Homework 1
March 2023

Fission Reactor Physics 1

Assignment 1

A Boiling Water Reactor (BWR) operates at 1000 psi. At that pressure, the density of water and of steam are respectively 0.74 g/cm^3 and 0.036 g/cm^3. The microscopic cross section of H and O at neutron speed of 2200 cm/s are 38 b and 4.2×10^{-5} b .

- What is the macroscopic total cross section of the water?
- What is the macroscopic total cross section of the steam?
- If, on average, 40% of the volume is occupied by steam then what is the macroscopic total cross section of the steam-water mixture?
- What is the macroscopic total cross section of water under atmospheric conditions at room temperature?

Assignment 2

Determine:

- The fraction of fission neutrons born with energy of less than 0.1 MeV.
- The fraction of fission neutrons born with energy greater than 10 MeV.

Solve this problem both analytically and numerically.

Assignment 3

How many parts per million of boron must be dissolved in water at room temperature to double its absorption cross section for thermal neutrons?

Assignment 4

What is the total macroscopic thermal cross section of uranium dioxide (UO_2) that has been enriched to 4%?

Assignment 5

Equal volumes of graphite and iron are mixed together. Fifteen percent of the volume of the resulting mixture is occupied by air pockets. Find the total macroscopic cross section given the following data $\sigma_c = 4.75$ b, $\sigma_{fe} = 10.9$ b, $\rho_c = 1.6$ g/cm^3, $\sigma_{fe} = 7.7$ g/cm^3. Is it reasonable to neglect the cross section of air?

	σ_f b	σ_a b	σ_t b	ρ g/cm^3
PuO_2	1.95	2.4	8.6	11
UO_2	0.05	0.404	8.2	11
Na	-	0.0018	3.7	0.97
Fe	-	0.0087	3.6	7.87

Assignment 6

For thermal neutrons calculate *eta* as a function of uranium enrichment (in atoms and in weight) and plot your results.

Assignment 7

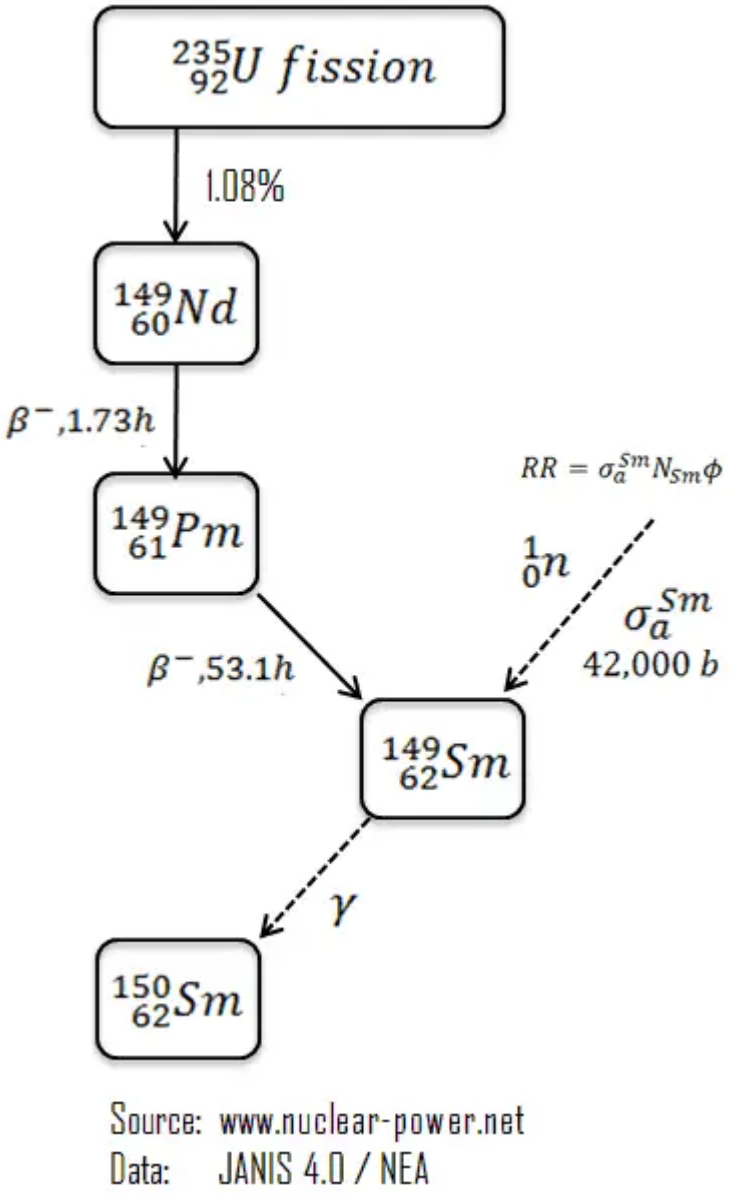
A sodium-cooled fast reactor is fuelled with PuO_2, mixed with depleted UO_2. The structural material is iron. Averaged over the spectrum of fast neutrons, the microscopic cross sections and densities are the following: The fuel is 15% PuO_2 and 85% UO_2 by volume. The volumetric composition of the core is 30% fuel, 50% coolant and 20% structural material. Calculate κ_∞ assuming that the values of u for plutonium and uranium in the fast spectrum are 2.98 and 2.47, respectively, and that the cross sections of oxygen can be neglected. What fraction of the mass of the core does the fuel account for?

Assignment 8

Suppose the non-leakage probability for a sodium cooled fast reactor specified in problem 7 is 0.90. Using the data from problem 7, adjust the volume fractions of PuO_2 and UO_2 in the fuel so that $\kappa = 1.0$. What is the % in the fuel by volume?

Assignment 9

An important difference between Xe135 and Sm149 is that samarium 149 is a stable isotope and remains in the core after shutdown. There are only two ways of samarium removal, and one of these processes is the samarium burn up when the reactor is at power operation. The samarium burnup rate depends upon the neutron flux and the samarium 149 concentration (i.e., the reaction rate).



Use the following data to compute the reaction rate: mass U = 100 t, enrichment = 0.02, thermal power = 3 GW, σ_f = 585 b, energy per fission = 200.7 MeV and the data reported in figure.
From the decay chain listed above, compute the Promethium and Samarium concentration (initial concentration equal to zero) for:

- 7 days reactor operation
- after 7 days, shutdown for 1 day
- reactor restart and operation for 3 days