UNIT III

Interaction of radiation with matter lipids

Interaction of Neutrons with matter

- Because neutrons are neutral particles, their interactions in the absorber differ from those of the charged particles.
- They interact primarily with the nucleus of the absorber atom and very little with the orbital electrons.
- The way in which neutrons interact with matter depends to a large extent on their energies, which can range from hundreds of MeV down to fractions of an eV
- The nuclear force , which leads to these interactions, is very short ranged whichmeans the neutrons have to pass close to a nucleus for an interaction to take place.
- Because of the small size of the nucleus in relation to the atom as a whole, the neutrons will have a low probability of interaction, and could thus travel considerable distances in matter.
- The neutrons can interact with the atomic nuclei in one of the following ways:

➢ Spallation reaction

➢ Elastic scattering

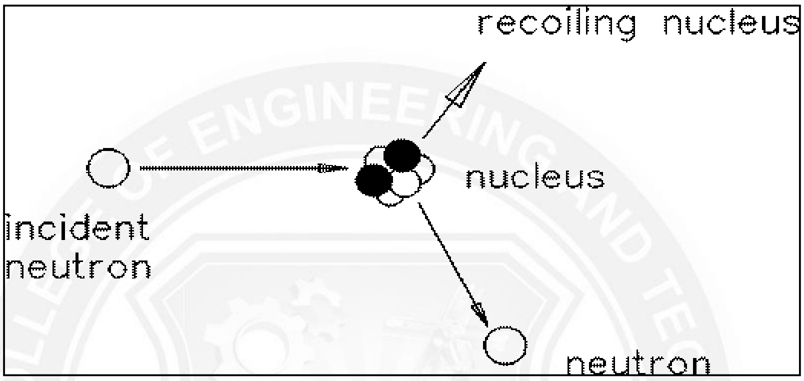
➢ Inelastic scattering

➢ Transmutation

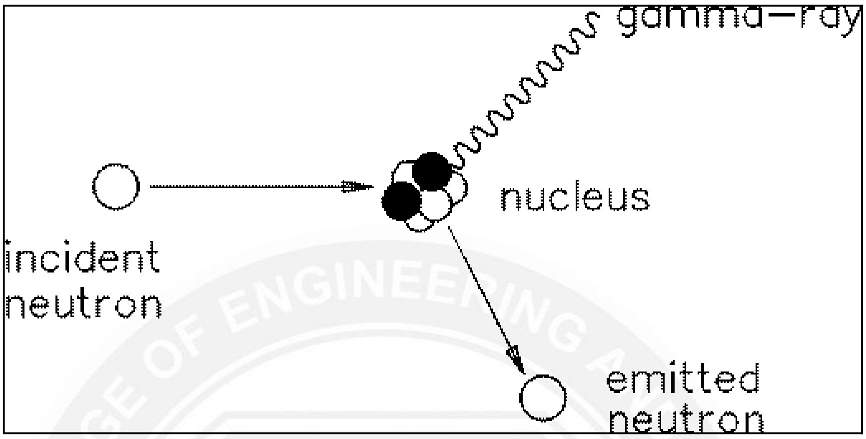
➢ Radiative capture.

- **Spallation reaction**: At very high energies (over 150 MeV) neutrons may strike a nucleus producing a shower of secondary particles. These high energy secondary particles would be very harmful to anyone exposed to them
- If the sum of the kinetic energies of the neutron and the nucleus before collision is equal to the sum of these quantities after collision, then the interaction is called**elastic**.
- This is analogous to a billiard ball type of collision. The neutron collides with anucleus and rebounds in a different direction.
- The energy the neutron loses is gained by the target nucleus which moves away at anincreased speed.

- If the neutron collides with a massive nucleus it rebounds with almost the same speedand loses very little energy.
- Light nuclei, on the other hand, will gain a lot of energy from such a collision and willtherefore be more effective for slowing down neutrons.



- If a part of the initial energy is used for the excitation of the struck nucleus, the collision is termed **inelastic**.
- A neutron may strike a nucleus and form a compound nucleus instead of bouncing off as in elastic scattering.
- This nucleus is unstable and emits a neutron of lower energy together with a gamma photon which takes up the remaining energy. This process is called **inelastic scattering**.
- It is most effective at high neutron energies in heavy materials, but at lower energies (a few MeV) elastic scattering becomes a more important reaction for energy loss provided there are light nuclei present.



- When neutrons, protons , or other secondary particles produced by spallation strike a nucleus and form a compound nucleus which then ejects a different particle, a **transmutation** is said to have occurred.
- This is because the target nucleus is changed from one element to another. These nuclear reactions are most likely to occur when the energy of the incident particle is between a few MeV and several tens of MeV.
- An example is the neutron-proton (n,p) reaction with oxygen can be given as: ^{16}O captures a high energy neutron and emits a proton to form N. The product, N is radioactive with a half-life of 7.2 seconds; it is a beta emitter and also emits very hard gamma-rays which

$$^{16}_{8}O(n,p)^{16}_{7}N$$

have energies of 6 or 7 MeV

- In addition to (n,p) reactions, many other reactions are possible such as (p,n), (p,2n), (n,2n) and (n, α). Most of these reactions result in nuclei which are deficient in neutrons and therefore decay by positron emission or electron capture.
- The (n, α) reaction in boron is an important reaction which is used for the detection ofslow neutrons . Slow neutrons are captured by Boron causes the following reaction:

$$^{10}_{5}B + ^{1}_{0}n \Rightarrow ^{7}_{3}Li + \alpha$$

- **Radiative Capture:** This is one of the most common neutron reactions. The neutron is again captured by a nucleus which emits only a gamma photon. This reaction, which occurs in most materials, is the most important one for neutrons with very low energy. The product nuclei of (n, α) reactions are usually radioactive and are betaand gamma emitters.
- Two of the neutron capture reactions are the (n,γ) reaction in ^{59}Co, which is normal stablecobalt metal and quite commonly occurs in steel, to produce ^{60}Co , which is radioactive.
- The cobalt readily captures neutrons, and ^{60}Co has a half-life of about 5 years
- The other is the neutron capture in sodium (Na), which is normal and stable. In this casethe product is the radioisotope Na. Traces of sodium are present in the concrete shielding.