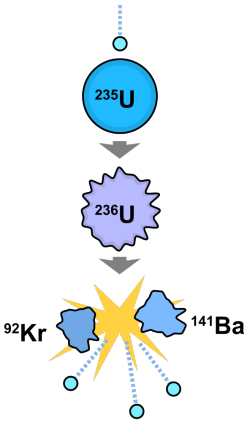
4.8.1 Nuclear fission

Nuclear fission is a term used for the process in which a large, unstable nuclei splits in two, releasing energy in the process. The energy released in the nuclear fission of uranium is the basis of electricity production in nuclear power stations.

videos

The induced fission of uranium-235



Uranium-235 is the 'fuel' used in most nuclear power stations. Unlike conventional fuels, the uranium-235 is not burnt, but split.

(1) The atomic number of uranium is 92. How many protons, and neutrons does a nucleus of uraniu-235 have?

When a uranium-235 nucleus is hit by a slow-moving neutron, it can capture the neutron to become uranium-236, which is unstable. Uranium-236 splits ('fissions') into two roughly equal pieces and 3 fast moving neutrons. The process leads to a large release of energy.

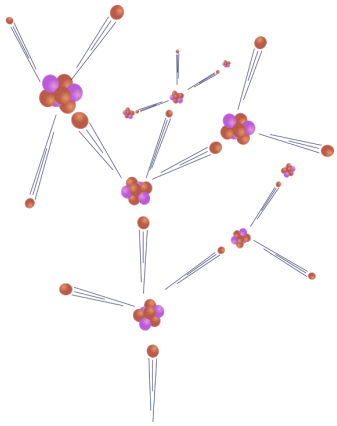
(2) What store of energy do the fast-moving products of the reaction have?

If the mass of all bits produced by nuclear fission is added up, it is found to be less than the start mass of the uranium-235 plus the neutron. Some of the mass has been transformed into energy according to the formula:

$$\Delta E = \Delta m c^2$$

where $\Delta E = energy\ released, \Delta m = loss\ in\ mass, c = speed\ of\ light\ (= 3 \times 10^8 m/s)$

(3) How much energy would be released if 0.001kg was converted to energy? (Hint: Use the equation, above with 0.001 for the mass.)

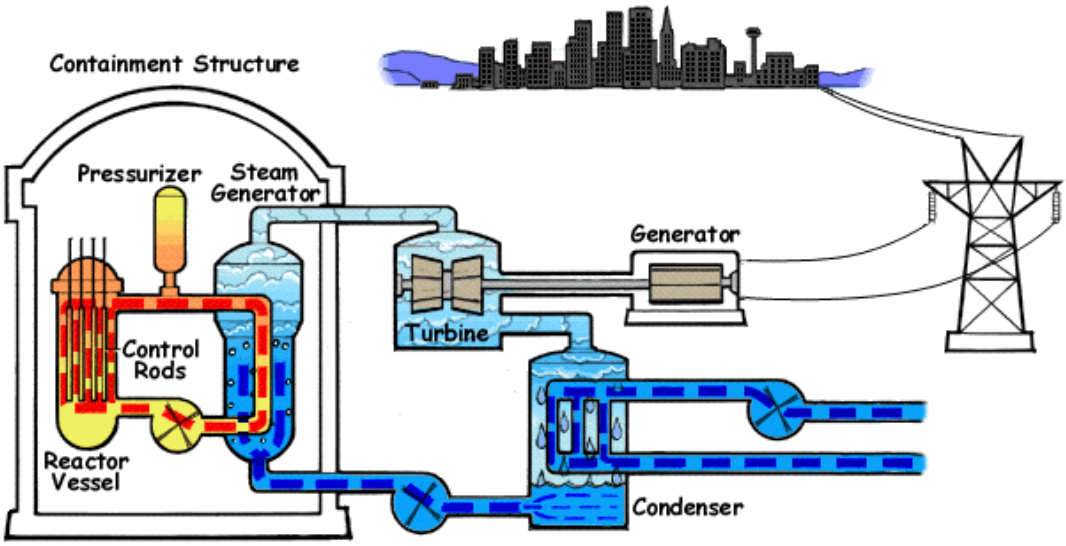


If uranium-235 nuclei are packed together in sufficient concentration, the released neutrons can hit other uranium-235 atoms and cause them to fission. This is called a chain reaction. However, fission only happens if the neutrons are moving slowly. A 'moderator' (often water) is used to slow the neutrons down.

In a nuclear power station, the chain reaction is controlled using 'control rods'. These rods absorb neutrons. When they are lowered into the reactor, remove neutrons and reduce the rate of the reaction.

A pressurized water reactor (PWR)

Below is a diagram of a PWR. As the name indicates, it uses water under pressure as a coolant and as a moderator. The section outside the containment structure outside is the same as a conventional fuel burning power station. Steam is used to turn a generator, which in turn turns a generator. The steam is then



condensed back into water and reused.

Use information from the link to answer the following questions:
https://energyeducation.ca/encyclopedia/Pressurized_water_reactor

(4) What does the moderator do and why is it necessary?

(5) The water can reach a temperature of 325°C *after passing through the reactor. Why doesn't it turn to steam?*

(6) What are the control rods made out of, and how do they control the reaction rate?

(7) What is 'enriched' uranium? What percentage of uranium-235 is needed for a pressurised water reactor?

(8) Why do you think there are separate water systems for cooling and for steam generation?

(9) Why do power stations need to be located near to a source of water (i.e. lake, river, sea)?