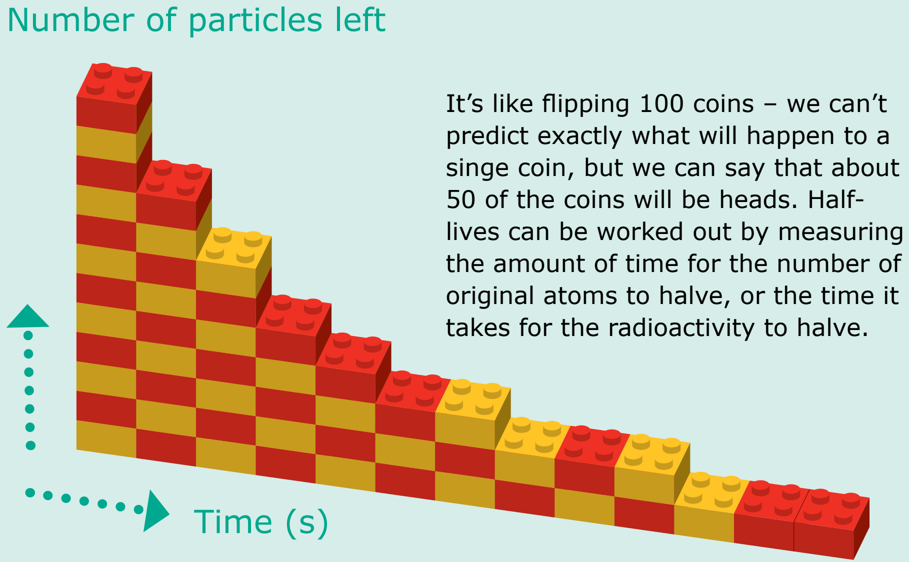
HALF-LIFE

The half-life of an element tells us how long it will take for half of the nuclei in a sample of an unstable element to decay. So, after one half-life, only half of the lump will be the original element. After two half-lives, this is divided by two again, meaning that only a quarter of the original element will be left. Although we can't know anything about one single nucleus, we can estimate what will happen to a lot of nuclei over time.



It's like flipping 100 coins – we can't predict exactly what will happen to a singe coin, but we can say that about 50 of the coins will be heads. Half-lives can be worked out by measuring the amount of time for the number of original atoms to halve, or the time it takes for the radioactivity to halve.

For more information on our outreach activities, go to our website
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SEPnet
South East Physics Network **Outreach**

Queen Mary
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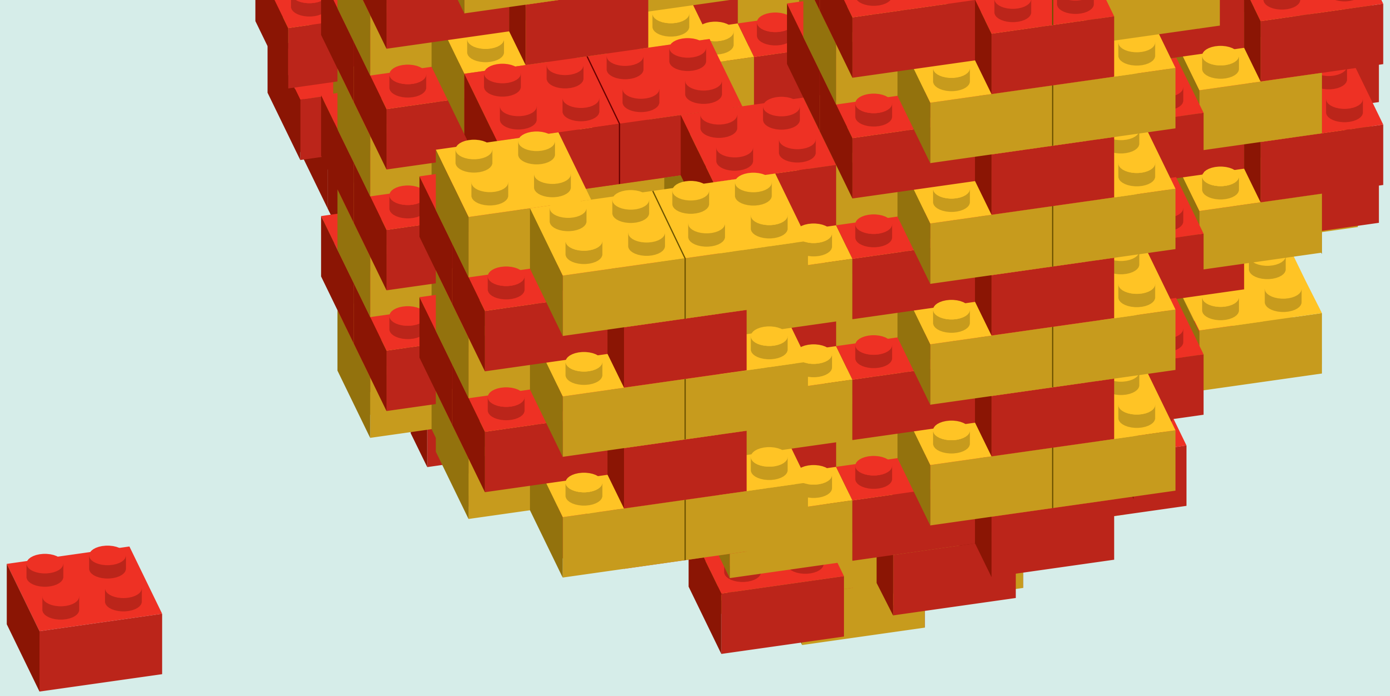

FISSION AND FUSION: A PHYSICS KIT

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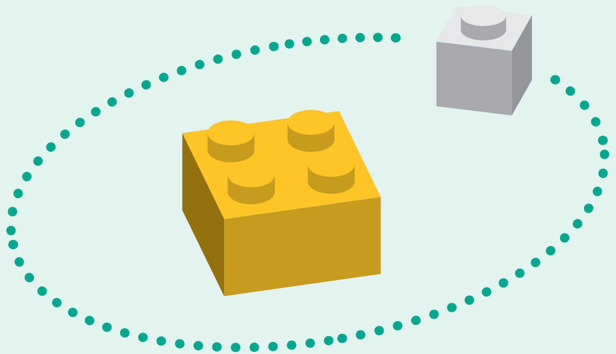
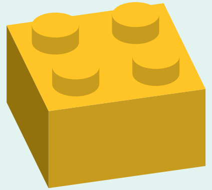
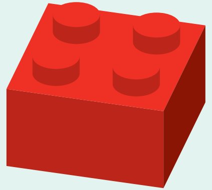
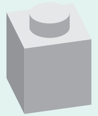
FISSION AND FUSION: A PHYSICS KIT

WHAT'S INSIDE THE ATOM?


Hydrogen atom


Proton


Neutron

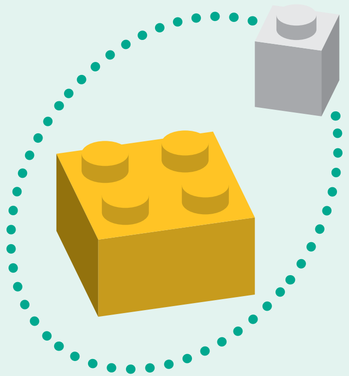

Electron

The first person to suggest that things were made up of tiny particles was a Greek person called Democritus, over 4000 years ago. He thought that if you cut a piece of material in half over and over again, you would eventually get to a bit that was uncuttable. The Ancient Greek word for uncuttable is atomos, so he called this thing an atom.

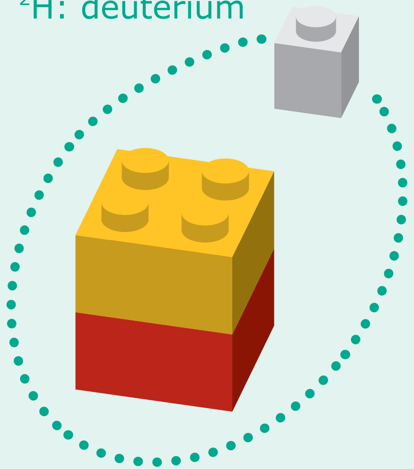
Atoms are pretty small. There are about 20 million atoms just in the full stop at the end of this sentence. But Democritus was wrong about one thing: atoms are not the smallest things – they can be cut. Inside an atom, there are three smaller things: protons, which are positively charged, neutrons, which are neutral and electrons, which are negatively charged. The protons and neutrons form the nucleus, the centre of the atom, and this is surrounded by electrons. The simplest atom is hydrogen, shown here.

ISOTOPES

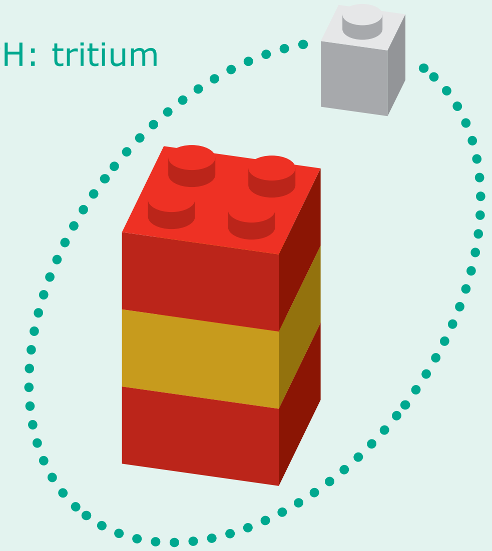
^{1}H: hydrogen



^{2}H: deuterium



^{3}H: tritium

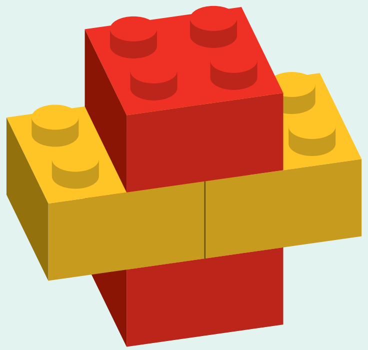


Protons and electrons have opposite charges, which means that they attract one another. As protons and electrons have equal and opposite charges, each proton attracts one electron, so atoms tend to have equal numbers of protons and electrons. What makes each element behave in its own special way is the number of electrons surrounding the nucleus, so the number of protons is what makes an element unique. What this does mean is that because the number of neutrons doesn't change the number of electrons (they don't have any charge, so they can't attract or repel anything), we can add neutrons to a nucleus without changing the way an element reacts with other elements.

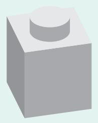
These variations are called different isotopes: three isotopes of hydrogen are shown here. The important thing that is different about deuterium and tritium is that they are two- and three- times as heavy as normal hydrogen.

RADIOACTIVITY

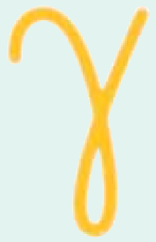
Alpha particle



Beta particle



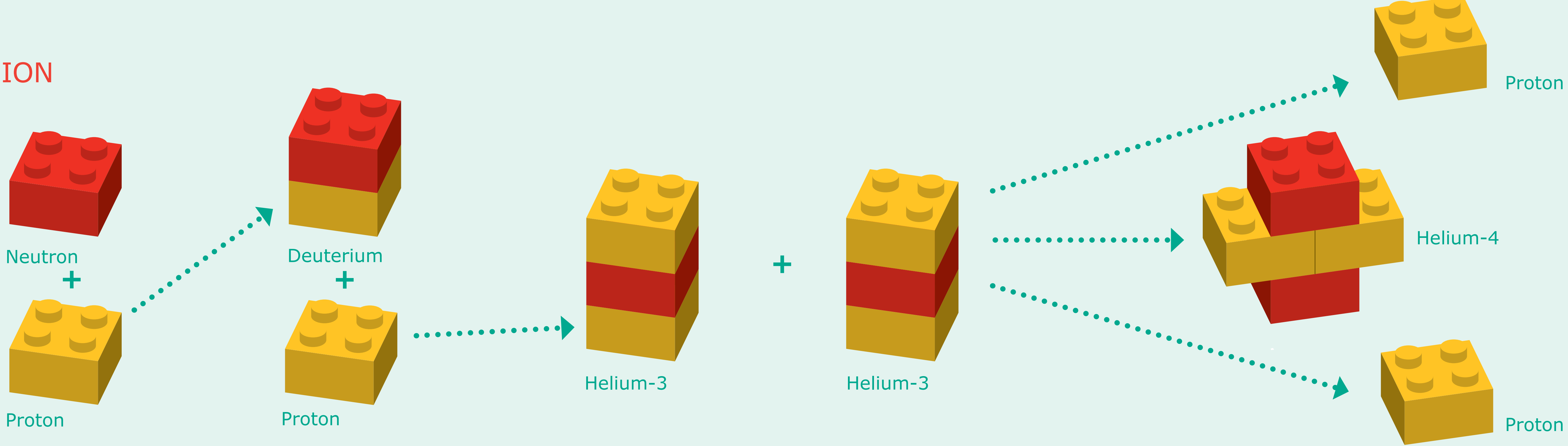
Gamma radiation



Although adding extra neutrons to a nucleus might not change how it behaves around other elements, it can lead to some very important effects. The nucleus is held together by a special force called the strong force, which only has effects at really short distances, like those inside a nucleus (protons are only 0.000000000002m apart!). This force can overcome the repulsion caused by putting positively charged protons near one another. Adding extra neutrons adds more of this force, and makes it easier for the atom to hold together. However, sometimes there are just too many protons, and the atom can break apart. This is known as radioactivity. The nucleus will split into smaller parts or fire something out, which makes it easier for the strong force to hold it all together.

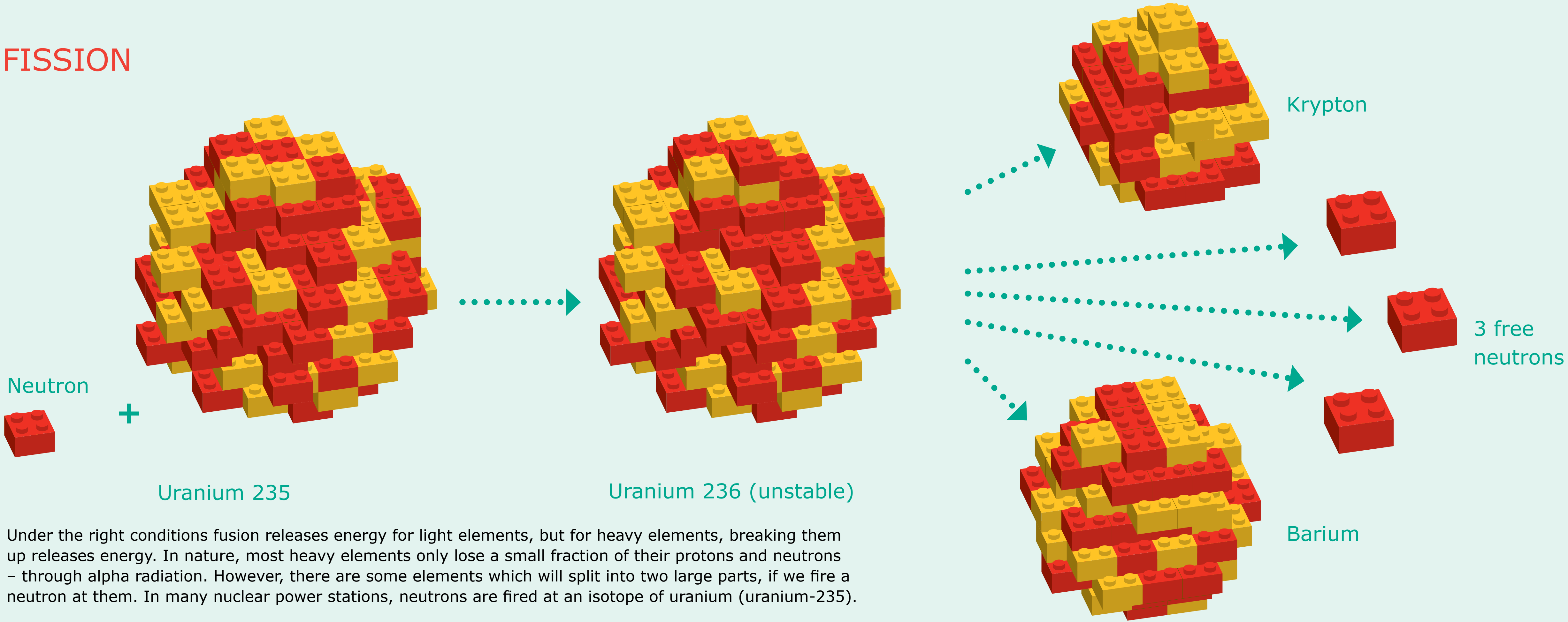
There are three things which can be emitted when a nucleus breaks apart in this way, meaning that there are three types of radiation. Alpha radiation is where an entire helium nucleus – two protons and two neutrons – is thrown out of the atom. Because the particle is quite big and heavy, this can't get through much, and can be stopped by a piece of paper. Beta radiation is where one of the neutrons inside the atom turns into a proton, and throws out an electron. Electrons are much lighter than protons and neutrons, so this can go quite a long way – although it is still stopped by some thick aluminum. The final type of radiation is gamma rays – high energy light rays. These don't weigh anything at all, so can go through a lot of things, including people. You need a few cm of lead to stop this type of radiation.

FUSION



At the beginning, the Universe was mainly made up of protons, so the only element around was hydrogen. Over time, inside stars like our Sun, these hydrogen atoms were stuck together, to produce all the elements we see around us. Here, the process for making helium – the second heaviest element – is shown. First of all, a proton sticks to a neutron, to make deuterium. The neutron comes from a process very similar to the beta decay described on the last page, except here, a proton turns into a neutron (and emits something called a positron, which weighs the same as an electron, but has the opposite charge). This makes deuterium. If we add another proton to this, we get helium-3. Finally, once we have two helium-3 nuclei, we can combine them to make helium-4, the most common isotope of helium. Lots of energy is released at every stage of this process, in the form of light, so this is the process that makes the Sun shine.

FISSION



Under the right conditions fusion releases energy for light elements, but for heavy elements, breaking them up releases energy. In nature, most heavy elements only lose a small fraction of their protons and neutrons – through alpha radiation. However, there are some elements which will split into two large parts, if we fire a neutron at them. In many nuclear power stations, neutrons are fired at an isotope of uranium (uranium-235).

This extra neutron causes the nucleus to become unstable, and to break into two parts: krypton and barium. After the split, there are three neutrons left over, which can then go on to cause more uranium 235 to break apart. This is called induced fission.

CHAIN REACTIONS

If every neutron released from induced fission were to induce fission in another uranium atom, then there would very quickly be many many reactions going on at once. This is called a chain reaction – where one event causes three more, which in turn each cause three more.

This is what happens in an atomic bomb, and is why they are so dangerous. This is not what we want in a nuclear reactor.

In order to avoid this, reactors are equipped with special materials, which absorb some of the extra neutrons completely (like silver or boron). The energy is generated in the form of heat: the reactor is surrounded by water which absorbs the energy generated by the splitting of atoms, and heats up, with the steam from the boiling water turning turbines, just like in coal powered plants.