Nucleus is a very tiny object so, the vast space inside an atom is empty. So, when an incident particle is bombarded to a target nucleus, vast majority of incident particles penetrates through the empty space of the material and only a few amounts of incident particles actually interact with the target nucleus and lead to some kind of nuclear reaction. Now is it possible to count how many particles will actually interact with the target nucleus?

So, nuclear cross section is simply defined as an area around the nucleus on which if particles incident, it will most definitely lead to an interaction with the nucleus and all the other incident particles outside this area will penetrate through without interacting with nucleus. Nuclear cross section depends upon variety of factors, first of all it depends upon the kind of incident particles. If incident particle is proton, it will repel nucleus and move away. Because proton is positively charged so is the nucleus. It is very difficult to induce a reaction between protons and nucleus. Therefore, this cross-section area corresponding to incident proton will be very less. Let’s take the case of neutrons, if the incident particles had neutrons in them, neutrons are uncharged so, they are not repelled by nucleus. So, the vast majority of neutrons which come near a nucleus will obviously interact. So, the cross-section area corresponding to neutron will be greater. It also depends upon the energy of the incident particles. If the velocity of the incident neutron is very high, it will penetrate through the material without interacting with target nucleus. If we take a low velocity neutron or thermal neutron, which has a higher D Broglie wavelength has more probability of interacting with the target nucleus.

So, we can define nuclear cross-section also known as interaction cross-section is that area around the nucleus facing the incident particles, within which the incident particles will lead to an interaction with the nucleus.

The greater is nuclear cross-section, more is the likelihood of interaction and more is the likelihood of nuclear reaction. This area can be greater than the actual size of the nucleus or it could be equal to the actual size of the nucleus based upon the nature of the nuclear reaction.

Nuclear cross-section has a unit called barn. 1 barn= 10-28m2=100 fm.

Now we have to find out how many incident particles will interact with target nucleus. Let’s take, certain kinds of incident particles which are incident to some sort of a material. We have taken a rectangular slab of that material which contains the target nucleus.

The area of cross-section facing upon the incident particles is ‘A’. let’s take a very small section of this particular rectangular slab having thickness of ‘dx’. The number of incident particles is given by ‘N’ (N0 is for initial particles and Nx is for final particles). The number of incident particle which survive at a distance of ‘x’ and after penetrating through a distance of ‘dx’, the quantity of incident particle will decrease and will become N(x)- dN. So, N(x) is a number of particles at a distance of ‘x’ and N(x)- dN is the number of incident particle at a distance of x+dx. dN is the number of interactions and also can be defined as the decrease in number of incident particles. N(x)- dN represent a number of particles which actually survives.

To calculate how many interactions will take place, we need to know how much target nuclei exists within this small slice. Let’s suppose the number density of the target nucleus within the small slice is basically given by ‘n’. ‘n’ is number of atoms per unit volume in this kind of a material. The number of target nucleus exists in this small slice can be found out by multiplying ‘n’ with the volume of the slab. Number of target nucleus in ‘dx’= n\*A\*dx. We also need to know, the amount of area corresponding to this number of nuclei within which incident particles will actually lead to an interaction. So, the amount of nuclear cross section corresponding to this many number of nuclei is n\*A\*dx\*σ. The actual area facing the incident particles is ‘A’. but what is the amount of area available for interaction?

No. of interactions/total number of incident particles = total nuclear cross-section/area of cross-section of slab.

dN/N= n\*A\*dx\*σ/A

dN/N= n\*dx\* σ

after integration from (x=0 to x) we get,

N(x)= N0e-nσx

So, this represents an exponential decay or exponential decrease in the number of incident particles as it penetrates through some kind of a material medium. Here the surviving number of particles is given by N and N0 is the incident particles. The exponential decay depends largely on σ. Sigma (σ)represents the nuclear cross-section.It also depends on ‘n’, number density. In a denser material the decrease is going to happen sharply. In a less dense material the decrease happens slowly. So, as a summary, this expression will tell us how many particles will actually survive and how many of them will lead interaction with nucleus.

Now, let’s suppose the rate of a nuclear reaction is given by ΔN/Δt. Here, ΔN simply represents the number of interactions that take place when the incident particles penetrate through some distance and Δt simply represents per unit time.

Now, we get reaction rate from this. Reaction rate = N0 -N/ Δt. We can simplify this to, (N0 - N0e-nσx)/ Δt, again, N0/ Δt (1- e-nσx)

We can make here some assumptions under different situations.