(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:

^{135}Te(3.5%, 18 s)^{135}I(2.5%, 6.61 h)^{135}Xe(0.6%, 9.10 h, 2.65*10^{6} b)^{135}Cs(2*10^{6} y)^{135}Ba(stable)

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*10^{17} n m^{-2} s^{-1}. These data are used to judge simplifications in the equations.

At equilibrium:

$dN_{Te}/dt=F*y_{Te}-N_{Te}*\lambda_{Te}$, $dN_I/dt=F*(y_{Te}+y_I)-N_I*\lambda_I$, and $dN_{Xe}/dt=F*(y_{Te}+y_I+y_{Xe})-N_{Xe}*(\lambda_{Xe}+\phi*\sigma_{Xe})$,

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:

$N_{Te}=F*y_{Te}/\lambda_{Te}$, $N_I=F*(y_{Te}+y_I)/\lambda_I$, and $N_{Xe}=F*(y_{Te}+y_I+y_{Xe})/(\lambda_{Xe}+\phi*\sigma_{Xe})$.

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

$barn := 10^{-28}\cdot m^2$ $\qquad \phi := 4.4\cdot 10^{17}\cdot m^{-2}\cdot sec^{-1}$ $\qquad P_{th} := 1912\cdot 10^6\cdot watt$

$f_U := 3.1\cdot 10^{10}\cdot sec^{-1}\cdot watt^{-1}$ $\qquad F := P_{th}\cdot f_U$ $\qquad \sigma_{Xe} := 2.65\cdot 10^6\cdot barn$

$y_{Te} := 3.5\cdot\%$ $\qquad y_I := 2.5\cdot\%$ $\qquad y_{Xe} := 0.6\cdot\%$

$t_{hTe} := 18\cdot sec$ $\qquad t_{hI} := 6.61\cdot hr$ $\qquad t_{hXe} := 9.10\cdot hr$

$\lambda_{Te} := \frac{ln(2)}{t_{hTe}}$ $\qquad \lambda_I := \frac{ln(2)}{t_{hI}}$ $\qquad \lambda_{Xe} := \frac{ln(2)}{t_{hXe}}$

$N_{Te} := \frac{F\cdot y_{Te}}{\lambda_{Te}}$ $\qquad N_I := \frac{F\cdot(y_{Te}+y_I)}{\lambda_I}$ $\qquad N_{Xe} := \frac{F\cdot(y_{Te}+y_I+y_{Xe})}{\lambda_{Xe}+\phi\cdot\sigma_{Xe}}$

$\frac{N_{Te}}{N_I} = 4.413\cdot 10^{-4}$ $\qquad \frac{N_I}{N_{Xe}} = 4.299$ $\qquad$ 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 > Xe is then sufficient. The eqn. for the amount of Xe is: $N_{Xe}=N_{0Xe}*exp(-\lambda_{Xe}*t)+N_{0I}*(\lambda_I/(\lambda_I-\lambda_{Xe}))*(exp(-\lambda_{Xe}*t)-exp(\lambda_I*t))$. From the time derivative (=0) of this equation we obtain the solution for the maximum in Xe-amount.

$$t_{max} := \frac{ln\left[\frac{N_{Xe}\cdot\lambda_{Xe}+\frac{N_I\cdot\lambda_I\cdot\lambda_{Xe}}{\lambda_I-\lambda_{Xe}}}{N_I\cdot\frac{\lambda_I^2}{\lambda_I-\lambda_{Xe}}}\right]}{\lambda_{Xe}-\lambda_I} \qquad t_{max} = 3.237\cdot 10^4\cdot sec \qquad t_{max} = 9\cdot hr$$