Classification of Neutrons

Thermal neutrons:

-Thermal neutrons are in approximate thermal equilibrium with their surroundings. Their energy distribution is given by the Maxwell-Boltzmann formula.

- The most probable energy at room temperature (20°C) is 0.025eV. The average energy is 0.038Ev

Fast neutrons: neutrons with energies above 0.1MeV.

Slow neutrons: neutrons with energies between those for thermal and fast neutrons.

Interactions of Neutrons with Matters

Attenuation of neutrons:

- Neutrons are uncharged and can travel appreciable distance in matter without interaction.
- Under conditions of "good geometry", a narrow beam of monoenergetic neutrons is attenuated exponentially

Neutrons can interact with a atomic nuclei through

- **Elastic scattering**: the total kinetic energy is conserved – the energy loss by the neutron is equal to the kinetic energy of the recoil nucleus.
- **Inelastic scattering**: the nucleus absorbs some energy internally and is left to an excited state.
- **(Thermal) neutron capture**: the neutron is captured or absorbed by a nucleus, The reaction changes the atomic number and/or atomic mass number of the struck nucleus.

-Hydrogen nucleus does not have excited state. Only elastic scattering and neutron capture is possible.

-The neutron cross section for carbon has considerable structuresn resultant from the combined effects of elastic, inelastic and capture process.

Elastic Scattering of Neutrons

Elastic scattering is the most important process for slowing down fast neutrons. Due to the rapid increase in the probability of neutron capture, the neutrons, once slowed down, will eventually be captured by target nuclei.

Elastic scattering plays an important role in neutron energy measurements. For example, a proton-neutron telescope illustrated below can be used to accurately measure the spectrum of neutrons in a collimated beam.

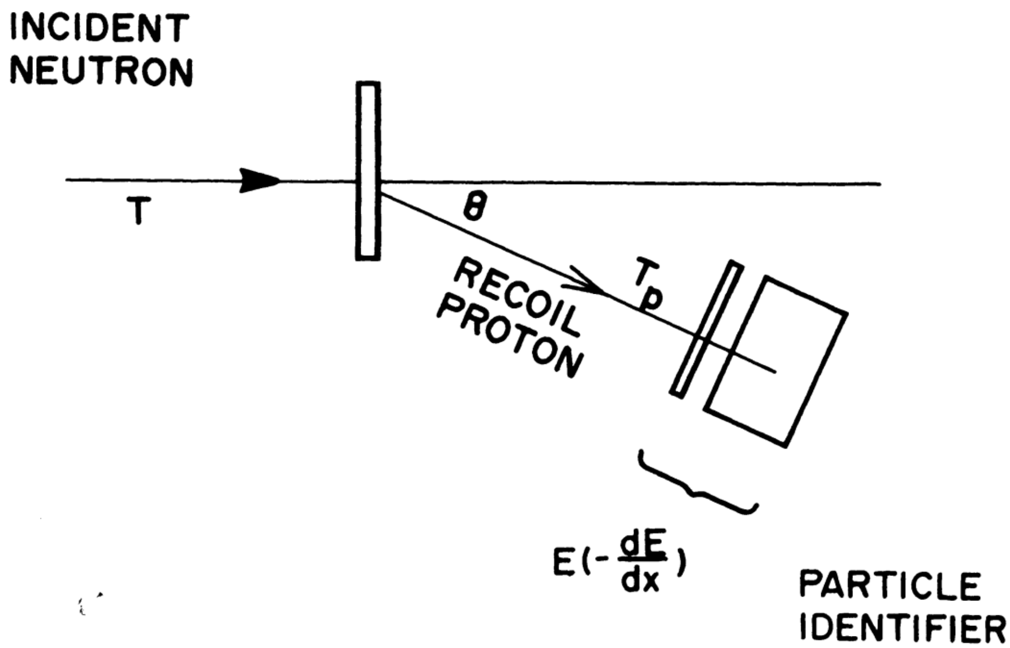

FIGURE 10.36. Arrangement of proton-recoil telescope for measuring spectrum neutron beam.

The **maximum energy** that a neutron of mass M and kinetic energy En can transfer to a nucleus of mass m in a single elastic collision given by

$E_{max}=E_n=4M_m/(M+m)^2$

Interaction of Slow Neutrons (E<0.5eV)

- Significant interactions include ***elastic scattering*** and ***neutron induced nuclear reactions***.

- Due to the low neutron energy, very little energy can be transferred by elastic scattering.

-The more significant effect of elastic scattering is to ***slow down*** slow neutrons and turn them into ***thermal neutrons*** (average E<0.025eV at room temperature).

- Neutron absorption followed by the immediate emission of a gamma ray photon and other particles

The most important interactions between slow neutrons and absorbing materials are ***neutron-induced reactions***, such as (n,g), (n,a), (n,p) and (n,fission) etc. These interactions lead to more prominent signatures for neutron detection.

Nuclear cross section

We define a cross section for reaction in the usual way:

$$\sigma = \frac{\text{number reactions/nucleus /second}}{\text{number incident particles/cm}^2 \text{ / second}}$$

σ clearly has units of area (cm^2)

For a Maxwell-Boltzmann distribution of reactant energies the average of the cross section times velocity is

$$\langle \sigma_{Ij} \mathrm{v} \rangle = \left(\frac{8}{\pi\mu} \right)^{1/2} \left(\frac{1}{kT} \right)^{3/2} \int_0^\infty \sigma_{Ij}(E)\, E\, e^{-E/kT}\, dE$$

where μ is the "reduced mass"

$$\mu = \frac{\mathrm{M_I m_j}}{\mathrm{M_I + m_j}}$$

for the reaction I (j, k) L

Center of mass system – that coordinate system in which the total initial momenta of the reactants is zero.

The energy implied by the motion of the center of mass is not available to cause reactions.

Replace mass by the "reduced mass"

$$\mu = \frac{\mathrm{M_1 M_2}}{\mathrm{M_1 + M_2}}$$

The Cross Section

$$\text{D} = \frac{h}{p} = \frac{1}{k}$$

How much I+j looks like the target nucleus with j sitting at its surface. Liklihood of staying inside R once you get there.

Area subtended by a Compton wavelength in the c/m system

$$\sigma(E) = \pi\lambda\!\!\!^{-2} \quad \rho P_l(E) \quad X(E, A)$$

geometry term

penetration factor

nuclear structure

probability a flux of particles with energy E at infinity will reach the nuclear surface. Must account for charges and QM reflection