ME-427 INTRODUCTION TO NUCLEAR ENGINEERING
PROBLEM SET 2

Due: 5 Nov 1984

Pr. 1. A beam of 2 MeV neutrons is incident on a slab of heavy water (D_2O). The total cross sections of deuterium and oxygen at this energy are 2.6 b and 1.6 b, respectively.

(a) What is the macrosopic total cross section of D_2O at 2 Mev neutron energy?

(b) How thick must the slab be in order to reduce the intensity of uncollided beam by a factor of 10?

Solution

(a) for D_2O

$\Sigma_t = N_D\ \sigma_D + N_O\ \sigma_O$ where $\sigma_D = 2.6$ b and $\sigma_O = 1.6$ b

$\rho_{D_2O} = 1.106\ \text{g/cm}^3$ $\quad M_{D_2O} = 20.0276$ amu

$$\Sigma_t = \frac{(1.106)\ (6.023\ 10^{24})}{20.0276}\ \left[(2)\ (2.6) + 1.6\right]\ 10^{-24} = 0.226\ \text{cm}^{-1}$$

(b)

$$\frac{I}{I_0} = e^{-\Sigma L} \quad \Rightarrow \quad e^{-0.226 L} = 0.1 \quad \Rightarrow \quad L = 10.2\ \text{cm}$$

Pr. 2. There are no resonances in the total cross section of C-12 from 0.01 eV to over 1 MeV. If the radiative capture cross section of this nuclide at 0.0253 eV is 3.4 mb, what is the value of σ_C at 1 eV?

Solution

$$\sigma \ \square \ \frac{1}{\sqrt{E}}$$

$$\frac{\sigma}{2.4} = \frac{\sqrt{0.0253}}{1} \quad \Rightarrow \quad \sigma = 0.54\ \text{mb}$$

Pr. 3. Fission can be induced when γ rays are absorbed by a heavy nucleaus. What energy γ rays are necessary to induce fission in U-235?

Solution

To induce fission in U-235 $E_\gamma \geq E_{critical}$

Or $E_\gamma \geq 5.75$ MeV (from Table 3.3, Int. To Nucl. Eng. by Lamarsh)

Pr. 4. The mass attenuation coefficient of lead at 0.15 MeV is 1.84 cm^2/g. At this energy, the principal mode of interaction is by photoelecric effect. What thickness of lead is required to reduce the intensity of a 0.15 MeV γ-ray beam by a factor of 1000?

Solution

$$\frac{\mu}{\rho} = 1.84 \text{ cm}^2/\text{g}$$

$$\Sigma_t = (1.84 \text{ cm}^2/\text{g})\,(11.35 \text{ g/cm}^3) = 20.884 \text{ cm}^{-1}$$

$$\frac{I}{I_0} = e^{-20.884\,L} \quad \Rightarrow \quad L = \frac{\ln(1000)}{20.884} = 0.33 \text{ cm}$$

Pr. 5. A collimated beam of 2200 m/s neutrons has an intensity of 100 000 neutrons/cm^2. What would be its intensity after passing through a sheet of 0.25 cm pure aluminum?

Solution

$I_0 = 10^5$ neutrons/cm^2.s

$\Sigma_t = N_{Al}\,(\sigma_s + \sigma_a)_{Al}$ where $(\sigma_s)_{thermal} = 1.4$ b and $(\sigma_a)_{at\ 0.025\ eV} = 0.230$ b

$$N_{Al} = \frac{(2.7)\,(6.023\ 10^{23})}{26.9815} = 6.0271\ 10^{22} \text{ atoms/cm}^3$$

$$\Sigma_t = (6.0271\ 10^{22})\,(1.4 + 0.230)\,10^{-24} = 0.0982 \text{ cm}^{-1}$$

$$I = I_0\, e^{-\Sigma_t L} = 10^5\, e^{-(0.0982)\,(0.25)} = 97\,500 \text{ neutrons/cm}^2$$

Pr. 6. Thermal fission of a U-233 nucleus produces 4 neutrons and 2 fission fragments, one of which is La-143 (12.9157 amu). What is the other fission tragment? Compute the energy released if the second fragment has a mass of 86.9224 amu.

Solution

$^{233}_{92}U + ^{1}_{0}n \rightarrow (^{234}_{92}U)^* \rightarrow ^{143}_{57}La + ^{87}_{35}F + 4\ ^{1}_{0}n$

The second fission fragment is $^{87}_{35}Br$

Energy released:

$Q = \left[(233.0395 + 1.008665) - (142.917 + 86.9224 + (4)(1.008665)\right] (931.481)$

$= 163.4$ MeV   Exothermic reaction