

Problem Set 4 SES #11

Question 1:

Explain why a simple diffusion model can be appropriate for gas molecules but not for neutrons?

Question 2:

In the neutron balance equation, describe two potential source terms that can be present in a nuclear reactor.

Question 3:

Starting from the steady-state neutron transport equation (no time variation, i.e. equilibrium), derive the neutron diffusion equation in one dimension.

Question 4:

State in which region the diffusion approximation breaks down and explain why.

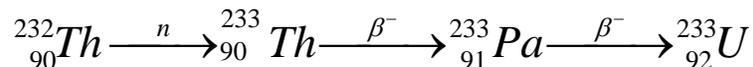
Question 5:

Derive the interface conditions in neutron diffusion.

Question 6:

A Molten Salt Thermal Reactor is initially loaded with 200 kg of U-235 and maintains a constant flux of 10^{14} n/cm²sec. This reactor design uses fuel dissolved into the molten salt to power the reactor which, in turn, allows fission products to be removed directly from the coolant.

For this specific reactor, we wish to replace all 200 kg. of U-235 with the equivalent number of atoms of U-233 over time. This can be done through dissolving Th-232 into the core, producing U-233 through the following reaction



For this problem, we wish to find the atom flow rate of Th-232 into the reactor necessary to maintain a constant number of fissile atoms (U-235 and U-233) over the entire time of operation.

Here are some assumptions you can make in modeling the reactor:

- The decay of U-235, Th-232 and U-233 is negligible.
- The decay of Th-233 happens so quickly, you can say that the absorption of a neutron by Th-232 directly produces Pa-233.

- Pa-233 absorption cross section is so small that only loss due to decay is taken into account.
- a) Set up the differential equation for U-235 and solve for the number of U-235 atoms in the core over time. Then determine the corresponding time dependence of the U-233 content.
- b) Set up the differential equation for U-233 and solve for the Pa-233 content in the reactor over time.
- c) Set up the differential equation for Pa-233 and solve for the Th-232 content in the reactor over time.
- d) Set up the differential equation for Th-232 and include an additional time dependent term, $A(t)$, corresponding to the atom flow rate of Th-232 into the core. Solve for $A(t)$.
- e) Using the table of values given below, calculate the initial and equilibrium atom flow rate of Th-232 into the core.

X	λ_x	σ_a^x
${}_{90}^{232}Th$	$1.56 \times 10^{-18} \text{ sec}^{-1}$	6.53 barns
${}_{91}^{233}Pa$	$2.98 \times 10^{-7} \text{ sec}^{-1}$	34.7 barns
${}_{92}^{233}U$	$1.38 \times 10^{-13} \text{ sec}^{-1}$	510 barns
${}_{92}^{235}U$	$3.12 \times 10^{-17} \text{ sec}^{-1}$	593 barns

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