the model does not justify this label. **[1 mark]**

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3 Following the next neutrons continued

3(f) Contrast a controlled reactor chain with an uncontrolled chain that produces an explosion. Refer to further fissions and the release of energy. **[2 marks]**

4 Testing the control settings

In each separate model test, 100 nuclei undergo fission in one generation and emit 300 neutrons. Each neutron not absorbed elsewhere or lost causes exactly one new fission in fresh fuel. Generations have equal durations. Table 1 gives the losses.

Table 1

Setting	Neutrons emitted	Absorbed elsewhere or lost
X	300	200
Y	300	100
Z	300	300

4(a) Calculate the number of new fissions in the next generation for settings X, Y and Z. **[3 marks]**

4(b) Which setting can maintain a steady chain at this stage? Explain using the starting 100 fissions and show why Y is not steady. **[2 marks]**

4(c) A safety note states that the fuel remains hot and its radioactive products can still emit radiation after shutdown. A visitor says setting Z makes the material immediately safe to handle. Evaluate the claim using both facts in the note. **[2 marks]**



5 Testing a fusion headline

Table 2 describes one experimental pulse. The 100 MJ supplied to the hot fuel is already included in the 160 MJ whole-facility input; do not add them. The 120 MJ is energy released by fusion, not a measurement of electricity delivered. No commercial-plant performance is implied.

Table 2

Energy boundary for one pulse	Energy / MJ
Supplied to hot fuel	100
Whole-facility input (includes the 100 MJ)	160
Energy released by fusion	120

5(a) A fusion label says, “The new nucleus is heavier than either light nucleus, so its mass must equal their combined starting mass.” Correct the conclusion and link your answer to the energy released. **[2 marks]**

5(b) Using the whole-facility input and fusion output, calculate the energy shortfall for this pulse. **[1 mark]**

5(c) The headline says, “120 MJ exceeds 100 MJ, so this experiment proves we can supply net electricity to the museum.” Give two reasons why Table 2 does not support this conclusion. **[2 marks]**

5(d) A supplied note says the light nuclei repel one another and must get very close to fuse. Heating makes them move faster. Use these facts to explain why a high temperature helps fusion occur. **[2 marks]**

5(e) Before approving a much larger fusion exhibit, why should engineers use a small experimental model to test the energy claim? Give one reason linked to this situation. **[1 mark]**



6 Writing the final museum explanation

Table 3 gives selected evidence for the museum display. Use the nuclear processes and the supplied evidence, not assumptions that every nuclear-energy claim describes the same system.

Table 3

Resource	Selected supplied evidence
Uranium fission	Finite fuel; no CO ₂ from the fission reaction; radioactive waste; mining disturbs land.
Natural gas	Finite fuel; combustion releases CO ₂ ; supply can be adjusted when fuel is available.

6(a) A label states, “Because no carbon dioxide is released in the fission reaction, fission electricity has no environmental effects.” Use Table 3 to give two reasons this is not a sound conclusion. **[2 marks]**

6(b) Give one further piece of evidence needed before recommending an electricity resource for the museum, beyond the selected facts and single test pulse supplied here. **[1 mark]**

6(c) Write an explanation for the museum comparing neutron-induced fission with fusion. Explain how one fission can begin a chain, how neutron absorption can control it, and how fusion differs, including its mass–energy link. Use linked sentences, not only process names. **[6 marks]**

Review: fission splits a large nucleus; fusion joins light nuclei. Released neutrons must cause further fissions for a chain reaction. Stopping a chain does not instantly remove heat or radioactive material. Compare energy claims at the same boundary.

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