Exam 1 (Fall 2008)

Question 1 (5 pts each / 25 pts total)

a) Calculate Q-value of the following reaction

$$^{2}H \ + \ n \ \ \rightarrow \ \ ^{3}H \ + \ \gamma \, (6.256 MeV)$$

b) Calculate binding energy of last neutron of ^{3}H
c) Calculate decay constant of ^{238}Np (See Chart of Nuclides in Appendix)
d) Circle possible reactions between a neutron and an hydrogen nucleus (^{1}H)

Elastic scattering	Fission
(n,2n)	Capture
Inelastic scattering	

e) Write the photo-neutron reaction that appears commonly in light and heavy water reactors.

Data

Mass of ^{2}H = 2.0136 amu
Mass of ^{3}H = 3.0160 amu
Mass of neutron = 1.008665 amu

Question 2 (10 pts)

Using the chart of nuclide provided, identify two pathways for the breeding of ^{239}Pu from ^{238}U (any two). Indicate which pathway is the most likely to occur in a high flux environment (i.e. reactor), this pathway may be different than the two you have written. (See Chart of Nuclides in Appendix)

Question 3 (10 pts)

In order to determine the macroscopic and microscopic cross section for a certain single isotope material, you set up a collimated neutron source on one side and a neutron detector on the other. The intensity of the neutron beam is initially 10^5 neutrons per cm^2 per second. After passing through the 2 cm. thick sample, the beam is measured at $2.6*10^3$ neutrons per cm^2 per second. If the density of the material is 3.6 grams per cubic centimeter and the molar mass is 10 grams per mole, calculate the macroscopic and microscopic total cross section.

Question 4 (15 pts)

A molten salt reactor using Thorium-232 as a blanket and Uranium-233 as the fuel is being planned to run entirely off of the U-233 produced from the blanket. It is currently being fueled only by U-235. Because the Th-232 in the blanket can be pumped continuously from the blanket surrounding the core, Pa-233 can be extracted before any radiative capture can occur, thereby removing any losses of Pa-233 due to neutron absorption. The Pa-233 is stored in a container and the U-233 is accumulated outside the core. (Additional data in Appendix)

a. Write down the nuclear reactions that will lead to the production of U-233 from the neutron capture of Th-232. Why can you ignore Th-233 for the rest of this problem?
b. Set up the differential equations you would use to analyze the Pa-233 and U-233 content over time.
c. Solve the differential equations in a. for the case in which no Pa-233 or U-233 is initially present. (assume U-233 to be stable)
d. How much Th-232 would be needed produce 200 kg of U-233 fuel from the blanket in one year? You can keep your answers in terms of number of atoms.

$\Phi = 10^{14}$ neutrons/cm^2.s
σ_c of Th-232 = 8 barns

Question 5 (10 pts)

a) Explain <u>briefly</u> the presence of resonances in neutron cross section spectrum
b) Describe differences in the resonances between light and heavy nucleus
c) Calculate the resonance averaged capture cross section of ^{157}Gd in the 12 eV to 0.12 MeV range.

   Resonance integral of ^{157}Gd is 762 barns.

Question 6 (15 pts)

From the data provided in Tables 1 and 2:

- Calculate the average number of collisions needed to thermalize a neutron from 10 MeV to 1 eV in moderators 1,2 and 3 of Table 2.
- Compute the moderating ratio or slowing down ratio for all three moderators.
- Indicate which of these moderators is the best at slowing down neutrons
- Indicate which of these moderators is the most effective moderator

Table 1

Isotopes	A	σ_s (barns)	σ_a (barns)
X	12	100	3
Y	6	500	2
Z	32	140	5

Table 2

Moderator	Chemical Formula	Σ_s (cm^{-1})	Σ_a (cm^{-1})
1	X	10.0	0.03
2	XY_2	110.0	0.07
3	Z_2	0.7	0.025

Question 7 (15 pts)

Describe <u>in a few words</u> and name the 3 energy regions of a light water reactor spectrum.

Draw the spectrum.

Appendix: Chart of Nuclides

94	237Pu 45.2 D ∈: 100.00% α: 4.2E-3%	238Pu 87.7 Y α:100.00% sF: 1.9E-7%	239Pu 24110 Y α:100.00% sF: 3.E-10%	240Pu 6561 Y α:100.00% sF: 5.7E-6%	241Pu 14.290 Y β−:100.00% α: 2.5E-3%
	236Np 153E+3 Y ∈:86.30% β−:13.50%	237Np 2.144E+6 Y α:100.00% sF ≤ 2E-10%	238Np 2.117 D β−:100.00%	239Np 2.356 D β−:100.00%	240Np 16.9 M β−:100.00%
92	235U 7.04E+8 Y 0.7204% α: 100.00% sF: 7.0E+9%	236U 2.342E7 Y α: 100.00% sF: 9.4E-8%	237U 6.75 D β−: 100.00%	238U 4.468E9 Y 99.2742% α: 100.00% sF: 5.5E-5%	239U 23.45 M β−: 100.00%
	143		**145**		**147**

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22.05 Neutron Science and Reactor Physics
Fall 2009