Problem 1. 2-7

Suppose we consider a beam of neutrons incident upon a thin target with an intensity of $10^{12}\frac{neutrons}{cm^2 s}$. Suppose further that the total cross section for the nuclei in this target is $4b$. Using this information, determine how long one would have to wait, on the average, for a given nucleus in the target to suffer a neutron interaction.

Solution

We know that our reaction rate is equal to $intensity * cross\ section$. Our mean time before a reaction is the inverse of the rate:

$$\frac{1}{intensity * cross\ section} = 2.5 * 10^{11} s$$

Problem 2. 2-11

Using the data from BNL-325, compute the mean free paths of neutrons with the following energies in the specified materials:

(a) $14MeV$ neutrons in air, water, and uranium (characteristic of thermonuclear fusion neutrons),

(b) $1MeV$ neutrons in air, water, and uranium (fast breeder reactor neutrons), and

(c) $0.05eV$ neutrons in air, water, and uranium (thermal reactor neutrons).

Solution

	$14MeV$	$1MeV$	$0.05eV$
U	$3.54cm$	$2.91cm$	$1.42cm$
Water	$10.04cm$	$1.79cm$	$0.53cm$
Air	$1.27 * 10^2 cm$	$5640cm$	$2041cm$

Problem 3. 2-12

Determine the kinetic energy at which the wavelength of a neutron is comparable to:

(a) the diameter of a nucleus,

(b) an atomic diameter,

(c) the interatomic spacing in graphite, and

(d) the diameter of a nuclear reactor core.

(Only rough estimates are required.)

Solution

The deBroglie wavelength of a particle is expressed by:

$$\lambda = \frac{h}{\sqrt{2Tm}}$$

from which we derive:

$$T = \frac{h^2}{2m\lambda^2}$$

Object	λ	T
the diameter of a nucleus	15 fm	3.63 MeV
an atomic diameter	350 pm	$6.68 * 10^{-9} MeV$
the interatomic spacing in graphite	0.142 nm	$4.06 * 10^{-9} MeV$
the diameter of a nuclear reactor core	1 m	$8.18 * 10^{-28} MeV$

Problem 4. 2-15

Using the Maxwell-Boltzman distribution $M(V,T)$, calculate the most probable energy of the nuclei characterized by such a distribution. Also calculate the average thermal energy of these nuclei.

Solution

Problem 5. 2-20

Determine the fission-rate density necessary to produce a thermal power density of $400kW/liter$ (typical of a fast breeder reactor core). Assume that the principle fissile isotope is $^{239}_{94}$Pu.

Solution

Each fission of $^{239}_{94}$Pu produces $211.5MeV$. Therefore:

$$
\begin{aligned}
TPD &= \frac{E}{fission} * FRD \\
FRD &= \frac{TPD}{\frac{E}{fission}} \\
&= \frac{400\frac{J}{s*L}}{211.5\frac{MeV}{fission}/6.2415 * 10^{12}\frac{MeV}{J}} \\
&= 1.18 * 10^{16}\frac{fissions}{L * s}
\end{aligned}
$$