(18.6) A γ-dose rate of 1 Sv is assumed to inactivate (kill) human cells. The body contains $6*10^{13}$ cells in a cell weight of 42 kg for a 70 kg man. (a) What average energy (in eV) has to be deposited in a cell to kill it? (b) Calculate the number of kidney cells destroyed for the dose received in exercise 18.5. For simplicity assume the cells to be cubic with a side length of about 11 µm.

Data, constants, and units:

$eV := 1.6021773 \cdot 10^{-19} \cdot joule$ $\quad MeV := 10^{6} \cdot eV$ $\quad keV := 1000 \cdot eV$ $\quad \mu m := 10^{-6} \cdot m$

$w_{R\beta\gamma} := 1$ $\quad w_{R\alpha} := 20$ $\quad E_{\alpha} := 4.198 \cdot MeV$ $\quad Sv := joule \cdot kg^{-1}$

Data given in the text:

$H_{kill} := 1 \cdot Sv$ $\quad m_{cells} := 42 \cdot kg$ $\quad m_{body} := 70 \cdot kg$

$D_{kill} := \dfrac{H_{kill}}{w_{R\beta\gamma}}$ $\quad m_{cell} := \dfrac{m_{cells}}{6 \cdot 10^{13}}$

(a)

$D_{tot} := m_{cells} \cdot D_{kill}$ $\quad d_{cell} := \dfrac{D_{tot}}{6 \cdot 10^{13}}$ $\quad d_{cell} = 7 \cdot 10^{-13} \cdot joule$ $\quad d_{cell} = 4.37 \cdot MeV$

Answer 4.37 MeV

(b) For α w_r is 20. By interpolation in Table 6.2 we obtain LET=157 keV/µm for E_{α}=4.198 MeV from 238U.

$LET := 157 \cdot \dfrac{keV}{\mu m}$ $\quad range := \dfrac{E_{\alpha}}{LET}$ $\quad range = 2.674 \cdot 10^{-5} \cdot m$ $\quad l_{cell} := 11 \cdot 10^{-6} \cdot m$

$n_{cells} := \dfrac{range}{l_{cell}}$ $\quad n_{cells} = 2.4$ $\quad$ thus a little more than 2 cells are affected

$e_{cell} := \dfrac{E_{\alpha}}{3 \cdot d_{cell}}$ $\quad e_{cell} \cdot w_{R\alpha} = 6.406$ $\quad$ thus 1 alpha kills 3 cells with margin.

The number of ^{238}U decayed i the kidneys can be calculated as follows:

$t_{biol} := 15 \cdot day$ $\quad$ this is so much shorter than the half-life of ^{238}U that we can neglect the physical half-life.

$\lambda_{eff} := \dfrac{ln(2)}{t_{biol}}$ $\quad t_{mean} := \dfrac{1}{\lambda_{eff}}$ $\quad R_{0U} := 124.392 \cdot sec^{-1}$ $\quad$ from 18.5

$Decays := t_{mean} \cdot R_{0U}$ $\quad Decays = 2.326 \cdot 10^{8}$

$Killed := 3 \cdot Decays$ $\quad Killed = 6.98 \cdot 10^{8}$

Answer: $6.98\ 10^{8}$ cells