NE124 Radioactive Waste Management, Fall 2006
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Solution set for Mid-term II

1. (1) d (2) c (3) e

2. (1) $y_{n-1} - y_0 = \frac{F}{E}\left(x_n - x_1\right)$ (2) $\rho \equiv \frac{Ey_N}{Fx_F}$, $\beta \equiv ED/F$ (3) $\rho = \beta\left(\frac{\beta^N - 1}{\beta^{N+1} - 1}\right)$.

3. (1) Radiotoxicity of 1 g of U-238 is 1.11 m^3.
(2) In uranium ore, there are U-238 and U-235, and their decay daughters. 99.3% of uranium is U-238, whose radioactivity is 1.22E4 Bq for 1 gram of U. 0.7% of uranium is U-235, whose radioactivity is 5.55E2 Bq for 1 gram of U. Decay daughters of each uranium isotope are assumed to be in secular equilibrium, that is, the same radioactivity for all nuclides in the chain. So, the radionuclide with the smallest MPC is the most toxic among the nuclides in the chain. From the U-238 chain, Pb-210 has the smallest MPC, and gives 33 m^3 for its toxicity. From the U-235 chain, Ac-227 has the smallest MPC, and gives 3 m^3 of toxicity. Thus, Pb-210 is the most toxic in the uranium ore.
(3) Because uranium is completely removed from the ore, in the mill tailings only decay daughters of uranium isotopes are included. Among them, Th-230 has the longest half life (80,000yr). So, The radiotoxicity decreases monotonically and nearly exponentially with time with the half life of Th-230. (Note that in this case there is no second plateau after 100,000 year time frame as we observed in the class. The second plateau in the mill-tailings toxicity curve is due to the re-established secular equilibrium by uranium in the mill tailings, which has not been recovered by the separation process.)

4. (1) The question is about adverse effects of long cooling time BEFORE reprocessing on the long-term safety of GEOLOGIC DISPOSAL. If we have a longer cooling time before reprocessing, Pu-241 decays to Am-241 with the half life of about 14 years. Under the current PUREX reprocessing scheme, americium will be included in the HLW. So, a long cooling time before reprocessing increases the mass of Am-241 in the HLW. Am-241 will furthermore decay to Np-237, which is the main contributor to the annual dose and environmental impact of a geologic repository.
(2) Because the yields of fission product nuclides and the fission energy per atom of fissile isotope are different for differing fissile isotope.
(3) For this evaluation, F(12 months, infinity) and F(24 months, infinity) must be evaluated from the table. By interpolation, these are obtained as 0.181 and 0.142, respectively. With these values, the decay heat power is calculated by (0.181 – 0.142) [MeV/fission] x 1150 [MWe]/0.32 /203 [MeV/fission] = 692 kW thermal.

5. (1) Because at the beginning of the irradiation the fuel composition must be equal to that for the previous cycle, we can write $f + (1-f)C_1 = C_1^o$. Substituting $C_1 = C_1^o \exp(-d)$ yields $f + (1-f)C_1^o \exp(-d) = C_1^o$.
Therefore, $C_1^o = \frac{f}{1-(1-f)\exp(-d)}$.
(2) The mass deficit at the partitioning must be made up. At the partitioning, we lose the mass $\Delta = fC_p + \alpha fC_1$. Because $C_1^o + C_p^o = C_1 + C_p = 1$, this is rewritten as $\Delta = f(1-C_1) + \alpha fC_1$.
(3) The reduction factor is defined as the ratio of the fuel nuclide mass lost as waste at the partitioning process to the mass made up. Therefore, $\rho = \frac{\alpha fC_1}{\Delta}$. Substituting the result of the previous problem,

$$\rho = \frac{\alpha C_1}{(1-C_1) + \alpha C_1} = \frac{\alpha C_1}{1 - C_1 + \alpha C_1} = \frac{\alpha f \exp(-d)}{1-(1-\alpha f)\exp(-d)}.$$