As in equations (6-15) and (6-14). the energy of the neutrons at the source is E_o and the formula predicts the average of the displacement-squared for neutrons of energy E. E′ is the variable of integration and disappears upon substitution of the limits.

Referring to Figure 18, page 37, we note that the cross section for neutrons inhydrogen is very nearly constant (~ 21 barns) over a wide range of energies - from about 1 ev (where the effect of chemical binding forces becomes negligible) to about 10 kev. For slowing down in this region, λ is constant, and the formula (6-16) can be reduced to the form:

$$r^2_{av} = f(E_o) - 6\lambda^2 \log_e E \qquad (6\text{-}17)$$

Using Ra-Be as a neutron source in a tank of water, we find the following data experimentally:

Slowing to Rh resonance (1.28 ev): $r^2_{av} = 276.6\ cm^2$

Slowing to I resonance (37 ev): $r^2_{av} = 262.2\ cm^2$

It follows then from equation (6-17), which is valid in this range of energies, that:

$$[(r^2)_{av} \text{ for Rh}] - [(r^2)_{av} \text{ for I}] = 6\lambda^2 \log_e(37/1.28) = 14.4\ cm^2$$

from which $\lambda^2 = (14.4/20.2\ cm^2$ or $\lambda = 0.84$ cm. This is an average mean free path, to be compared with appropriate averages of differential data. Recent data on Ra-Be neutrons in water [Phys. Rev. 73:271 (1948)] indicates that r^2_{av} for indium (1.44 ev) is 272 cm^2.

6.4 DISTRIBUTION OF NEUTRONS FROM POINT SOURCE - AGE EQUATION

In the last section, we have discussed one description of the space distribution of neutrons for a a point source in an infinite homogeneous medium. In this section, we shall derive an expression for the neutron "age" rather than the average of the displacement-squared. This "age" is likewise a distance-squared. (The somewhat misleading nomenclature results from the analogy between the present problem and heat flow.)

As before, neutrons with energy E_o are fed into the scattering medium. Our interest is in the space distribution of neutrons of various energies. Accordingly we define a steady-state neutron density function $n(x,y,z,\epsilon)$ such that $n(x,y,z,\epsilon)\,dxdydzd\epsilon$ is the number of neutrons in the volume element dxdydz, with the logarithm of their energy between ϵ and $\epsilon + d\epsilon$ (where, as before, $\epsilon = \log_e E$). Consider the volume element and the neutrons in it in the given energy range. Per unit time, this volume element will receive neutrons in this energy range from two sources: (1) from diffusion of neutrons of this energy from outside the volume element and (2) from higher energy neutrons in the volume element which have their energy degraded into the given energy range.

From the first source, diffusion, the contribution to the neutron population in the volume element can be calculated using methods of kinetic theory. The diffusion coefficient is:

$$D = \lambda_t v/3 = \frac{\lambda v}{\left(3[1 - \cos\phi_{av}]\right)} \qquad (6\text{-}18)$$

where λ is the mean free path for scattering, $(\cos\phi)_{av}$ the average of cosines of the angle of scattering in the laboratory system, and v the neutron velocity. λ_t is called the "transport mean free path." It is the distance that a neutron would travel on the average in the direction of its initial motion after an infinite number of collisions, each collision resulting in an average deflection given by $(\cos\phi)_{av}$

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