Nuclear fission

4.4.4.1 · Atomic structure · revision notes

Nuclear fission is the splitting of a large, unstable nucleus such as uranium-235 or plutonium-239. You need to describe what happens in fission, explain how a chain reaction happens and how it is controlled in a nuclear reactor, and draw or interpret fission diagrams. GCSE Physics only, not in Combined Science.

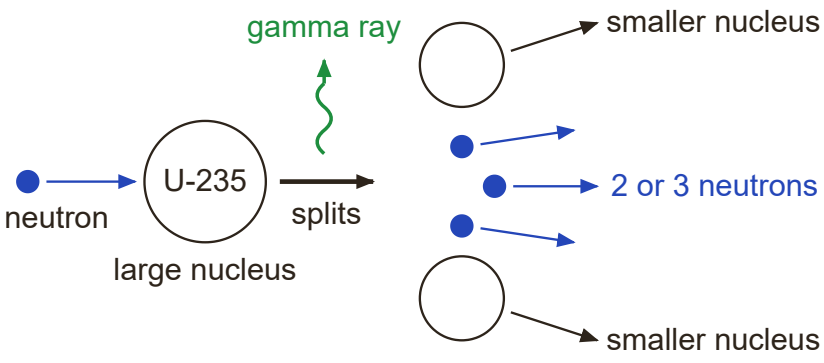
Key facts

- Fission: a large, unstable nucleus splits into two smaller nuclei
- Usually starts when the nucleus absorbs a neutron; spontaneous fission is rare
- Chain reaction: the released neutrons cause further fissions
- Nuclear weapon: uncontrolled chain reaction
- Fuels: uranium-235 and plutonium-239
- Products: 2 smaller nuclei + 2 or 3 neutrons + gamma rays, all with kinetic energy
- Nuclear reactor: controlled chain reaction (control rods absorb neutrons)

Notes

What happens in fission

- **Nuclear fission** is the splitting of a large and unstable nucleus, such as uranium or plutonium.
- Spontaneous fission (splitting without a trigger) is rare. Usually the nucleus must first **absorb a neutron**.
- The nucleus then splits into **two smaller nuclei**, roughly equal in size, and emits **two or three neutrons** and **gamma rays**.

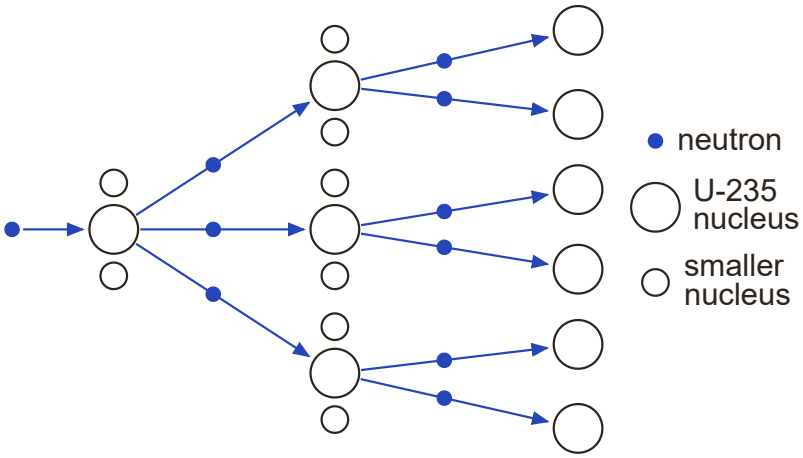


Fission of uranium-235. All the products move off fast: they have kinetic energy.

- Energy is released. All of the fission products have **kinetic energy**.
- A fission equation balances like any nuclear equation: $^{235}_{92}\mathrm{U} + {}^{1}_{0}\mathrm{n} \rightarrow {}^{144}_{55}\mathrm{Cs} + {}^{90}_{37}\mathrm{Rb} + 2\,{}^{1}_{0}\mathrm{n}$. Check: 235 + 1 = 144 + 90 + 2, and 92 = 55 + 37. Grade 7+ only

Chain reactions

- The neutrons released can be absorbed by other uranium or plutonium nuclei, which then split too. This is a **chain reaction**.
- Each fission releases 2 or 3 neutrons, so without control the number of fissions grows very quickly.
- In a diagram, show a neutron being absorbed by a large nucleus, the nucleus splitting into two smaller nuclei, and 2 or 3 neutrons coming out, each going on to a new large nucleus.



A chain reaction: each fission releases neutrons that cause more fissions.

Controlled and uncontrolled chain reactions

- In a **nuclear reactor** the chain reaction is **controlled**, to control the energy released.
- **Control rods** absorb some of the neutrons. Lowering them further into the reactor slows the reaction; raising them speeds it up.
- For a steady rate, on average one neutron from each fission goes on to cause another fission.
- The energy released is used to heat water to make steam, which turns turbines to generate electricity.
- The explosion of a **nuclear weapon** is caused by an **uncontrolled** chain reaction.

How to answer each type of question

Describe the process of fission

3 to 4 marks | **Grade 5**

1. Start with the nucleus absorbing a neutron.
2. Say what it splits into.
3. Say what else is emitted and that energy is released.

Example. Describe what happens when a uranium-235 nucleus undergoes fission.

Model answer. The nucleus absorbs a neutron (1). It splits into two smaller nuclei of roughly equal size (1). Two or three neutrons are released, along with gamma rays (1). Energy is released / the products have kinetic energy (1).

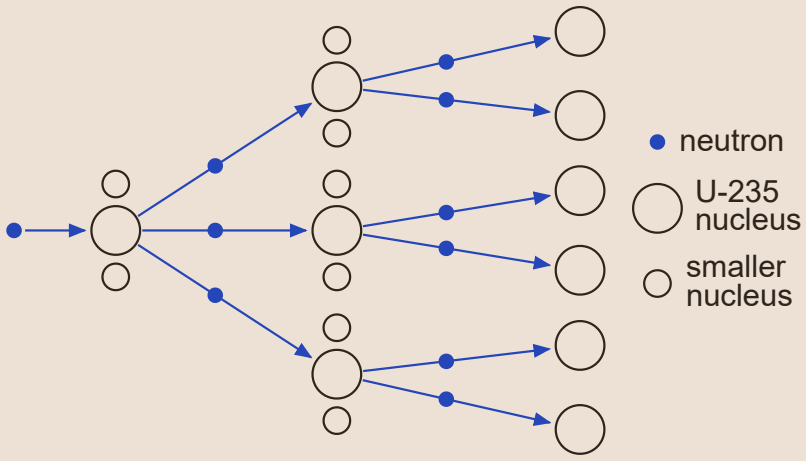
Explain how a chain reaction happens

3 marks | Grade 6

1. Say that each fission releases 2 or 3 neutrons.
2. Say that these neutrons are absorbed by other nuclei.
3. Say that those nuclei split and release more neutrons, so it continues.

Example. Explain how a chain reaction can happen in a sample of uranium-235. You may draw a diagram to help your answer.

Model answer.



When a nucleus undergoes fission it releases 2 or 3 neutrons (1). These neutrons can be absorbed by other uranium-235 nuclei (1), which then undergo fission and release more neutrons, so the process keeps going (1).

Explain how the reaction is controlled

3 marks | Grade 7

1. Name control rods and say they absorb neutrons.
2. Say how moving the rods changes the rate.
3. State the aim: on average one neutron from each fission causes another.

Example. Explain how the rate of fission in a nuclear reactor is kept steady.

Model answer. Control rods absorb neutrons (1). The rods are moved further in or out of the reactor to change how many neutrons are absorbed (1), so that on average only one neutron from each fission goes on to cause another fission (1).

Complete a fission equation 2 marks **Grade 7**

1. Add up the top numbers on the left, including the neutron.
2. Subtract the known top numbers on the right, remembering to count every neutron.
3. Check the bottom numbers balance too.

Example. The equation shows the fission of a plutonium-239 nucleus.

$$^{239}_{94}\mathrm{Pu} + {}^{1}_{0}\mathrm{n} \rightarrow {}^{134}_{54}\mathrm{Xe} + {}^{a}_{40}\mathrm{Zr} + 3\,{}^{1}_{0}\mathrm{n}$$

Determine the value of a.

Model answer.

Left side: 239 + 1 = 240 (1)

a = 240 − 134 − 3 = 103 (1)

(Check: 94 = 54 + 40.)

Don’t lose marks

- Saying fission starts with the nucleus absorbing a proton or an alpha particle. It absorbs a neutron.
- Saying the nucleus splits into lots of pieces, or into protons and neutrons. It splits into two smaller nuclei, plus 2 or 3 neutrons.
- Saying control rods absorb 'energy' or 'radiation'. They absorb neutrons.
- Drawing a chain reaction where each fission releases only one neutron, or where the neutrons do not go on to other nuclei.
- Describing fission as an atom splitting. Write about the nucleus: describing it only in terms of atoms loses the marks for absorbing a neutron and splitting.

More tips

Memory tricks

- Fission = splitting (a fissure is a split or crack).
- Fission recipe: 1 neutron in → 2 smaller nuclei + 2 or 3 neutrons + gamma rays + energy out.
- Control rods catch neutrons: more rod in → fewer neutrons → slower reaction.

Exam technique

- In chain reaction diagrams, label the neutrons, the large nuclei and the smaller nuclei produced.
- Write 'the nucleus absorbs a neutron' rather than just 'is hit by a neutron'.
- When comparing a reactor and a weapon, the key words are 'controlled' and 'uncontrolled'.

What each grade needs

What you need to be able to do, from the first marks up to the top grade.

Grade 4 **Define nuclear fission**

The splitting of a large, unstable nucleus into two smaller nuclei.

Grade 4

Name nuclear fuels used for fission

Uranium (e.g. uranium-235) and plutonium (e.g. plutonium-239).

Grade 5

Describe the products of fission

Two smaller nuclei of similar size, two or three neutrons and gamma rays, all with kinetic energy.

Grade 5

Compare a reactor with a nuclear weapon

In a reactor the chain reaction is controlled; in a weapon it is uncontrolled, causing an explosion.

Grade 6

Explain how a chain reaction happens

Neutrons released by one fission are absorbed by other nuclei, which also split.

Grade 6

Draw or interpret a chain reaction diagram

Show each fission releasing 2 or 3 neutrons that go on to cause more fissions.

Grade 7

Explain how a reactor controls fission

Control rods absorb neutrons so that, on average, one neutron from each fission causes another.

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