Fission and fusion

To know what occurs in nuclear fission and nuclear fusion processes
To know what a chain reaction is, how it occurs and what critical mass is
To be able to state and explain whether fission or fusion will occur

Nuclear Fission

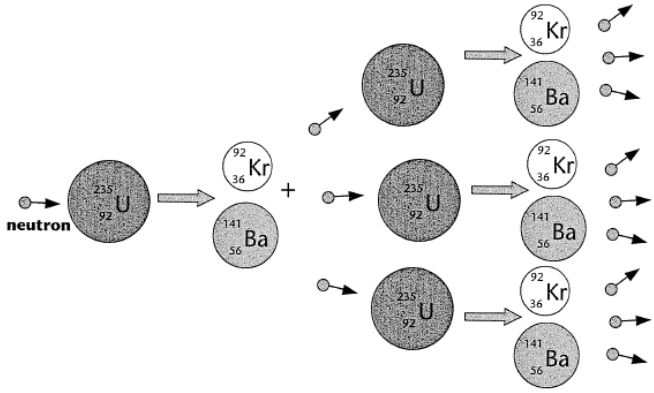
Fission occurs when a nucleus splits into two smaller nuclei

We make fission happen by firing slow moving neutrons at Uranium 235, Plutonium 239 or Thorium 232 nuclei. We call this *induced fission*. In this processes the nucleus absorbs a neutron then splits to form two lighter nuclei, releases energy and any neutrons left over, usually 2 or 3.
Here is a possible equation for the fission of Uranium 235:

$$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{144}_{56}Ba + ^{90}_{36}Kr + 2^{1}_{0}n + energy released, E$$

Chain Reaction

In the above reaction two free neutrons were released, these can also be absorbed by two heavy nuclei and cause a fission process. These nuclei would release more neutrons which could cause further fissions and so on.



Critical Mass

For a chain reaction to happen the mass of the fissionable material must be greater than a certain minimum value. This minimum value is known as the *critical mass* and is when the surface area to mass ratio is too small.

If mass < critical mass: more neutrons are escaping than are produced. Stops
If mass = critical mass: number of neutrons escaping = number of neutrons produced. Steady
If mass > critical mass: more neutrons are produced than are escaping. Meltdown

Nuclear Fusion

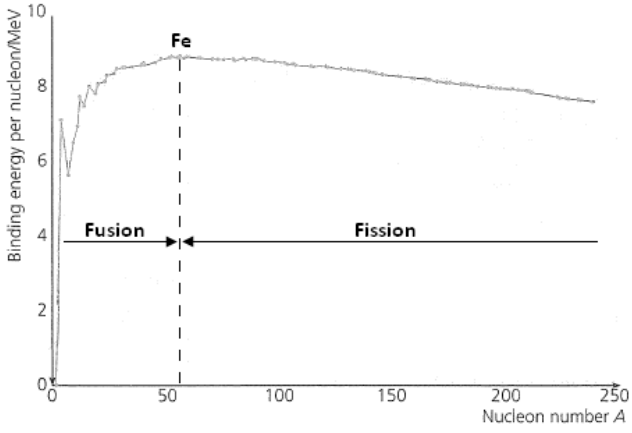
Fusion occurs when two nuclei join to form a bigger nucleus

The two nuclei must have very high energies to be moving fast enough to overcome the electrostatic repulsion of the protons then, when close enough, the strong nuclear force will pull the two nuclei together.
Here is an example of the fusing of two hydrogen isotopes:

$$^{2}_{1}H + ^{3}_{1}H \rightarrow ^{4}_{2}He + ^{1}_{0}n + energy released, E$$

Which Will Happen?

Looking at the graph we can see the Iron 56 has the highest binding energy per nucleon, the most energy required to remove one proton or neutron from the nucleus. This makes it the most stable.



Nuclei lighter than Iron will undergo fusion.
Protons and neutrons feel the attraction of the strong nuclear force but only protons feel the repulsion of the electrostatic force. For light nuclei, adding an extra proton increases the strong nuclear force to pull the nucleon together. This is because at this range the s.n.f. force is stronger than the other three fundamental forces.
The nucleons move closer together → potential energy is lost → energy is given out

Nuclei heavier than Iron will undergo fission.

Beyond Iron, each proton that is added to the nuclei adds to the electrostatic repulsion. The bigger the nucleus become the less the outer protons feel the strong nuclear force from the other side. We can see the binding energy per nucleon decrease for heavier nuclei.
A big nucleus will break into two smaller nuclei, each being stronger bonded together due to the smaller size. The nucleons move closer together → potential energy is lost → energy is given out.