University of California
Department of nuclear Engineering

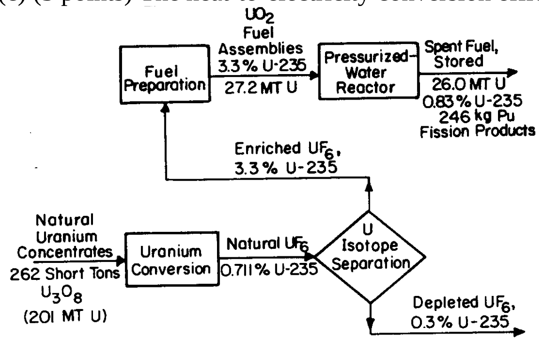
NE 124
Mid-Term Examination I

Fall 2006
Professor J. Ahn

CLOSED BOOK
12:40 pm – 2:00 pm, October 5, 2006
(Undergraduate students: choose any 4 problems, and answer.
Graduate students: answer all 5 problems.)

1. (15 points) Consider transmutation of plutonium 239 by a light water reactor. We assume that fresh fuel initially contains N_{28}^{o} atoms of U-238 and N_{49}^{o} atoms of Pu-239. To simplify, we assume that the fresh fuel contains no U-235. We also neglect the production of Pu-239 in the core by absorption of resonance neutrons in U-238. Plutonium 239, therefore, is generated only by thermal neutron capture by U-238 and consumed by its fission. Assume that the thermal flux ϕ_M is constant with time and uniform in the core. The number, N_{28}^{o}, of U-238 atoms is assumed to be constant with time. The absorption cross section of Pu-239 is σ_{49}. The absorption cross section of U-238 is σ_{28}. t is time.
(a) (5 points) Write the governing equation and the initial condition for the number, $N_{49}(t)$, of Pu-239 atoms in the reactor core. Solve the equation.
(b) (5 points) Define and formulate the burn-up for this system in terms of the parameters in this model.
(c) (5 points) To avoid breeding of ^{239}Pu in the fuel (i.e., to keep the number of atoms of ^{239}Pu always smaller than N_{49}^{o}), what condition need to be satisfied among the parameters in this model?

2. (15 points) The figure below shows the current fuel flow in the United States. It shows that 201 metric ton of natural uranium is necessary to operate 1000MWe power reactor for one calendar year. In the figure, the capacity factor=0.8 and the heat-to-electricity conversion efficiency =0.325 are assumed. Calculate the natural uranium requirement for 1 GWe electricity generation for one calendar year for the following cases:
(a) (5 points) The concentration of ^{235}U in the depleted uranium is reduced to 0.2%.
(b) (5 points) The capacity factor is increased to 0.95.
(c) (5 points) The heat-to-electricity conversion efficiency is increased to 0.34.



3. (15 points) You have 1 metric ton of uranium ore. Uranium content in the ore is 1 weight%. Use the data shown in the table, if necessary.
(a) (5 points) Calculate the total radioactivity contained in this amount of ore? Assume that uranium isotopes in the ore are in secular equilibrium with their daughter nuclides.
(b) (10 points) Consider three stages in a fuel cycle: (1) the uranium mill, (2) the uranium conversion plant, and (3) the uranium isotope separation plant. What kind of radioactive effluents (products, wastes, gases released in to the atmosphere, etc.) would come out of each of these stages? Show also radionuclides that are included in each effluent. You may assume typical values for separation efficiencies at each stage. State clearly the assumptions you have made in your solution.

Nuclide	Half-life	radiation	Nuclide	Half-life	radiation
U-238	4.51E9 y	Alpha	U-235	7.1E8 y	Alpha, gamma
Th-234	24.1 days	Beta	Th-231	25.5 h	Beta
Pa-234	1.17 min	Beta, gamma	Pa-231	3.25E4 y	Alpha, gamma
U-234	2.47E5 y	Alpha	Ac-227	21.6 y	Alpha, beta
Th-230	8.0E4 y	Alpha	Th-227	18.2 days	Alpha, gamma
Ra-226	1602 y	Alpha	Fr-223	22 min	Alpha, gamma
Rn-222	3.821 days	Alpha	Ra-223	11.43 days	Alpha, gamma
Po-218	3.05 min	Alpha	Rn-219	4.0 sec	Alpha, gamma
Pb-214	26.8 min	Beta, gamma	Po-215	1.78 ms	Alpha
Bi-214	19.7 min	Beta, gamma	Pb-211	36.1 min	Beta, gamma
Po-214	164 micro sec	Alpha	Bi-211	2.15 min	Alpha, gamma
Pb-210	21 y	Beta	Tl-207	4.79 min	Beta, gamma
Bi-210	5.01 days	Beta	Pb-207	stable	
Po-210	138.4 days	Alpha			
Pb-206	stable				

4. (15 points) Consider extraction of H^+ in the aqueous phase by the organic solvent TBP by the following equilibrium:

$$H^+(aq) + NO_3^-(aq) + TBP(org) \Longleftrightarrow HNO_3\bullet TBP(org)$$

(a) (5 points) Write the equilibrium constant K_H in terms of the concentrations of the species appearing in the above reaction.
(b) (5 points) Write the definition of the distribution coefficient D_H for H^+.
(c) (5 points) Assume that the concentration of total TBP, both combined and uncombined, in the organic phase is C. Obtain the equation for the distribution coefficient D_H for H^+ in terms of C, K_H and aqueous concentrations. Assume $K_H = 0.145$, $C = 1.5$ mol/liter, and $[NO_3^-] = 2$ mol/liter. Would D_H increase or decrease if pH of the aqueous phase increase?

5. (15 points) Answer the following questions:
(a) (5 points) How and where is ^{14}C generated in a nuclear fuel cycle? Why is this nuclide of concern in the waste management?
(b) (5 points) Select a radionuclide (other than ^{14}C) that is important in radioactive waste management for nuclear fuel cycle. Discuss how and where mainly that nuclide is generated in the fuel cycle, and explain why that nuclide is so important.
(c) (5 points) Answer the following true/false questions. Explain briefly your answer.

(c-1) Radioactivity of any radionuclide in spent fuel from a PWR decreases monotonically with time after it is discharged from a reactor.
(c-2) Because wastes from reactor decommissioning are mostly concrete and structural materials consisting of reactor buildings, decommissioning wastes can be regarded as non radioactive.
(c-3) With careful choice of solvents and operating conditions, perfect separation of one material from another is possible by a multi-stage solvent-solvent extraction process.
(c-4) All fission-product isotopes in a spent fuel at discharge from a reactor core are radioactive.
(c-5) Radionuclides included in activated materials are so short-lived that these can be regarded as non-radioactive after a storage period of 10 years.