Interaction Between
Ionizing Radiation And Matter, Part 3
Neutrons

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Neutrons

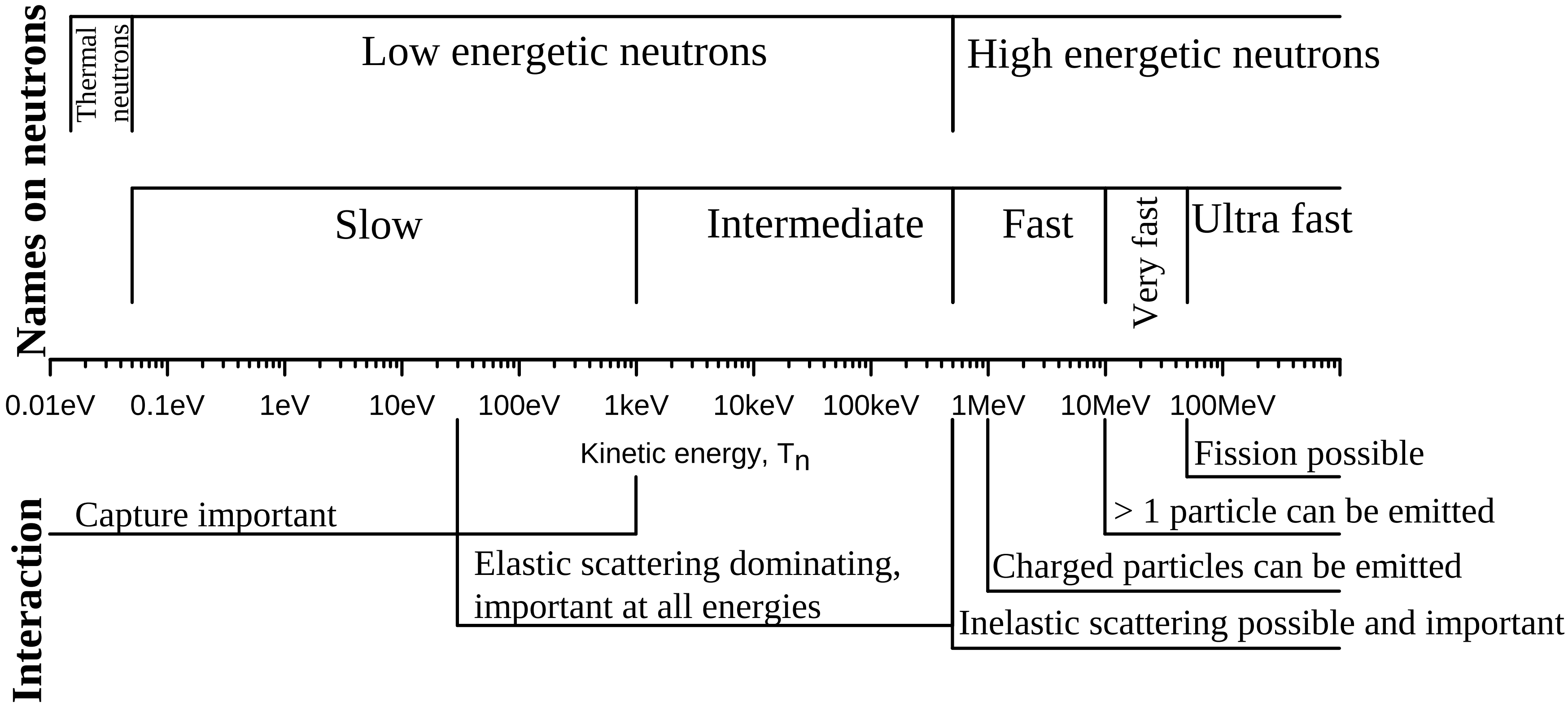
- Uncharged particles; mass close to that of protons
- Unstable as free particle; disintegration to a proton, an electron and an antineutrino ($t_{1/2}$=12 min)
- Do not interact with electrons
- Only nuclear interactions; complicated relations
- Similar to photons; energy attenuation can roughly visualized with the same formalism

Neutron interactions

- Basically two types of interaction:
  - elastic scattering against the nucleus
  - absorption processes (capture): unstable nucleus is created, deexcitation give emission of particles n (inelastic scattering), p, α, nucleus fragments

Neutron interactions(2)

- Cross section depend on:
  - Kinetically energy T_n
  - Nucleus structure



Low energy, $T_n < 500$ keV

- Potential (1) – and resonance(2) scattering
  1: scattered on the nucleus surface
  2: absorbed by the nucleus, but reemitted
  The nucleus are given kinetic energy
  Case (1): Cross section ~ Constant
- When slowing down: neutron captured by a nucleus, the compound nucleus deexcitation by
  γ-emission
  Cross section ~ 1/v

Elastic scattering

- Conservation of kinetic energy and momentum gives the same results as in charged particles.
- Elastic scattering by a nucleus with mass number A give minimum neutron energy at a nucleus scattering angel of $\chi=0^o$

$$T_{min,n} = T_{0,n} - T_{max,nucleus} = T_0 - 4\frac{m_1 m_2}{(m_1+m_2)^2}T_0$$

$$m_1 = m_n \ , \ \ m_2 = Am_n \qquad \Rightarrow T_{min,n} = \left(\frac{A-1}{A+1}\right)^2 T_0$$

- Highest moderation is given in hydrogen rich absorbent

Thermal neutrons

- When the neutron is totally slowed down, and is in thermal equilibrium with its environment, it is given:

  $T_n = kT = 0.025$ eV at T = 293 K

  k: Boltzmann constant

- ^{235}U has a high capture cross section of thermal neutrons – give fission
- ^{1}H has a low (1/150 of the total) capture cross section of thermal neutrons – give deuteron and γ

High energy, $T_n > 0.5$ MeV

- Inelastic scattering: (n, nγ), nucleus is absorbing the neutron, then reemission together with a γ-quant. Threshold value ~0.5 MeV
- Occur at certain energies; *Resonances*
- Absorption lead to emission of charged particles: (n, p), (n, α). Threshold value ~1 MeV
- Emission of more than one particle: (n, np), (n, nα). Threshold value ~10 MeV
- Highly complicated cross sections

Neutron attenuation

- A neutron beam passing trough a medium of thickness x, it is given that:

$$N = N_0 e^{-\mu x}$$

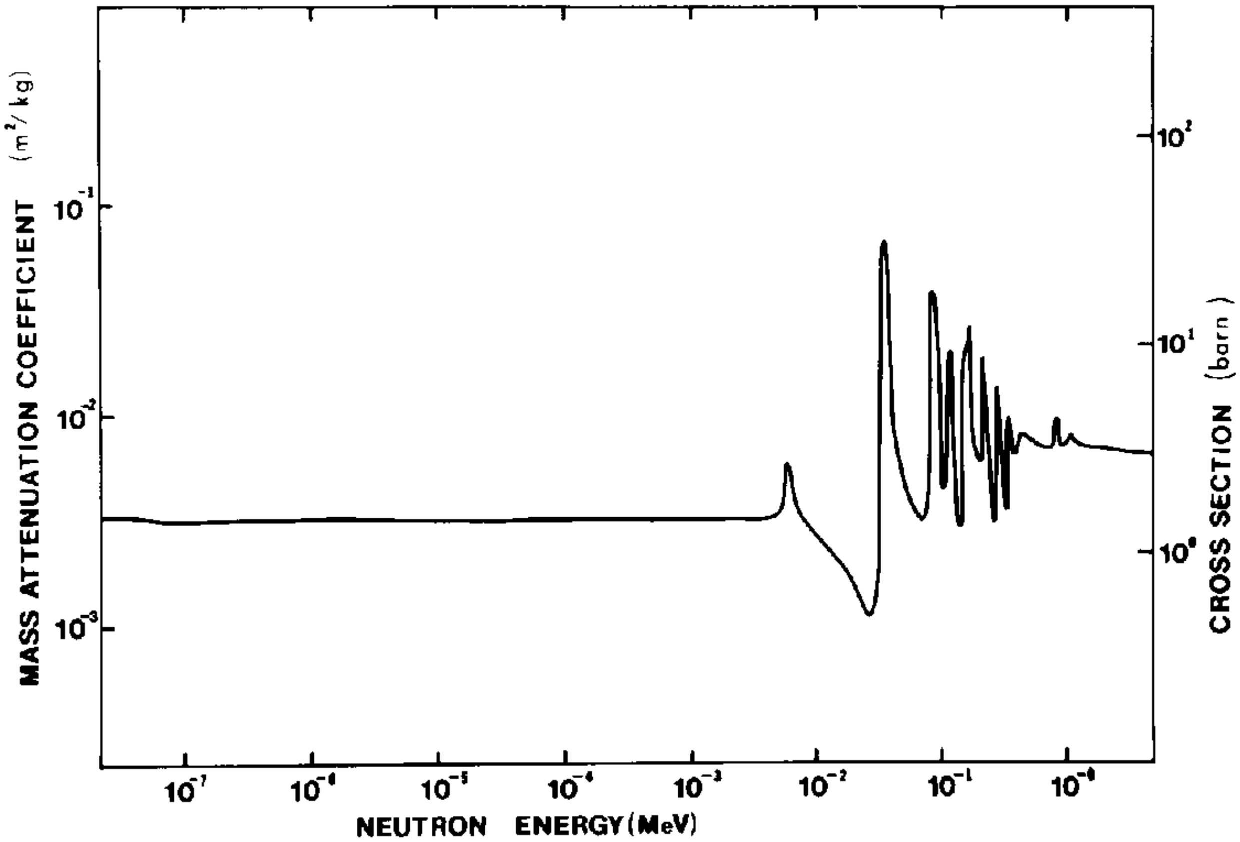
μ : attenuation coefficient

$$\mu = \rho \frac{N_A}{A} \sigma$$

- Note: the cross section variation can be extremely large in a small energy distribution

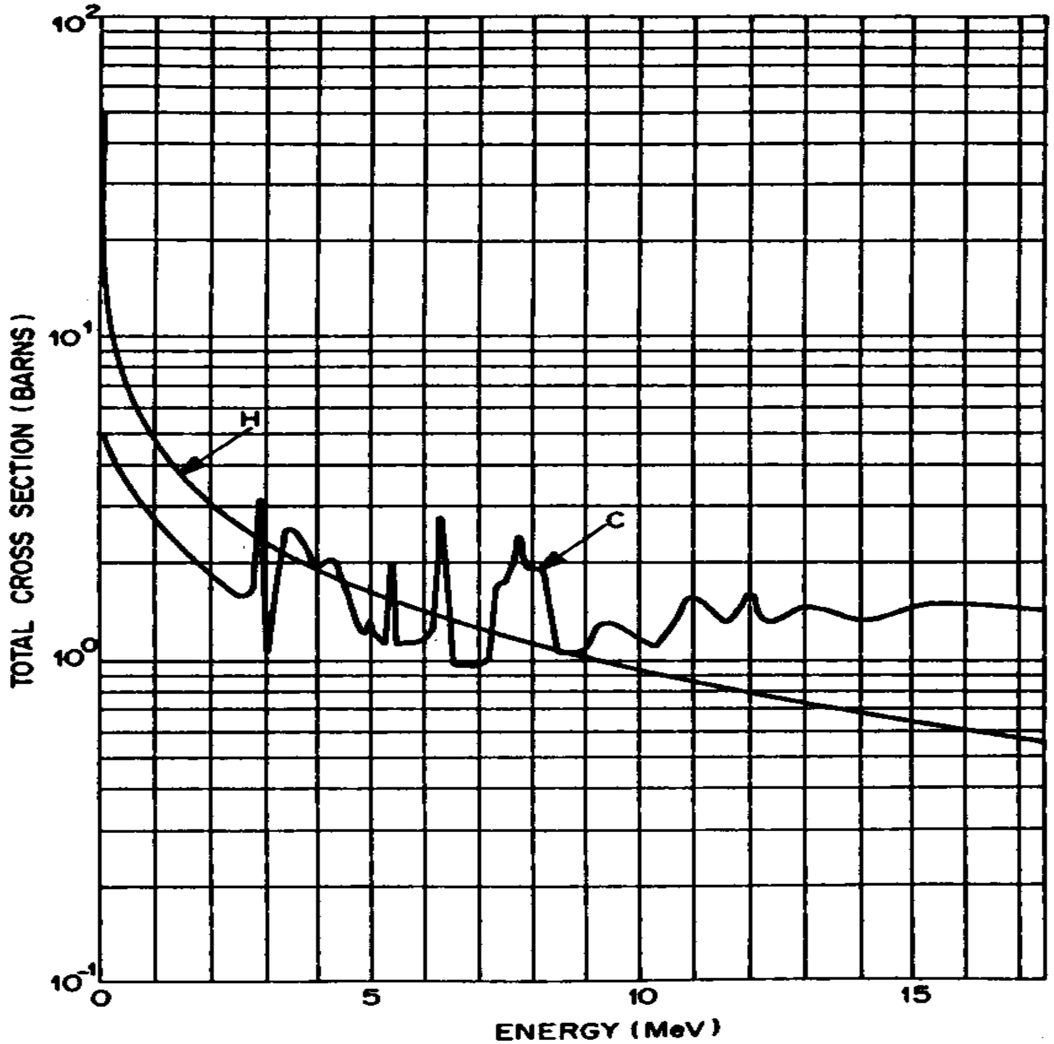
Example of cross section

- Neutrons in ^{27}Al



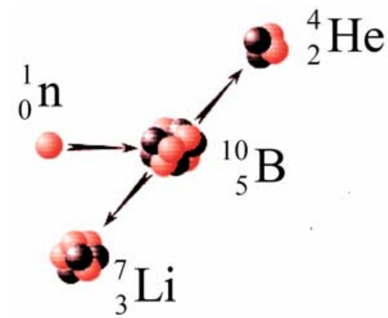
Example of cross section(2)

- ^{1}H and ^{12}C



Boron neutron therapy

- ^{10}B has a high capture cross section of thermal neutrons neutrons 3840 barns (^{1}H only 0.33 barns)
- The result is an unstable nucleus that disintegrate to ^{7}Li and ^{4}He (+ (+ kinetic energy and photon)



- Can be used in cancer cancer treatment: