## 2.7 Natural uranium reactors

A useful and appropriate starting point for the discussion of nuclear reactors is to consider the state of naturally-occurring uranium. As noted earlier the most common isotope is $^{238}U$ and the fission cross-section for $^{238}U$ has the form shown in figure 1. Thus only high energy or *fast neutrons* with energies greater than

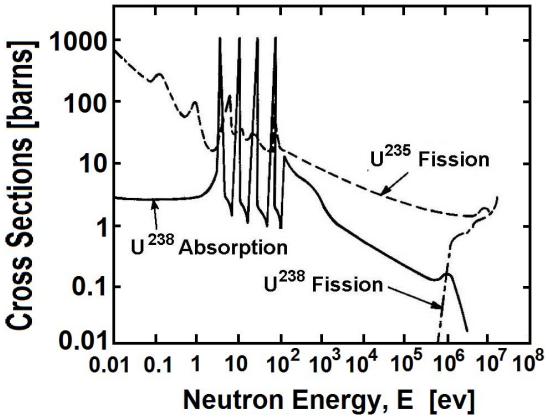


Figure 1: Qualitative representations of how the fission cross-sections for $^{235}U$ and $^{238}U$ as well as the absorption cross-section for $^{238}U$ vary with the neutron energy.

about 2 $MeV$ can cause fission of $^{238}U$. However, the absorption and scattering cross-sections are much larger and therefore any population of neutrons in $^{238}U$ rapidly declines; such a *reactor* is very subcritical.

Now consider a naturally-occurring mixture of $^{238}U$ and $^{235}U$. As previously stated and illustrated in figure 1, the "fissile" isotope $^{235}U$ can be fissioned even with low energy neutrons and therefore the presence of the $^{235}U$ causes an increase in the reactivity of the mixture. However, the high absorption cross-section of the "fertile" isotope $^{238}U$ still means that the reactivity of the mixture is negative. Thus no chain reaction is possible in natural uranium. One can visualize that if it were possible then this would have happened at some earlier time in the earth's evolution and that no such unstable states or mixtures could be left today. Such has also been the fate of higher atomic weight elements that may have been produced during nuclear activity in the past.

There are several different ways in which the naturally-occurring uranium mixture might be modified in order to produce a critical or supercritical chain reaction in which the neutron population is maintained. One obvious way is to create a mixture with a higher content of $^{235}U$ than occurs naturally. This is called enriched uranium and requires a process of separating $^{238}U$ and $^{235}U$ in order to generate the enriched mixture. Since $^{238}U$ and $^{235}U$ are almost identical chemically and physically, separation is a difficult and laborious process, the main hurdle during the Manhattan project.