The Cross-Section

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The Cross-Section

Say that you have a beam of particles.

It is incident on some material.

How many nuclear reactions will take place per unit time?

To calculate this you have to know the *intensity of the beam*, the *number of nuclei that the beam could interact with* and the *cross section* for the particular nuclear reaction.

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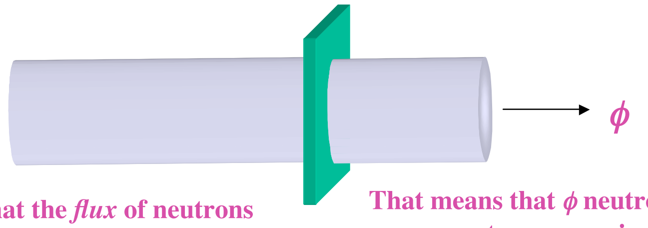
The Cross-Section

Lets start off by considering a beam of neutrons (say) that is incident on a thin block of material.



Say that the *flux* of neutrons in the beam is ϕ.

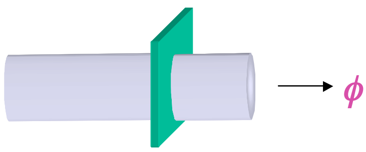
That means that ϕ neutrons per square meter are passing any section every second.

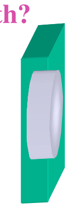
We wish to know the number of nuclear reactions taking place per second – the *reaction rate*.

To calculate this you have to know the *intensity of the beam* (the *flux*), the *number of nuclei that the beam could interact with* and the *cross section* for the particular nuclear reaction, as was mentioned before.

The Cross-Section

How many nuclei does the beam interact with?





Suppose that the beam has area A and the thickness of the block is d.

Then the beam interacts with a volume $V = Ad$ of the material.

If the block contains n atoms per unit volume, then the beam interacts with nAd nuclei.

If each nucleus has an *effective area*, σ for interaction with the beam then the reaction rate is $\psi = \phi nAd\sigma$.

Sigma, σ, is the *cross-section*.

The Cross-Section

The cross-section is a measure of the probability that a reaction will occur – expressed as an effective area presented to the beam of particles.

Each reaction has its own cross-section.

This characterises the way in which the particular nucleus interacts with a particular particle

Let's repeat it.

If the block contains *n* atoms per unit volume, then the beam interacts with *nAd* nuclei.

If each nucleus has an effective area, σ for interaction with the beam then the reaction rate is $\psi = \phi n A d \sigma$.

The Cross-Section

The intensity of the beam is expressed as the *flux*.

The number of nuclei that the beam could interact with depends on the density of nuclei (atoms) in the material.

The cross-section expresses the probability that the reaction would take place and it is expressed as the effective area that the nucleus presents to the beam.

Exercise 19

1. Say that the the total cross-section for the reaction $^{197}Au(n,\gamma)^{198}Au$ is 93 barns, for *thermal* neutrons.

   In a particular irradiation position in the reactor SAFARI the thermal neutron flux is 3.0×10^{13} $n.cm^{-2}.s^{-1}$

   A gold foil with a mass of 100 mg is placed in this position.

   What is the reaction rate?

   How many reactions will have taken place after the foil has been in position for an hour?

$$A_v = 6.022 \times 10^{26} \text{ atoms per kilomole}$$

$$\rho_{Au} = 19.3 \times 10^{3} \text{ kg.m}^{-3}$$

Note.

Because of the structure of the nucleus, the cross-section can be very sensitive to the *energy* of the incoming particle.

This is particularly important in the operation of nuclear reactors where the behaviour of the *fission* and *capture* cross-sections with neutron energy is extremely important.

We will return to this later but first let's discuss *radioactivity*.