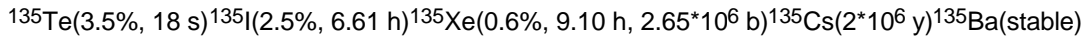


(19.13) A BWR has operated at full power for a week. At what time after a scram would the Xe poisoning reach its maximum? Use data in Table 19.4.

Consider the FP-chain:



After a week of full power operation the chain is in radioactive equilibrium.

For simplicity assume a reactor power of 1912 MW_{th} and a n-flux of $4.4 \cdot 10^{17} \text{ n m}^{-2} \text{ s}^{-1}$. These data are used to judge simplifications in the equations.

At equilibrium:

$$dN_{\text{Te}}/dt = F \cdot y_{\text{Te}} - N_{\text{Te}} \cdot \lambda_{\text{Te}}, \quad dN_{\text{I}}/dt = F \cdot (y_{\text{Te}} + y_{\text{I}}) - N_{\text{I}} \cdot \lambda_{\text{I}}, \quad \text{and} \quad dN_{\text{Xe}}/dt = F \cdot (y_{\text{Te}} + y_{\text{I}} + y_{\text{Xe}}) - N_{\text{Xe}} \cdot (\lambda_{\text{Xe}} + \phi \cdot \sigma_{\text{Xe}}),$$

where F is the fission rate during operation and zero after stop, ϕ is the neutron flux. As all dN/dt are zero, this leads to the relations:

$$N_{\text{Te}} = F \cdot y_{\text{Te}} / \lambda_{\text{Te}}, \quad N_{\text{I}} = F \cdot (y_{\text{Te}} + y_{\text{I}}) / \lambda_{\text{I}}, \quad \text{and} \quad N_{\text{Xe}} = F \cdot (y_{\text{Te}} + y_{\text{I}} + y_{\text{Xe}}) / (\lambda_{\text{Xe}} + \phi \cdot \sigma_{\text{Xe}}).$$

First we use these equations to look at the ratio between the number of Te, I and Xe atoms.

$$\text{barn} := 10^{-28} \cdot \text{m}^2$$

$$\phi := 4.4 \cdot 10^{17} \cdot \text{m}^{-2} \cdot \text{sec}^{-1}$$

$$P_{\text{th}} := 1912 \cdot 10^6 \cdot \text{watt}$$

$$f_{\text{U}} := 3.1 \cdot 10^{10} \cdot \text{sec}^{-1} \cdot \text{watt}^{-1}$$

$$F := P_{\text{th}} \cdot f_{\text{U}}$$

$$\sigma_{\text{Xe}} := 2.65 \cdot 10^6 \cdot \text{barn}$$

$$y_{\text{Te}} := 3.5 \cdot \%$$

$$y_{\text{I}} := 2.5 \cdot \%$$

$$y_{\text{Xe}} := 0.6 \cdot \%$$

$$t_{\text{hTe}} := 18 \cdot \text{sec}$$

$$t_{\text{hI}} := 6.61 \cdot \text{hr}$$

$$t_{\text{hXe}} := 9.10 \cdot \text{hr}$$

$$\lambda_{\text{Te}} := \frac{\ln(2)}{t_{\text{hTe}}}$$

$$\lambda_{\text{I}} := \frac{\ln(2)}{t_{\text{hI}}}$$

$$\lambda_{\text{Xe}} := \frac{\ln(2)}{t_{\text{hXe}}}$$

$$N_{\text{Te}} := \frac{F \cdot y_{\text{Te}}}{\lambda_{\text{Te}}}$$

$$N_{\text{I}} := \frac{F \cdot (y_{\text{Te}} + y_{\text{I}})}{\lambda_{\text{I}}}$$

$$N_{\text{Xe}} := \frac{F \cdot (y_{\text{Te}} + y_{\text{I}} + y_{\text{Xe}})}{\lambda_{\text{Xe}} + \phi \cdot \sigma_{\text{Xe}}}$$

$$\frac{N_{\text{Te}}}{N_{\text{I}}} = 4.413 \cdot 10^{-4}$$

$$\frac{N_{\text{I}}}{N_{\text{Xe}}} = 4.299$$

Hence we can neglect the initial number of atoms of shortlived Te in comparison with the number of I-atoms.

The solution for the mother-daughter problem $I > \text{Xe}$ is then sufficient. The eqn. for the amount of Xe is: $N_{\text{Xe}} = N_{0\text{Xe}} \cdot \exp(-\lambda_{\text{Xe}} \cdot t) + N_{0\text{I}} \cdot (\lambda_{\text{I}} / (\lambda_{\text{I}} - \lambda_{\text{Xe}})) \cdot (\exp(-\lambda_{\text{Xe}} \cdot t) - \exp(-\lambda_{\text{I}} \cdot t))$. From the time derivative ($=0$) of this equation we obtain the solution for the maximum in Xe-amount.

$$t_{\text{max}} := \frac{\ln \left[\frac{N_{\text{Xe}} \cdot \lambda_{\text{Xe}} + \frac{N_{\text{I}} \lambda_{\text{I}} \lambda_{\text{Xe}}}{\lambda_{\text{I}} - \lambda_{\text{Xe}}}}{\frac{\lambda_{\text{I}}^2}{N_{\text{I}} (\lambda_{\text{I}} - \lambda_{\text{Xe}})}} \right]}{\lambda_{\text{Xe}} - \lambda_{\text{I}}}$$

$$t_{\text{max}} = 3.237 \cdot 10^4 \cdot \text{sec}$$

$$t_{\text{max}} = 9 \cdot \text{hr}$$