4.8.2 Nuclear fusion

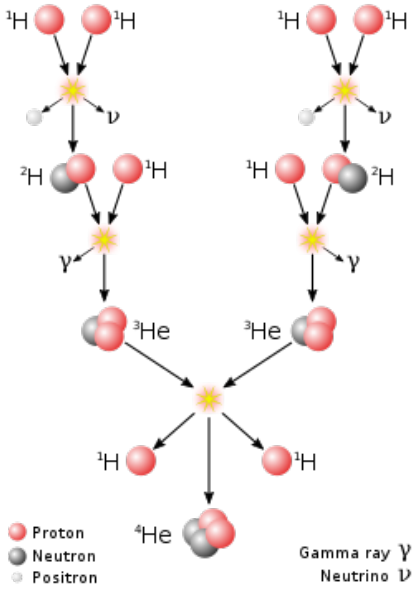
videos

Nuclear fusion is a term used for the process in which smaller nuclei are fused (joined) together to produce larger nuclei, releasing energy in the process. Nuclear fusion occurs in the Sun and other stars and is how they generate the huge amounts of energy that they emit as radiation. It is also the process by which all the elements heavier than hydrogen and helium were formed.

Fusion in stars

A star spends most of its life fusing hydrogen in its core (the centre of the star). At this point in its lifecycle, it is known as a "main sequence" star. Very high temperatures and pressures are required to get the positively charged nuclei close enough to fuse. These are conditions only found in the core of the star. When nuclei are close enough the strong nuclear force binds the nuclei together making a larger nucleus.

The diagram (right) shows the fusion reactions taking place in main sequence starts. For GCSE you don't need to know all the details of these reactions, only that a series of fusion reactions changes hydrogen nuclei ($_1^1H$) into helium-4 nuclei ($_2^4He$) and energy is released.



Once a star has fused all the hydrogen in its core, it grows in size to become a Red Giant star or a Red Supergiant star. It starts to fuse together helium nuclei. Very large stars can fuse together even larger nuclei to make all the elements up to iron in the periodic table.

The elements larger than iron are formed when the cores of large stars collapse and then explode as "supernova explosions". The enormous temperatures and pressures are enough to fuse together nuclei to form the very heaviest elements (up to uranium).

(1) What is nuclear fusion?

(2) What are stars called when they are fusing hydrogen in their cores?

(3) What nuclei are formed when hydrogen nuclei are fused?

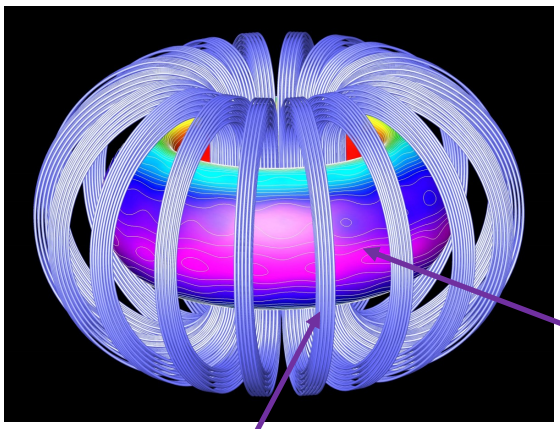
(4) What else is released during fusion?

(5) What type of stars form elements heavier that helium?

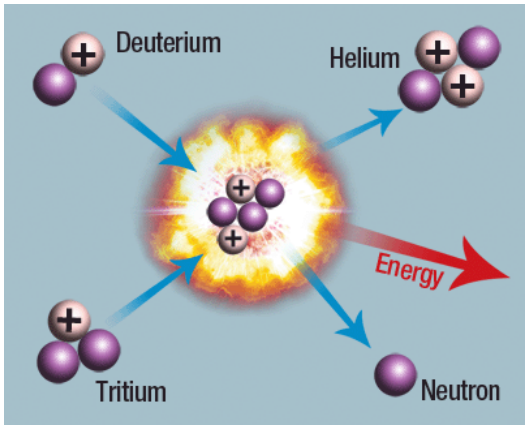
(6) What event is required to form the very heaviest elements?

Fusion power

There is a lot of potential in using controlled nuclear fusion to generate electricity. Compared to nuclear fission, it produces a lot less radioactive waste, the 'fuel' is readily available (it can be extracted from sea water), and fusion reactors are much safer. However, there are enormous technical difficulties to achieving the right conditions to sustain fusion reactions in a power station.



Some of the most promising designs use strong magnetic fields to confine a high-temperature plasma of fusing nuclei (in a sort of donut shape or torus). The plasma is so hot that it can't be allowed to come in contact with the walls of the reactor.



When the plasma is at a high enough temperature ($\approx 100\ million\ °C$), two isotopes of hydrogen (deuterium - containing one neutron, and tritium - containing 2 neutrons) begin to fuse and release energy. They fuse to produce helium-4 and a neutron. As the neutron is neutral, it can't be deflected by the magnetic field and so flies out and is absorbed by the walls of the reactor which heats up. This heat is then used turn water into steam, which drives a turbine linked to a generator, which generates electricity.

(6) What 3 advantages does fusion power have over fission power?

(7) What two nuclei are fused together in a fusion reactor?

(8) What is used to stop the plasma touching the sides of the reactor?

(9) What temperature is required for fusion reactions to take place?

(10) How is the reactor used to generate electricity?