Problem 1. Anderson 9.3

Consider the case of a 1 MeV neutron incident on a nucleus of mass number $A = 100$. Using $R = R_0 A^{1/3} = (1.1)10^{-15} A^{1/3}$m, calculate the time required for a single transversal of the nuclear diameter by the neutron. Assume a square well nuclear potential with depth of 10 MeV. Compare this time with an estimate of the compound nucleus lifetime from the uncertainty principle for a resonance with level width $\Delta E = 0.1\,\mathrm{eV}$

Solution

Please see attached code for work. The two values ($2.24 \times 10^{-22}\,\mathrm{s}$ for the transit of the nuclear diameter and $2.99 \times 10^{-23}\,\mathrm{s}$ for the Heisenberg energy and time relationship). These two values vary by an order of magnitude.

The relationship given in the notes indicates that $\Delta E \Delta t \geq h/2$, but other sources give the relationship as $\Delta E \Delta t \geq \hbar/2$. This extra factor of 2π would bring these answers closer together (though not match exactly).

Problem 2.

Look up the thermal neutron cross sections for each stable isotope of Cd, and then using those values determine the thermal neutron cross section for natural Cd (please include the natural abundances of each isotope that you use in this calculation)

Solution

The list of stable isotopes was obtained from the ENDF (`https://www.nndc.bnl.gov/sigma/index.jsp?as=116&lib=endfb7.1&nsub=10`), and the natural abundance fractions were obtained from NC State (`https://www.ncsu.edu/chemistry/msf/pdf/IsotopicMass_NaturalAbundance.pdf`).

Calculations were performed in the attached code. The results were

	Abundance	Cross Section	Isotope	Fractional Contribution	Macroscopic Cross Section	Nur
0	1.25	1.000	106	0.012500	4.914179e+22	
1	0.89	1.100	108	0.009790	5.305494e+22	
2	12.49	11.000	110	1.373900	5.209030e+23	
3	12.80	24.000	111	3.072000	1.126277e+24	
4	24.13	2.200	112	0.530860	1.023202e+23	
5	12.22	20600.000	113	2517.320000	9.496108e+26	
6	28.73	0.340	114	0.097682	1.553570e+22	
7	7.49	0.075	116	0.005618	3.367907e+21	

Problem 3. Anderson 9.9, change material to natural Cd

What thickness of Cd will remove 95% of a beam of 100 eV neutrons?

Solution

$$\phi = \phi_0 \exp\{(-\Sigma_i * t)\}$$

$$t = \frac{-\log\left(\phi/\phi_0\right)}{\Sigma}$$

$$\Sigma = \sum_{isotopes} N^{isotope}\sigma_{isotope}$$

$$N^{isotope} = \frac{A_v * \rho}{\bar{m_{\text{Cd}}}} f_{isotope}$$

$$\bar{m_{\text{Cd}}} = \sum_{isotopes} f_{isotope} m_{isotope} \approx \sum_{isotopes} f_{isotope} A_{isotope}$$

To reduce the beam by 95% a thickness of 2.57×10^{-2} cm is required

Problem 4.

What is the relative probability of production of I-131 with respect to production of Cs-137 in thermal neutron fission of U-235? Use the double-hump curve on Figure 9.18. What is the relative probability of production of Mo-99 with respect to production of Cs-137?

Solution

From Wikipedia (`https://en.wikipedia.org/wiki/Fission_product_yield#Ordered_by_yield_.28thermal_neutron_fission_of_U-235.29`), Cs-137 has a yield of 6.0899% while I-131 has a yield of 2.8336%. Mo-99 has a yield of 6.1%. Mo-99 is therefore about as likely to be produced as Cs-137, while I-131 is about half (46.6%) as likely to be produced as Cs-137.