

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 (D₂O). The total cross sections of deuterium and oxygen at this energy are 2.6 b and 1.6 b, respectively.

- (a) What is the macroscopic total cross section of D₂O 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 D₂O

$$\Sigma_t = N_D \sigma_D + N_O \sigma_O \quad \text{where } \sigma_D = 2.6 \text{ b and } \sigma_O = 1.6 \text{ b}$$

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

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

(b)

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

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

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

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

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

Solution

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

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

Pr. 4. The mass attenuation coefficient of lead at 0.15 MeV is $1.84 \text{ cm}^2/\text{g}$. At this energy, the principal mode of interaction is by photoelectric 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

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

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

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

Pr. 5. A collimated beam of 2200 m/s neutrons has an intensity of 100 000 neutrons/cm². What would be its intensity after passing through a sheet of 0.25 cm pure aluminum?

Solution

$$I_0 = 10^5 \text{ neutrons/cm}^2 \cdot \text{s}$$

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

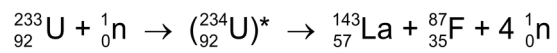
$$N_{\text{Al}} = \frac{(2.7) (6.023 \cdot 10^{23})}{26.9815} = 6.0271 \cdot 10^{22} \text{ atoms/cm}^3$$

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

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

Pr. 6. Thermal fission of a U-233 nucleus produces 4 neutrons and 2 fission fragments, one of which is La-143 (142.9157 amu). What is the other fission fragment? Compute the energy released if the second fragment has a mass of 86.9224 amu.

Solution



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

Energy released:

$$\begin{aligned} Q &= [(233.0395 + 1.008665) - (142.917 + 86.9224 + (4)(1.008665))] (931.481) \\ &= 163.4 \text{ MeV} \quad \text{Exothermic reaction} \end{aligned}$$