Nuclear fusion

4.4.4.2 · Atomic structure · revision notes

Nuclear fusion is the joining of two light nuclei to form a heavier nucleus, with some of the mass converted into the energy of radiation. You need to describe fusion and compare it with fission. Expect short 'describe' questions and 4 to 6 mark comparisons. GCSE Physics only, not in Combined Science.

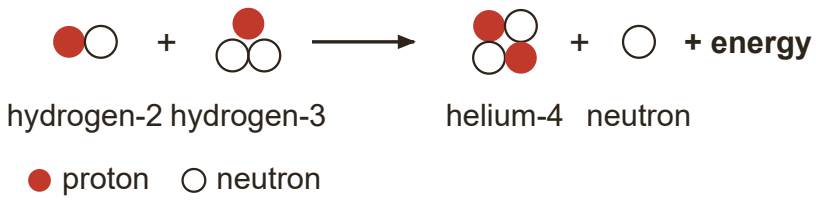
Key facts

- Fusion: two light nuclei join to form a heavier nucleus
- Stars: hydrogen nuclei fuse to form helium
- Grade 7+ only Fusion needs very high temperature and pressure, because positive nuclei repel
- Some of the mass is converted into energy of radiation
- Fission splits heavy nuclei; fusion joins light nuclei; both release energy
- Fission is used in power stations now; fusion is not yet used to generate electricity

Notes

What fusion is

- **Nuclear fusion** is the joining of two light nuclei to form a heavier nucleus.
- In this process some of the mass may be converted into the energy of radiation. The total mass of the products is slightly less than the total mass of the nuclei that joined.
- Example: two isotopes of hydrogen fuse to form helium: $^{2}_{1}\mathrm{H} + {}^{3}_{1}\mathrm{H} \rightarrow {}^{4}_{2}\mathrm{He} + {}^{1}_{0}\mathrm{n}$



Fusion of two hydrogen isotopes. The products have slightly less mass: that mass became energy.

- Fusion is the energy source of stars. In the core of the Sun, hydrogen nuclei fuse to form helium.

Why fusion is hard to achieve Grade 7+ only

- All nuclei are positively charged, so they repel each other.
- To fuse, they must get very close together. This needs a very high temperature (so the nuclei move very fast) and a high pressure (so they collide often).
- These conditions are very hard to create and contain on Earth. Experimental fusion reactors exist, but none yet generates electricity for everyday use.

Fission and fusion compared

- Fission: a large, heavy nucleus splits into two smaller nuclei. Fusion: two light nuclei join to form a heavier nucleus.
- Both release energy.
- Fission usually starts when a nucleus absorbs a neutron. Fusion needs very high temperatures and pressures.
- Fission fuels are uranium and plutonium; fusion fuels are light nuclei such as isotopes of hydrogen.
- Fission is used in nuclear power stations today. Fusion happens naturally in stars.

How to answer each type of question

Describe nuclear fusion 2 marks **Grade 4**

1. Say that two light nuclei join.
2. Say that a heavier nucleus forms and energy is released (some mass is converted to energy).

Example. Describe what happens during nuclear fusion.

Model answer. Two light nuclei join together (1) to form a heavier nucleus, and energy is released as some of the mass is converted into energy (1).

Complete a fusion equation 2 marks **Grade 6**

1. Add the top numbers on the left, then subtract any known top numbers on the right.
2. Do the same for the bottom numbers.

Example. Two hydrogen-2 nuclei fuse:
$${}^{2}_{1}\mathrm{H} + {}^{2}_{1}\mathrm{H} \rightarrow {}^{a}_{b}\mathrm{He} + {}^{1}_{0}\mathrm{n}$$
Determine the values of a and b.

Model answer.

a = 2 + 2 − 1 = 3 (1)

b = 1 + 1 − 0 = 2 (1)

Explain why fusion needs a very high temperature

3 marks | Grade 7

1. Say that nuclei are positive, so they repel.
2. Say that at a high temperature they move very fast.
3. Say that this lets them get close enough to fuse.

Example. Explain why nuclear fusion only happens at very high temperatures.

Model answer. Nuclei are positively charged, so they repel each other (1). At very high temperatures the nuclei move very fast / have a lot of kinetic energy (1), so they can overcome the repulsion and get close enough to fuse (1).

Compare fission and fusion

4 to 6 marks | Grade 8

1. Compare what happens to the nuclei.
2. Compare the nuclei (fuels) involved.
3. Compare the conditions needed and where each is used.
4. Include what they have in common: both release energy.

Example. Compare nuclear fission and nuclear fusion. (4 marks)

Model answer. In fission a large nucleus splits into two smaller nuclei, whereas in fusion two light nuclei join to form a heavier nucleus (1). Fission uses heavy nuclei such as uranium or plutonium, whereas fusion uses light nuclei such as isotopes of hydrogen (1). Both processes release energy (1). Fission usually starts when a nucleus absorbs a neutron, whereas fusion needs very high temperatures and pressures (1). Also credit: fission is used in power stations now, whereas fusion happens in stars and is not yet used to generate electricity.

Don’t lose marks

- Mixing up fission and fusion, the most common slip in this topic.
- Saying fusion joins atoms or molecules. It joins nuclei.
- Saying energy is 'created'. Some of the mass is converted into energy.
- Saying today's nuclear power stations use fusion. They use fission.

More tips

Memory tricks

- Fusion = fuse = join together. Fission = split.
- Heavy nuclei split (fission); light nuclei join (fusion).
- Stars run on fusion; today's nuclear power stations run on fission.

Exam technique

- In 'compare' questions, make every point about both processes, using 'whereas'. A list about only one process scores little.
- Say 'nuclei', not 'atoms', in your definitions of fission and fusion.
- Questions sometimes link fusion to stars in space physics, so be ready to use both topics together.

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 fusion**
Two light nuclei join to form a heavier nucleus.

Grade 5 — **State where fusion happens naturally**
In the cores of stars, e.g. hydrogen nuclei fuse to form helium in the Sun.

Grade 5 — **State where the energy comes from**
Some of the mass is converted into the energy of radiation.

Grade 6 — **Complete a fusion equation**
Balance the mass numbers and atomic numbers, as for any nuclear equation.

Grade 7 — **Explain why fusion needs extreme conditions**
Very high temperatures and pressures let positive nuclei overcome their repulsion and get close enough to fuse.

Grade 8 — **Compare fission and fusion in detail**
Compare what happens, the nuclei involved, the conditions needed and where each is used.

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