WJEC (Wales) Physics GCSE

2.9: Nuclear Decay & Nuclear Energy

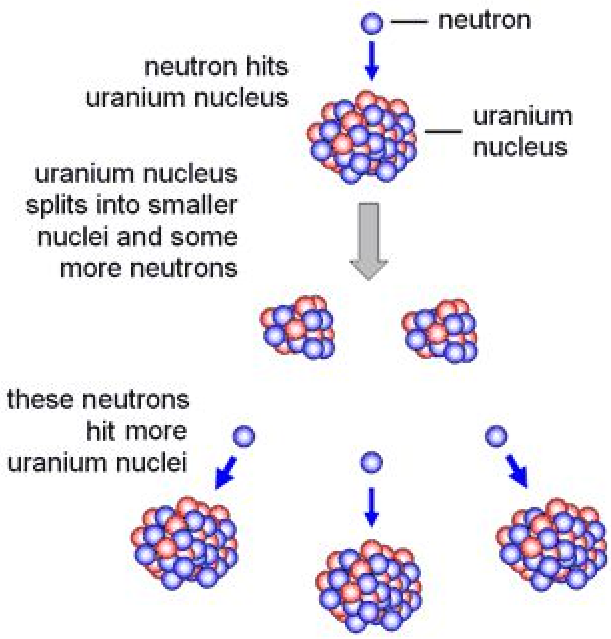
Detailed Notes

(Content in **bold** is for higher tier **only**)

Nuclear Fission

Nuclear reactors use the process of **nuclear fission** to generate **electricity**. Fission is the process of **splitting** a fissile nucleus after the **absorption** of a **slow neutron**. This makes the nucleus **unstable** so it splits apart into **two smaller nuclei**, also releasing two or three neutrons as well as a lot of energy.

The neutrons released are subsequently absorbed by other nuclei causing their splitting into smaller nuclei as well as the expulsion of another two or three neutrons. Hence a **chain reaction** is established.



Chain nuclear reaction of uranium-235 (bbc.co.uk).

Uranium-235 and **Plutonium** are the most commonly used in fission reactors as they have **large** nuclei which are **easily split**. The chain reaction, created in these materials, has to be **controlled** in nuclear reactors to prevent it becoming out of control and thus dangerous.

Nuclear fission equations can be written using $_0^1n$ as the symbol for a neutron. These equations need to be balanced.

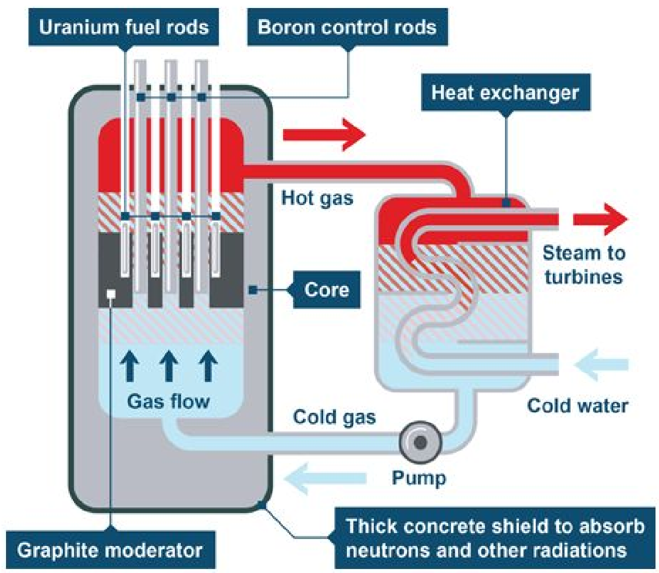
$$ {}_{92}^{235}U + {}_{0}^{1}n \longrightarrow {}_{56}^{144}Ba + {}_{36}^{89}Kr + energy $$

Generating Power

The heat energy released from the nuclear fission reactions is used to **boil water** and **generate steam**. The steam is then used to **drive a turbine** to generate **electricity**. All components are sealed inside a reactor with **steel lined concrete walls**. This prevents ionising radiation from escaping the reactor, reducing the public from being exposed to this potentially cancer-inducing radiation.

Controlling Reactions

To prevent the chain reaction becoming too large, like those in nuclear weapons, **control features** have to be implemented. **Control rods** and a **moderator** are used to control the rate of the reaction occurring in the reactor, by changing how much of the nuclear material is exposed. **Water** is typically used, as it may act as both a **moderator and a coolant**.



Inside components of a nuclear fission reactor (fity.club).

Graphite or boron are usually the materials used in **control rods**, which absorb excess radiation. They ensure that the number of neutrons in the reactor is low enough that a **sustainable reaction** is maintained. The **lower** down they are moved down into the reactor, the **more neutrons** they absorb so the **slower** the reaction is.

Once used, the control rods can **remain radioactive** for a very long time so have to be disposed of very carefully as **high level radioactive waste**.

Containing the Reactor

Nuclear reactors are **contained** within a **pressurised steel container** inside a **concrete building**. This containment building is built around the nuclear reactor and is designed to make sure that the radioactive material is **confined** under all conditions. It also **shields** the outside world from **penetrative gamma radiation**, which is released in abundance during fission chain reactions.

Nuclear Fusion

Lighter elements can undergo **nuclear fusion** to produce **heavier** elements. Only elements lighter than iron can fuse, however the main element to undergo fusion is **hydrogen**.

Nuclei are **positively charged** so would ordinarily **repel** each other at close proximities, however if they are **moving very fast**, they can **overcome** this electrostatic repulsion and **collide**. This collision releases a lot of **energy**. **High energy collisions** that result in fusion are more likely under **very hot conditions** where molecules move very **quickly**.

Hydrogen Fusion

Nuclear fusion is a process that takes place in stars, such as the Sun. Most of the fusion taking place in stars is between **hydrogen** nuclei to form **helium** nuclei. The two hydrogen nuclei: **hydrogen** and **deuterium** ($H\text{-}2$) fuse to form a **helium-3** nucleus.

This fusion reaction can be written as an equation and balanced.

$$ {}_{1}^{1}H + {}_{2}^{2}H \longrightarrow {}_{2}^{3}He + energy $$

Fusion Reactors

Nuclear fusion requires **very high temperatures and pressures**. These conditions are very **hard to recreate** in a reactor, especially for prolonged periods of time. Consequently, it is currently near impossible to use nuclear fusion as an energy source. Although, several reactors are being developed where **deuterium** ($H\text{-}2$) and **tritium** ($H\text{-}3$) nuclei are **accelerated** and **collided** to produce **helium** (${}_{2}^{4}He$) and a **neutron**.

$$ {}_{1}^{2}H + {}_{1}^{3}H \longrightarrow {}_{2}^{4}He + {}_{0}^{1}n + energy $$

This **excess neutron** can make the products of such a reaction **radioactive**, meaning a lot of **safety precautions** have to be taken around the reactor. At present, these reactors also require far more energy to run than is generated in the reaction. As a result, nuclear fusion is **not yet viable** as a sustainable energy generation method.