NUCL 511 HMWK 1

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Using the data given below, determine the I-135 and Xe-135 concentrations and generate their plots for the power history given on slide 20 of the lecture note 1.

One-group flux at full power ($\#/cm^2 s$)	1×10^{14}
Macroscopic fission cross section (Σ_f) (cm^{-1})	0.686
Fission yield of I-135	0.064
Half-life of I-135 (hr)	6.7
Fission yield of Xe-135	0.003
Half-life of Xe-135 (hr)	9.2
Microscopic Absorption cross section of Xe-135 ($barn$)	2.7×10^6

The power history from Slide 20 of the lecture note 1 is given in Figure 1.

We can split the power history into four sections:

1. The section before time $0\,hr$ where the concentrations are equal to their equilibrium concentrations.
2. The section between time $0\,hr$ and $60\,hr$ where the reactor is operating at half flux ($\phi = 0.5 \times 10^{15} \frac{n}{cm^2 s}$). In this case, the initial conditions will be the equilibrium values from the previous section.
3. The section between time $60\,hr$ and $120\,hr$ where the reactor is again operating at full flux ($\phi = 1.0 \times 10^{15} \frac{n}{cm^2 s}$). The initial conditions will be the final concentrations of the previous section, i.e. the concentrations just before time $60\,hr$.
4. Finally, the shutdown section, after $120\,hr$ where the flux has dropped to nothing ($\phi = 0 \frac{n}{cm^2 s}$). The initial conditions again come from the concentrations at the end of the last section (just before time $120\,hr$), but these are also equal to the equilibrium concentrations.

We can use the equilibrium equations from [1, p. 469]

$$N_I^{\infty} = \frac{\gamma_I F}{\overline{\lambda_I}} \tag{1}$$

$$N_{Xe}^{\infty} = \frac{\gamma_{Xe} F + \lambda_I N_I^{\infty}}{\overline{\lambda_{Xe}}} \tag{2}$$

to determine the values for section 1, and for all other sections we can use the equations solved from the rate equations in [1, pp. 468 - 469]

$$N_I(t) = N_I^0 \exp\left(-\overline{\lambda_I} t\right) + \frac{\gamma_I F}{\overline{\lambda_I}} \left(1 - \exp\left(-\overline{\lambda_I} t\right)\right) \tag{3}$$

$$\begin{aligned} N_{Xe}(t) = N_{Xe}^0 \exp\left(-\overline{\lambda_{Xe}} t\right) &+ \frac{\gamma_{Xe} F}{\overline{\lambda_{Xe}}} \left(1 - \exp\left(-\overline{\lambda_{Xe}} t\right)\right) + \frac{\gamma_I N_I^0}{\overline{\lambda_{Xe}} - \overline{\lambda_I}} \left(\exp\left(-\overline{\lambda_I} t\right) - \exp\left(-\overline{\lambda_{Xe}} t\right)\right) \\ &+ \frac{\lambda_I \gamma_I F}{\overline{\lambda_I}} \left[\frac{1}{\overline{\lambda_{Xe}}} \left(1 - \exp\left(-\overline{\lambda_{Xe}} t\right)\right) - \frac{1}{\overline{\lambda_{Xe}} - \overline{\lambda_I}} \left(\exp\left(-\overline{\lambda_I} t\right) - \exp\left(-\overline{\lambda_{Xe}} t\right)\right)\right] \end{aligned} \tag{4}$$

Finally, we can return results very similar to those provided in the slides, shown in Figure 2.

References

[1] John R Lamarsh. *Introduction to Nuclear Reactor Theory.* Addison-Wesley.

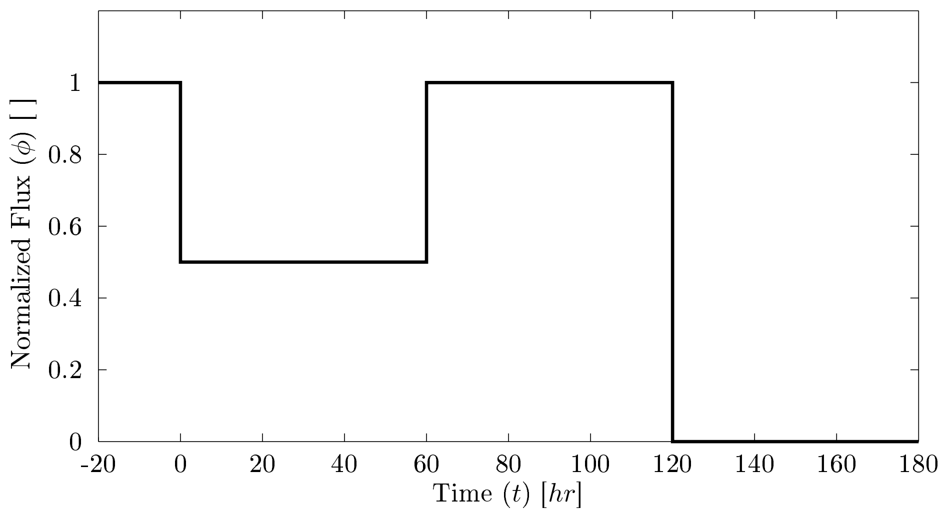

Figure 1: U-235 Fueled Reactor Power History - Adapted from Lecture Note 1, Slide 20

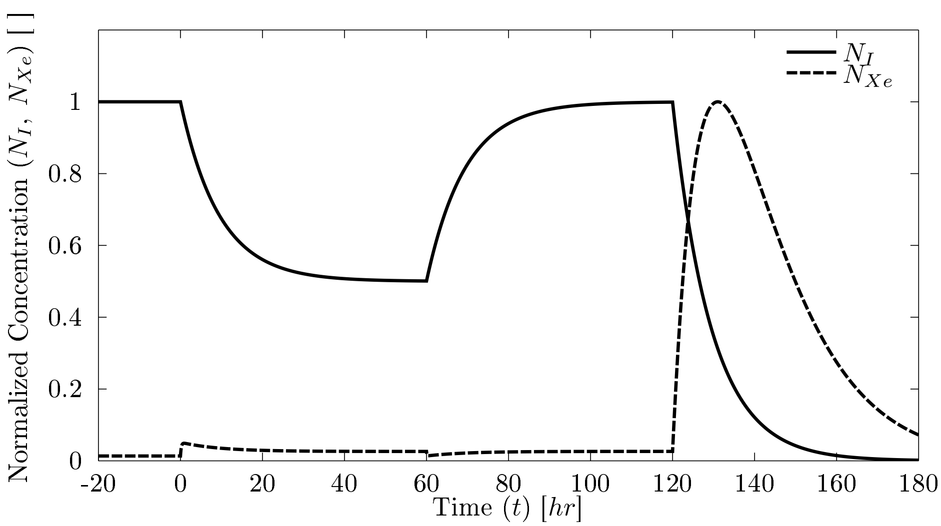

Figure 2: Xenon and Iodine Concentrations using Power History given by Figure 1