(19.8) A cubic unreflected graphite moderated natural uranium reactor contains 3% enriched uranium as UC homogeneously dispersed in the graphite matrix; the weight ratio C/U = 10. The resonance passage and thermal utilization factors are both assumed to be 0.9; ε = 1.00. Make an estimate of the critical size of the cube.

Data, constants, and units:

$N_A := 6.022137 \cdot 10^{23} \cdot mole^{-1}$ $Mw_U := \frac{3 \cdot 235 + 97 \cdot 238}{100} \cdot gm \cdot mole^{-1}$ $Mw_C := 12.00 \cdot gm \cdot mole^{-1}$

$barn := 10^{-28} \cdot m^2$ $\tau := 0.0380 \cdot m^2$ $L_{m2} := 0.287 \cdot m^2$

$\sigma_{\gamma 235} := 98.6 \cdot barn$ $\sigma_{f235} := 582.2 \cdot barn$ $\nu_{235} := 2.418$

$\sigma_{\gamma 238} := 2.70 \cdot barn$ $\sigma_{f238} := 0.5 \cdot 10^{-3} \cdot barn$

Data given in the text:

$\varepsilon := 1$ $p := 0.9$ $f := 0.9$

Calculations:

$m_U := 1 \cdot kg$ assumed for simplicity in calculation of mixture properties

$m_C := 10 \cdot m_U$ $N_U := \frac{m_U}{Mw_U} \cdot N_A$

$N_{235} := 0.03 \cdot N_U$ $N_{238} := 0.97 \cdot N_U$

$x_{235} := \frac{N_{235}}{N_{235} + N_{238}}$ $x_{238} := 1 - x_{235}$ $\alpha := \frac{\sigma_{\gamma 235} \cdot x_{235} + \sigma_{\gamma 238} \cdot x_{238}}{\sigma_{f235} \cdot x_{235}}$

$\eta := \frac{\nu_{235}}{1 + \alpha}$ $k_{inf} := \eta \cdot \varepsilon \cdot p \cdot f$ $k_{inf} = 1.485$

$L_2 := L_{m2} \cdot (1 - f)$ $M_2 := L_2 + \tau$

$B_2 := \frac{k_{inf} - 1}{M_2}$ $sidelength := \sqrt{\frac{33}{B_2}}$ $sidelength = 2.131 \cdot \mathrm{m}$