(19.6) The world's first water boiler reactor (LOPO, Los Alamos, 1944) was a homogeneous solution of enriched uranium sulfate as follows: 580 g ^{235}U, 3378 g ^{238}U, 534 g S, 14068 g O, and 1573 g H. From these values, and Tables 19.2 and 19.3, calculate η and *f*; neglect S. With *p* = 0.957, what will k_{infinity} be?

Data, constants, and units:

$barn := 10^{-28} \cdot m^2$ $\quad N_A := 6.022137 \cdot 10^{23} \cdot mole^{-1}$

$\sigma_{\gamma 235} := 98.6 \cdot barn$ $\quad \sigma_{\gamma 238} := 2.70 \cdot barn$ $\quad \sigma_{aH2O} := 0.66 \cdot barn$

$\sigma_{f235} := 582.2 \cdot barn$ $\quad \sigma_{f238} := 0.5 \cdot 10^{-3} \cdot barn$ $\quad \nu_{235} := 2.418$

$M_{235} := 235 \cdot gm \cdot mole^{-1}$ $\quad M_{238} := 238 \cdot gm \cdot mole^{-1}$

$M_O := 16.00 \cdot gm \cdot mole^{-1}$ $\quad M_H := 1.008 \cdot gm \cdot mole^{-1}$

Data given in the text:

$m_{235} := 580 \cdot gm$ $\quad m_{238} := 3378 \cdot gm$ $\quad p := 0.957$

$m_O := 14068 \cdot gm$ $\quad m_H := 1573 \cdot gm$ $\quad m_S := 534 \cdot gm$

Calculations:

$N_{235} := \frac{m_{235}}{M_{235}} \cdot N_A$ $\quad N_{238} := \frac{m_{238}}{M_{238}} \cdot N_A$

$x_{235} := \frac{N_{235}}{N_{235} + N_{238}}$ $\quad x_{238} := 1 - x_{235}$

$\alpha := \frac{\sigma_{\gamma 235} \cdot x_{235} + \sigma_{\gamma 238} \cdot x_{238}}{\sigma_{f235} \cdot x_{235}}$ $\quad \alpha = 0.196$ $\quad \eta := \frac{\nu_{235}}{1 + \alpha}$ $\quad \eta = 2.022$

$s_{afuel} := N_{235} \cdot \left(\sigma_{\gamma 235} + \sigma_{f235}\right) + N_{238} \cdot \sigma_{\gamma 238}$

$N_{H2O} := \frac{m_O + m_H}{2 \cdot M_H + M_O} \cdot N_A$ $\quad s_{aH2O} := \sigma_{aH2O} \cdot N_{H2O}$

$f := \frac{s_{afuel}}{s_{afuel} + s_{aH2O}}$ $\quad f = 0.750$ $\quad \varepsilon := 1$ $\quad$ ε = 1 for any homogeneous and dilute reactor

$k_{infinity} := \eta \cdot \varepsilon \cdot p \cdot f$ $\quad k_{infinity} = 1.451$