VTH BOOK - NUCLEAR POWER REVISION NOTES

Nuclear Power - the future?

- UK - approx 28% electricity from Nuclear Power (Fission).
- Political hotbed. Build more nuclear power stations - yes or no?
- Coal, oil and gas running out.
- Britain has saved 20,000 tonnes of Uranium
  - how long will it last?
  - Not very efficient at present - only 0.7% is the fissionable U-235. (7 in 1000 atoms).
  - 1976 Dounraey, Scotland - FAST BREEDER REACTOR powered on PLUTONIUM - by product of U-235 fission.

PLUTONIUM

- Element 94 in the periodic table - does not occur naturally in any significant quantities.
- Created in Nuclear reactor when U-238 absorbs neutrons. U-239 decays to Np-239, which decay to Pu-239, taking approx 2.35 days.
- Plutonium can the be seperated from the Uranium as it has different chemical properties.
- Can be used:
  - in fast breeder reactor to create energy [CONTROLLED FISSION].
  - to manufacture nuclear weapons [UNCONTROLLED FISSION].
    - ↳ 1x tennis ball size lump of Pu-239 could flatten a town.

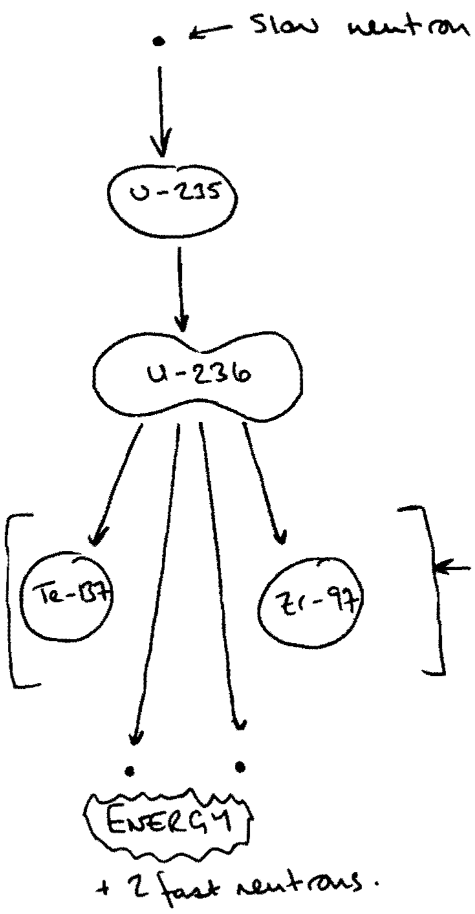
NUCLEAR FUSION

- Sun's energy is produced from the fusing together of hydrogen nuclei.
- FUSING means 'melting together'.
- At the centre of the Sun the temperature is about 15,000,000 K - at these temperatures the nuclei of atoms are stripped of all their electrons and are moving very quickly.
- FUSION involves two small nuclei colliding and sticking together to form a large nucleus - the fusion of two small nuclei's releases a lot of energy.
- At present - scientists are trying to develop an efficient way to reproduce FUSION and harness the energy for use commercially.

THE NUCLEAR DEBATE - See daytime notes.

<u>NUCLEAR FISSION</u>

- nuclei of some large atoms are unstable ⇒ lose alpha and beta particles to become more stable.
- Some heavy nuclei - eg. U235 - may increase their stability by <u>FISSION</u>
- Unlike α or β decay, which happens randomly, the fusion of a nucleus is caused by a neutron hitting it.



$$ {}^{1}_{0}n + {}^{235}_{92}U \rightarrow {}^{137}_{52}Te + {}^{97}_{40}Zr + 2\,{}^{1}_{0}n $$

<u>NB</u> there are a variety of different fission products that are possible.

<u>WHAT HAPPENS?</u>

- Slow moving neutrons collides with U-235 nucleus and is absorbed, creating a very unstable U-236 nucleus.
- U-236 is very unstable and splits into 2 daughter nuclei releasing several fast moving neutrons and a large amount of energy.
- The daughter nuclei and no. of neutrons released will vary → there are several different combinations that are possible.
- The daughter nuclei are usually radioactive and will decay by the emission of β particles to form more stable nuclei.

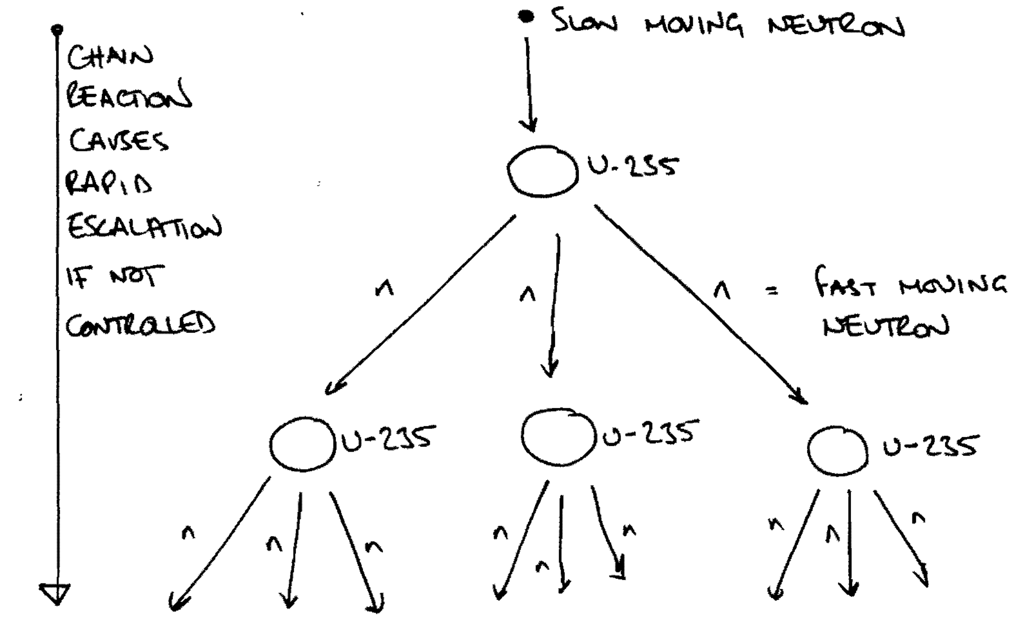
<u>FISSION ITSELF....</u>

- Releases a large amount of energy.
- The fission of a nucleus provides 40x more energy than the release of an alpha particle from a nucleus.

- Fission is important because we can control the rate at which it happens, such that we can use the energy released to create electrical energy.

CHAIN REACTION

- Once a nucleus has divided by fission, the emitted neutrons can strike other neighbouring nuclei causing a chain reaction.



- What is the difference between the initiating neutron and the ones created by fission? The initiating neutron is slow moving. Slow moving neutrons are more likely to trigger fission of U-235. Accordingly, a MODERATOR is used to slow down the fast moving neutrons released by fission in order to allow the chain reaction to develop.
- To control the rate of reaction, CONTROL RODS are used. Control rods absorb the neutrons, preventing them from being absorbed by the U-235.

WHERE DOES THE ENERGY IN NUCLEAR FISSION COME FROM?

- "As mass disappears, energy is created." A simplified statement of Einstein's Theory of Special Relativity $[E = mc^2]$
- The example we shall look at is:

$$^{1}_{0}n + ^{235}_{92}U \rightarrow ^{137}_{52}Te + ^{97}_{40}Zr + 2\,^{1}_{0}n \qquad (1)$$

- We will analyse the mass on both the left hand side [LHS] and the right hand side [RHS] of the above eqn.

ISOTOPE	MASS IN u
$^{235}_{92}U$	235.048
$^{92}_{137}Te$	136.918
$^{97}_{40}Zr$	96.966
$^{1}_{0}n$	1.008

Note
- $1u = 1.66 \times 10^{-27}$ kg
- In the equation the proton and mass numbers balance. However, on close inspection of the mass in u, we see that they are very slightly different.
- $1u = \frac{1}{12}^{th}$ the mass of a carbon atom.

- So, inserting into the eqn 1

$$LHS = {}^{1}_{0}n + {}^{235}_{92}U$$

$$= 1.008 + 235.048 = \underline{236.056u}$$

$$RHS = {}^{137}_{52}Te + {}^{97}_{40}Zr + 2\,{}^{1}_{0}n$$

$$= 136.918 + 96.966 + 2(1.008) = \underline{235.84u}$$

mass is lost in the reaction.

$\Delta m = 0.216u$.

The lost mass is turned into the k.E of the fission fragments

$$E = mc^2$$

$$E = 0.216 \times 1.66 \times 10^{-27} \times (3 \times 10^8)^2 = \underline{\underline{3.2 \times 10^{-11} J}}$$

NUCLEAR POWER STATIONS

- Several different types have been developed:
  - GAS COOLED NUCLEAR REACTOR - moderator is graphite, control rods BORON. Design of the first British Magnox Reactor.
  - BRITISH ADVANCED GAS COOLED REACTOR - CO_2 used as the moderator.
  - PRESSURISED WATER REACTOR - use water as both the coolant and moderator.

BASIC SYSTEM FUNCTION [Gas Cooled Nuclear Reactor]

- Energy released by the fission processes in the uranium fuel rods produces a lot of heat energy
- Heat is carried away by CO_2 gas which is pumped around the reactor.

- hot CO_2 gas used to produce superheated steam in the gas heat exchanger which then goes onto drive the turbines.
- From turbines onwards, it is the same process of electricity generation as a coal powered power station.

KEY TERMINOLOGY

- Fuel rods
  - made of U-238, enriched to about 2-4% U-235.
  - U-238 is the most common isotope, but only U235 will produce fission.
  - U-238 will absorb neutrons and decay to Pu-239 (by-product of U-235 fission).

- MODERATOR
  - fuel rods are embedded in graphite - the moderator.
  - Purpose of moderator is to slow down neutrons which are produced in fission.
  - A U-235 nucleus is split more easily by a slow moving neutron.
  - The fuel rods are long and thin so the high speed neutrons can escape to collide with the moderator.
  - In turn, the neutrons will then trigger a reaction in a neighbouring fuel rod.

- BORON CONTROL RODS
  - The rate of production of energy in the reactor is carefully regulated by the BORON CONTROL RODS.
  - Boron absorbs neutrons well, so by being lowered into the reactor, the reaction can be slowed.
  - In a emergency, they are pushed right into the reactor core, and the chain reaction stops completely.