Ch. 14: Neutron Reactions

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2006–03–20

- Bulk matter fairly transparent to neutrons.
- Reaction cross sections typically *increase* as neturon energy *decreases.*
- Free neutrons beta decay with a mean lifetime of about 10 min.
- However, neutrons in matter usually absorbed before decay (for a large sample size.)

Thermalization and neutron capture

Fast ($\sim$ 1 MeV) neutrons undergo scattering events with matter nuclei. KE is transferred from neutron to nuclei. Collides until KE $\sim k_B$T, becoming a **thermal neutron.**

When thermal, typically has a high cross-section for **neutron capture.**

$$^1_0\text{n} + {}^A_Z\text{X} \rightarrow {}^{A+1}_{Z}\text{X} + \gamma$$

where the γ acturally emerges from an excited state due to the capture. The product is typically radioactive and decays by α or β emission.

Moderators

Materials which have a low cross-section for fast neutron capture are **moderators:** most collisions are elastic and they can be used to slow the neutrons.

Maximum energy transfer in such collisions occurs when the particles involved have the same mass, so materials rich in hydrogen are good moderators. In general materials of low atomic mass are used as moderators (H_2O, D_2O, He, C.) Neutrons thermalize in about 1 ms.

Thermal neutrons have

$$K_{av} = \frac{3}{2} k_B T \approx 0.04 \text{ eV},$$

with $v_{RMS} \sim 2800$ m/s.

Fission

Split a heavy nucleus, leaving fragments of less total rest mass than parent.

A heavy nucleus releases about 200 MeV upon fission.

Thermal fission of Uranium-235:

$$ {}^{1}_{0}\mathrm{n} + {}^{235}_{92}\mathrm{U} \rightarrow {}^{236}_{92}\mathrm{U}^{*} \rightarrow \mathrm{X} + \mathrm{Y} + \text{neutrons} $$

X and Y are **fission fragments.** They have a distribution of masses and energies (see fig. 14.4). About 2.5 neutrons are released per fission.

$$ {}^{1}_{0}\mathrm{n} + {}^{235}_{92}\mathrm{U} \rightarrow {}^{141}_{56}\mathrm{Ba} + {}^{92}_{36}\mathrm{Kr} + 3\,{}^{1}_{0}\mathrm{n} $$

is typical. Most of the energy is kinetic energy of the fission fragments.