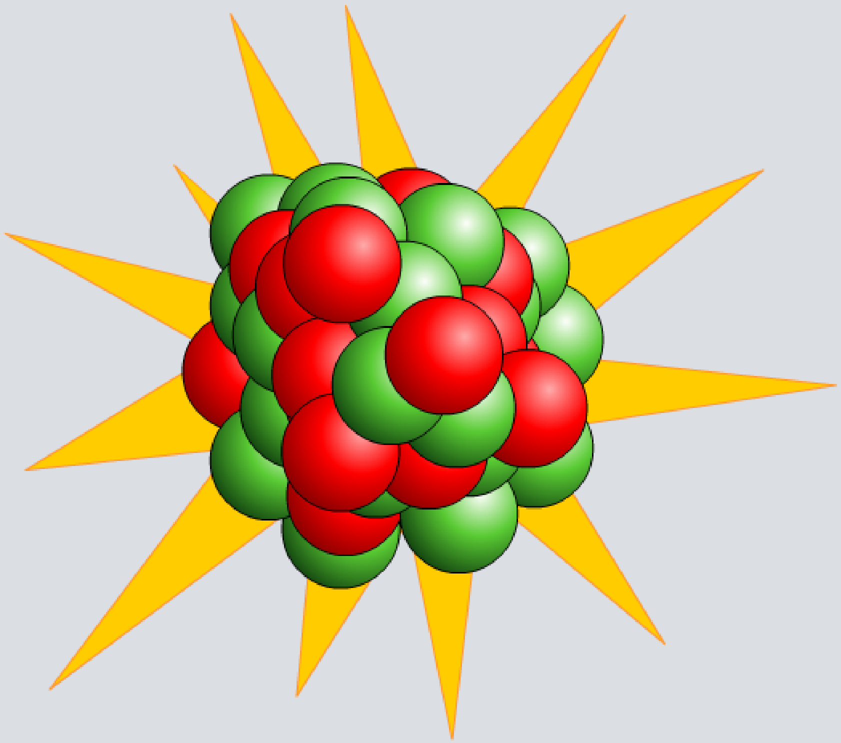
Nuclear Fission

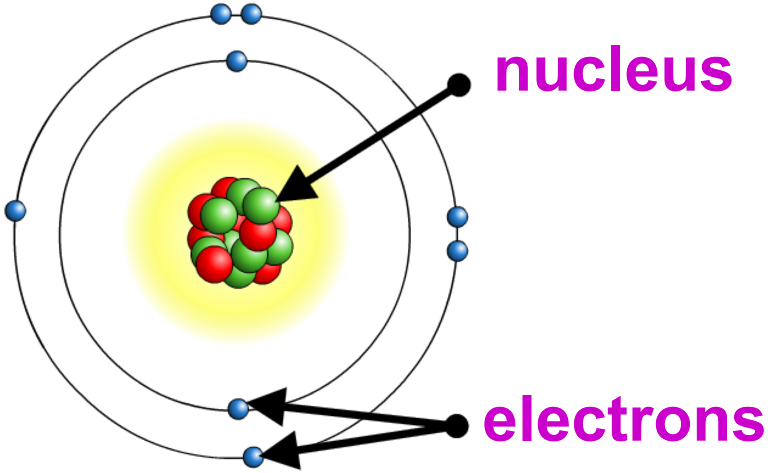


How do we get energy from atoms?

Atoms contain huge amounts of energy, and there are two ways in which this energy can be released.

One way is to split atomic nuclei in a process called **nuclear fission**.

Another way is to join nuclei together in a process called **nuclear fusion**.



The energy that holds particles together in a nucleus is much greater than the energy that holds electrons to a nucleus.

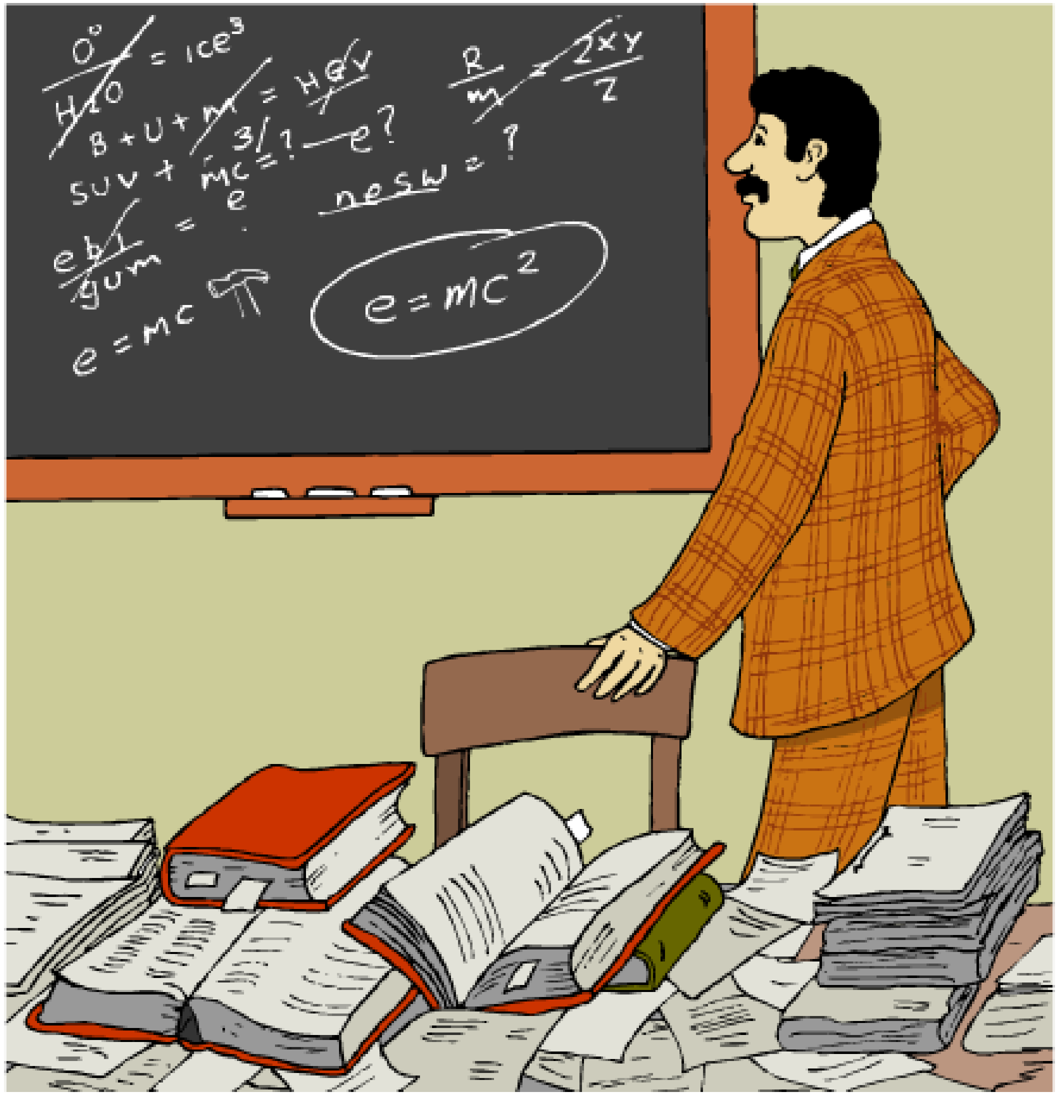
This is the why the energy released during nuclear reactions (involving nuclei splitting apart or joining together) is much greater than that for chemical reactions (involving electrons).

Einstein and $E = mc^2$

In 1905, Albert Einstein made the connection between energy and matter.

Einstein made the prediction that a small amount of matter could release a huge amount of energy.

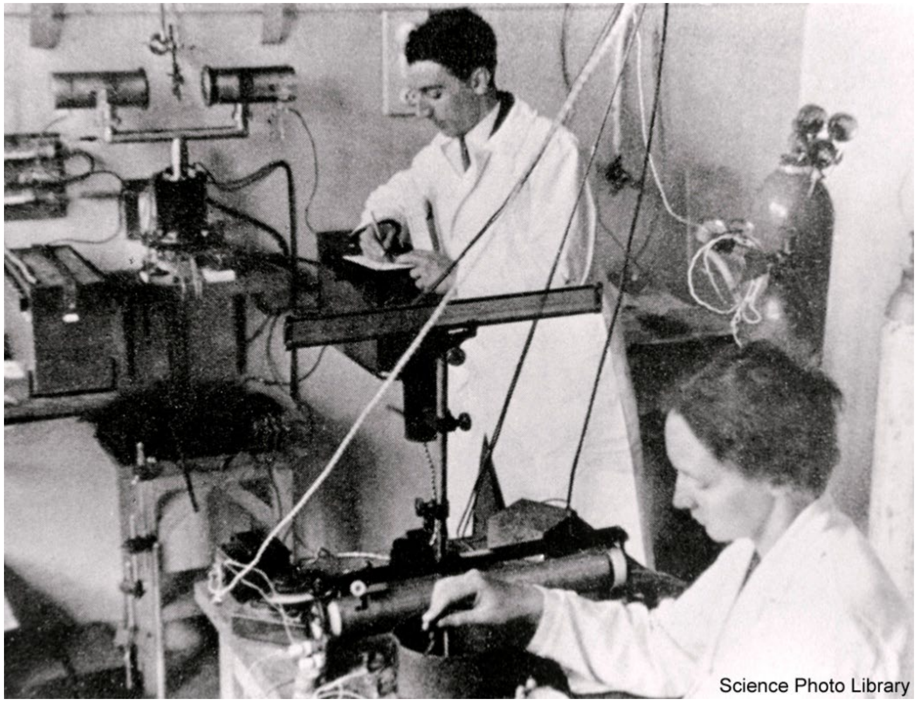
He expressed this in what is probably the most famous equation in physics, $E = mc^2$.



Proof of Einstein's theory

In 1933, work by Irène and Frédéric Joliot-Curie proved Einstein's prediction.

They produced a photograph that showed the creation of two particles (mass) when a particle of light (carrying energy) was destroyed.



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This was the first proof of the conversion of energy into mass.

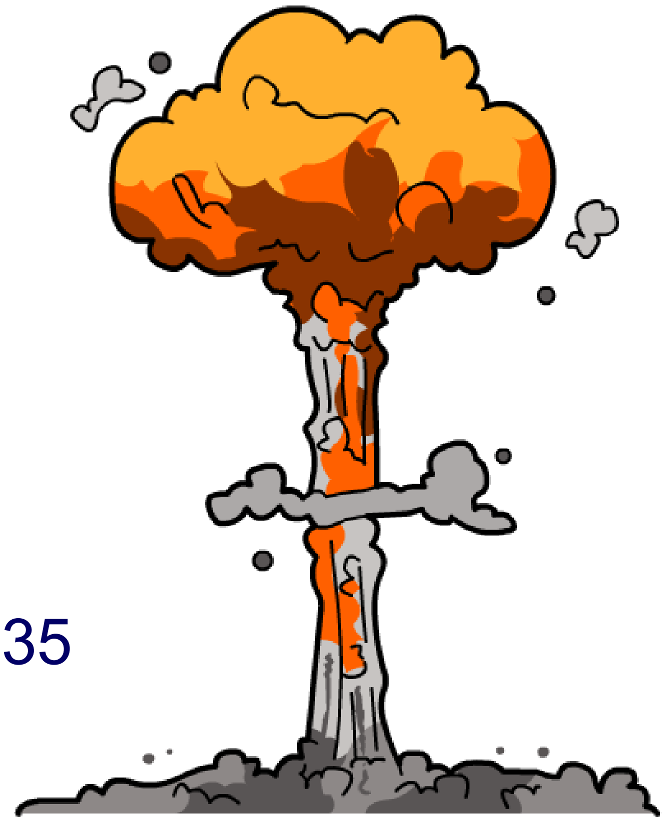
However, the strongest evidence of Einstein's theory came with discoveries about nuclear fission and fusion reactions, in which huge amounts of energy are released from atoms.

What is nuclear fission?

Nuclear fission occurs when a stable isotope is struck by a **neutron**. The isotope absorbs the neutron, becomes unstable and then splits apart, releasing large amounts of energy.

Unlike natural radioactive decay, fission is not a natural event.

Isotopes that undergo fission include uranium-235 and plutonium-239. These isotopes can both be used in nuclear reactors and in nuclear weapons.



The fission of 1 kilogram of uranium-235 releases more energy than burning 2 million kilograms of coal!

How is uranium used in nuclear reactors?

There are two major isotopes of uranium – 238 and 235. Uranium-238 is the major isotope, but it does not undergo nuclear fission.

Only 0.7% of naturally-occurring uranium is uranium-235, which does undergo nuclear fission.

Before it can be used as the fuel in nuclear power stations, uranium needs to be enriched until it has 3% uranium-235.

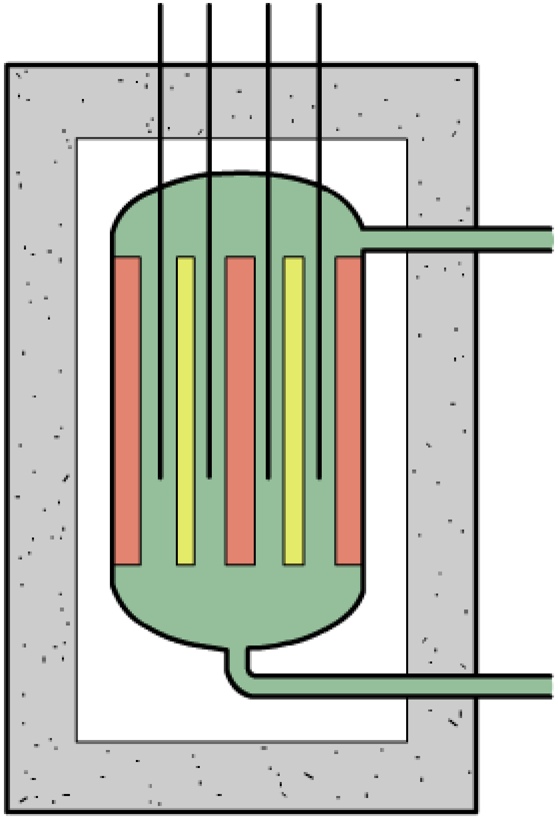
The enriched fuel is made into rods which are used in the reactor.

What is nuclear fission?

Nuclear fission is used to generate heat in a reactor in a nuclear power station.

This process involves atomic nuclei splitting into smaller nuclei and releasing energy.

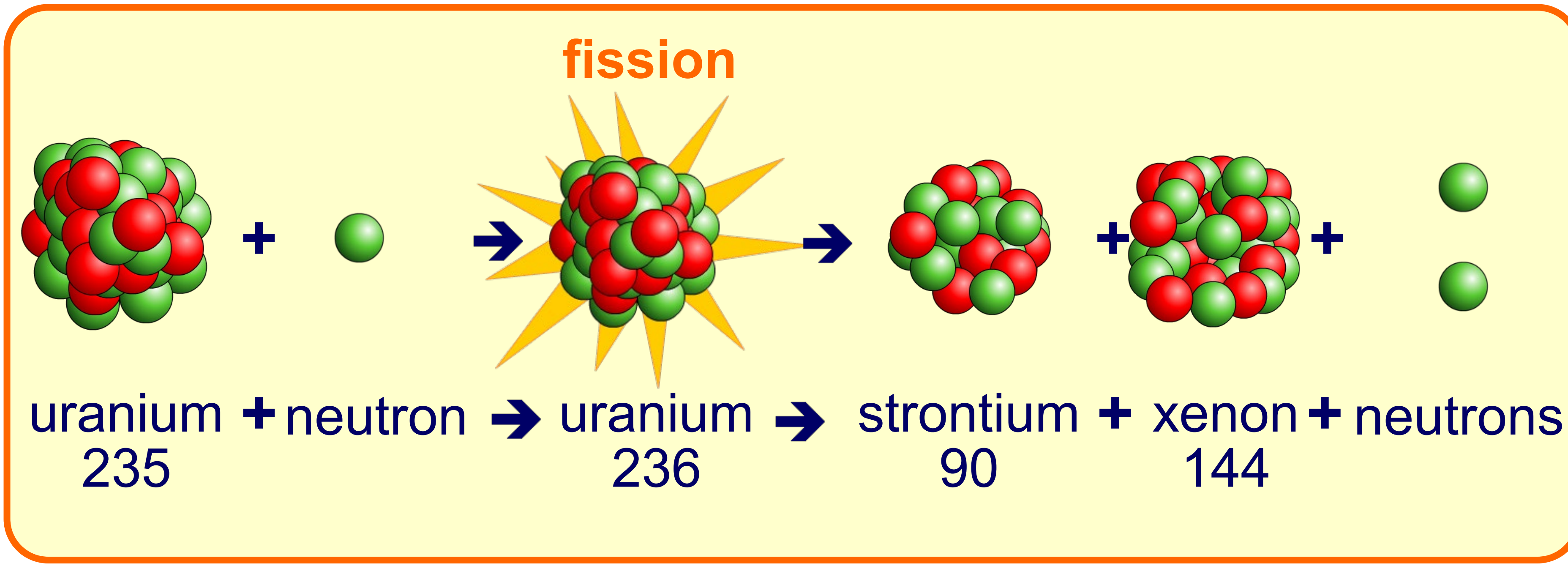
Click "**play**" to find out more about nuclear fission.



What are the products of fission?

When fission of uranium-235 occurs, it splits into two smaller nuclei, known as **daughter nuclei**.

Many possible daughter nuclei may be formed in a fission process. One example is shown below.



Where does the energy come from?

Barium and krypton are often the daughter nuclei formed by the fission of uranium-235. The decay equation for this is:

$$^{235}_{92}\mathbf{U} + ^{1}_{0}\mathbf{n} \rightarrow ^{90}_{36}\mathbf{Kr} + ^{143}_{56}\mathbf{Ba} + \mathbf{3}\,^{1}_{0}\mathbf{n}$$

In this decay equation, the number of protons and the mass numbers on both sides of the equation balance.

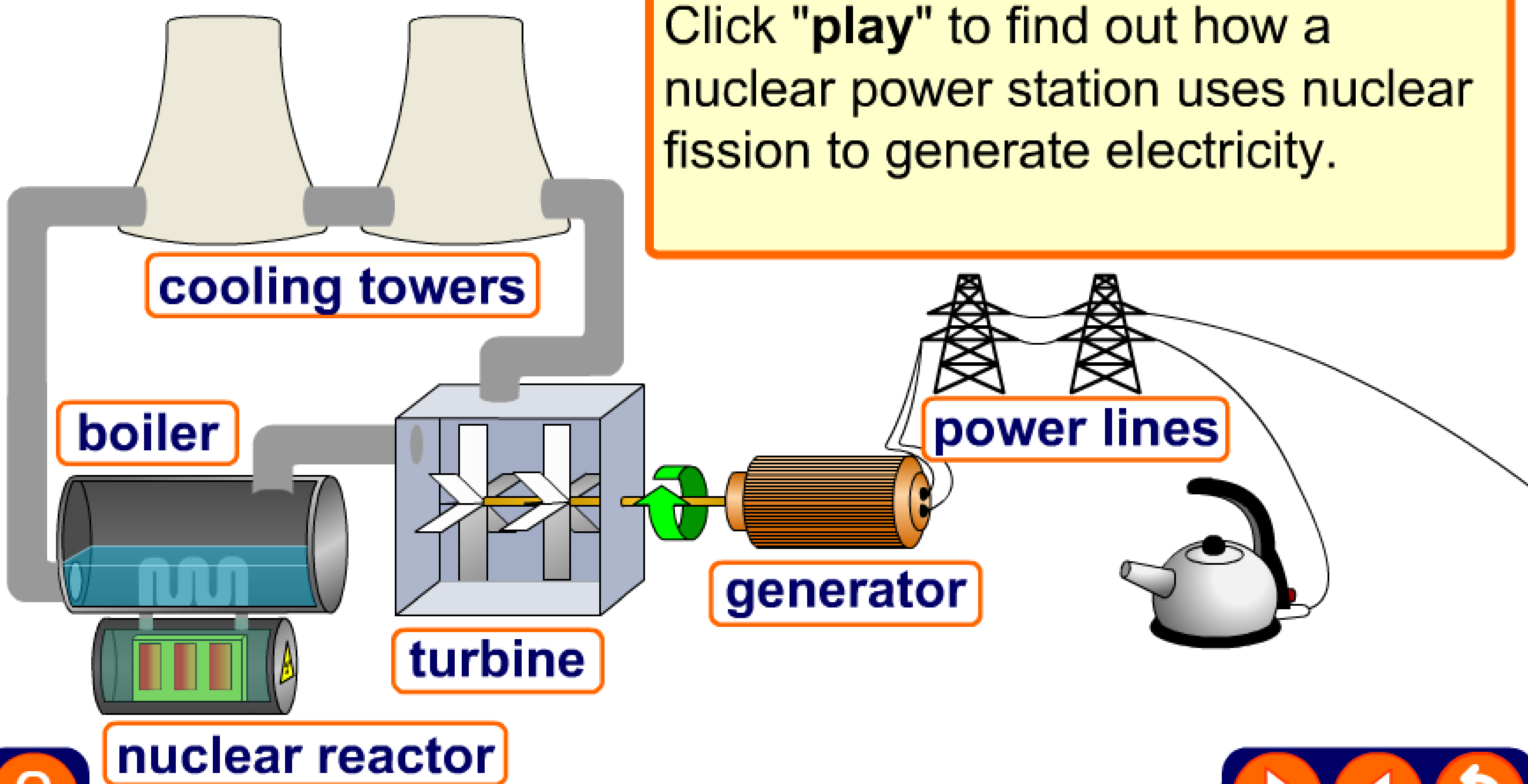
However, the particles after decay have slightly less mass than the particles before decay.

The mass that has been lost has turned into **energy**.

How does nuclear power work?

How is fission used in a nuclear power station?

Click "**play**" to find out how a nuclear power station uses nuclear fission to generate electricity.



What happens to the daughter nuclei?

Some of the daughter nuclei produced during nuclear fission are stable isotopes, but many are unstable and radioactive.

An example of an unstable daughter nucleus produced by nuclear fission is strontium-90.

Unstable daughter nuclei will decay into other radioactive isotopes.

The decay process continues until a stable isotope is formed.

This is called a **decay series**.

Strontium-90

↓ half-life = 28 years

Yttrium-90

↓ half-life = 64 hours

Zirconium-90 (stable)

Nuclear fission – true or false?