Fission of \(^{235}\text{U}\)

Neither \(^{235}\text{U}\) nor \(^{238}\text{U}\) fission spontaneously.

Extra energy is necessary to surmount the Coulomb barrier.

Neutron-induced fission

Although \(^{235}\text{U}\) does not fission spontaneously, if a neutron, even a slow (thermal) neutron, interacts with it, fission does take place.

This is what happens in neutron-induced fission.

The first step is that a neutron interacts with a \(^{235}\text{U}\) nucleus to produce the compound nucleus \(^{236}\text{U}^*\)

In the case of a thermal neutron the excitation energy of the \(^{236}\text{U}^*\) is just the binding energy of the last neutron (+ \(\sim 0.025\text{eV}\) which is negligible)
Neutron-induced fission

Exercise 28.

1. If the binding energy of the last neutron in $^{236}\text{U}$ is 6.55 MeV, what is the excitation energy of the compound nucleus after it absorbs a thermal (slow) neutron (the average thermal energy is 0.025 eV).

2. What is its excitation energy after it absorbs a fast neutron, say with an energy of 2 MeV?

Fission in $^{235}\text{U}$ with a slow neutron.

The 6.5 MeV binding energy of the neutron in $^{236}\text{U}$ excites the compound nucleus - it distorts - first scission and finally fission occurs.
Neutron-induced fission

There are three naturally occurring isotopes of the element uranium. The two that are important as reactor fuels are $^{235}$U and $^{238}$U.

The natural abundance of $^{238}$U is 99.28%
The natural abundance of $^{235}$U is 0.72%

We have seen above that $^{235}$U fissions with slow neutrons. What happens in the case of $^{238}$U?

If a neutron interacts with $^{238}$U we would get the compound nucleus $^{239}$U$^*$. It turns out that the binding energy of the last neutron in $^{239}$U is only 4.8062 MeV (Compared with 6.5452 MeV in the case of $^{236}$U).

This is not enough for the compound nucleus to overcome the fission barrier.

Reaction of $^{238}$U with a slow neutron.

$^{238}$U + n - fission does not occur with a slow neutron.

$^{238}$U + n (slow, i.e. its energy is negligible) $\rightarrow$ $^{239}$U$^*$ (compound nucleus) $\rightarrow$ $^{239}$U excited - excitation energy 4.8 MeV. $^{239}$U$^*$ de-excites by emitting a gamma-ray.

Radioactive $^{239}$U undergoes a $\beta$ decay.

The 4.8 MeV binding energy of the neutron in $^{239}$U is not sufficient to overcome the fission barrier - we get radiative capture: $^{238}$U(n,γ)$^{239}$U.
**Neutron-induced fission**

Reaction of $^{238}$U with a *fast* neutron.

$^{238}$U + n - fission *does* occur when the neutron is *fast*.

- $^{238}$U + n
- $^{238}$U compound nucleus with sufficient energy to overcome the fission barrier.
- Various fission products
- Fission neutrons
- $^{239}$U excited - excitation energy 4.8 MeV plus the (kinetic) energy of the neutron.

The 4.8 MeV binding energy of the neutron in $^{239}$U together with the energy (kinetic energy) of the incoming fast neutron excites the compound nucleus - it distorts - scission and finally fission occurs.

**The Liquid Drop Model and Fission**

**Exercise 29**

*Fission and the Coulomb barrier*

1. Discuss why $^{235}$U fissions with thermal neutrons, while $^{238}$U will only fission if the neutrons are fast (with energies of several MeV).

Do not take more than a page to do this.