Chemical Engineering 612

Reactor Design and Analysis

Lecture 8

4 Group Criticality Example

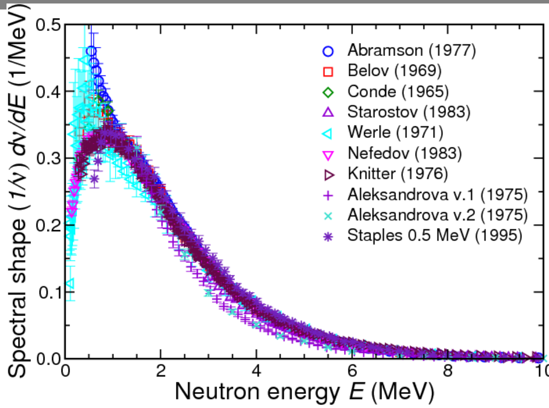
Spiritual Thought

"Historically, fear has often been used as a means to get people to take action. Parents have used it with their children, employers with employees, and politicians with voters. Experts in marketing understand the power of fear and often employ it… It is true that fear can have a powerful influence over our actions and behavior. But that influence tends to be temporary and shallow. Fear rarely has the power to change our hearts, and it will never transform us… People who are fearful may *say* and do the right things, but they do not *feel* the right things. They often feel helpless and resentful, even angry. Over time these feelings lead to mistrust, defiance, even rebellion."

Dieter F. Uchtdorf

Perfect Love Casteth Out Fear

Neutron Energies



- Fission neutrons
  - Distribution of speeds
  - 2 MeV typical
  - Often interested “slowing” neutrons
  - Collisions required to slow from energy E_1 to E_2 is given by:

$$n = \frac{1}{\xi} \ln \frac{E_1}{E_2}$$

- Thermal neutrons:
  - equilibrated with the vibrating atomic nuclei at room temperature (293 K)
  - Average energy of 0.025 eV (2200 m/s)
  - Maxwellian distribution of speeds
  - likely to lose OR GAIN energy from medium nuclei
  - Readily produce fissions in U^{235}, U^{233}, Pu^{239}

How to Decelerate a Neutron

$$\alpha = \left(\frac{A-1}{A+1}\right)^2$$

collision parameter

$$\frac{\Delta E}{E} = \frac{1-\alpha}{2}$$

$$u = \ln \frac{E_M}{E}$$

Lethargy;
E_M is an arbitrary E, usually the highest neutron energy in the system. As neutrons decelerate, u increases.

$$\xi = \Delta u = 1 - \frac{(A-1)^2}{2A} \ln \frac{A+1}{A-1} = 1 + \frac{\alpha}{1-\alpha} \ln \alpha \cong \frac{2}{A + \frac{2}{3}}$$

$$\lim_{A \to 1} \xi = 1$$

Capture and Absorption

- Decelerating Neutrons from fission energies (2-5 MeV) to thermal energies (0.025 eV)
  - Requires many collisions
  - Smaller Nuclides
  - Risk of “capture”
- Capture occurs in “resonance energy regions” (fuel)
- Also could be absorbed by the “moderator” (water)
- Can calculate probability of capture or absorption
  - Resonance integral
  - Absorption cross-sections

Collision parameters

Atom	A	α	ξ	n
H	1	0.000	1.000	18.2
H_2O	1, 16		0.920	19.8
D	2	0.111	0.725	25.1
D_2O	2, 16		0.509	35.8
He	4	0.360	0.425	42.8
Be	9	0.640	0.207	88.1
B	11	0.694	0.171	106.3
C	12	0.716	0.158	115.3
O	16	0.779	0.120	151.7
Na	23	0.840	0.084	215.4
Fe	56	0.931	0.035	515.6
^{238}U	238	0.983	0.008	2171.6

n values here assume a neutron slowing from 2 MeV to 0.025 eV

Multigroup Reactor Equations (4 group)

Derive a 4-group reactor equation (using diffusion theory) for neutrons in a bare, homogenous, spherical reactor. This reactor is at steady-state but is not necessarily critical. The following assumptions should be used in this derivation:

a. Fission neutrons are only born in the top two groups, i.e. groups 1 and 2.
b. The fast neutron generation distribution is as follows: X1 = 0.75, X2 = 0.25
c. Thermal neutrons only exist in the bottom group, i.e. group 4.
d. Only thermal neutrons induce fissions.
e. There are no up-scatterings in the thermal group (i.e. neutrons only lose energy)
f. The absorption and scattering cross sections can be combined to form a "removal" cross section, ΣR.
g. Scattered neutrons will only drop to adjacent energy levels. This means that the scattering cross section for group 1 represents neutrons scattered to group 2 only, or Σs1,2, etc. h. Because cross sections are energy dependent, there is a separate cross section of each type for each energy group, indicated by the appropriate subscript. i. v is specific to each energy group… however, only one energy group undergoes fission…