(18.2) Using the information above, how many grams of the body's molecules (assume average mole weight of 10^5) will be damaged in a year if the *G*(damage) value is $3.1*10^{-7}$ mol/J? Assume $E_{abs}(\beta) = E_{max}/3$.

Constants, units, and data:

$Bq := sec^{-1}$ $\quad eV := 1.6021773 \cdot 10^{-19} \cdot joule$ $\quad MeV := 10^6 \cdot eV$

$N_A := 6.022137 \cdot 10^{23} \cdot mole^{-1}$ $\quad M_w := 10^5 \cdot gm \cdot mole^{-1}$ $\quad G_{value} := 3.1 \cdot 10^{-7} \cdot mole \cdot joule^{-1}$

$t_{irr} := 1 \cdot yr$ $\quad t_{irr} = 3.156 \cdot 10^7 \cdot sec$ $\quad m_{body} := 70 \cdot kg$

Calculations:

$R_{3H} := 163.548 \cdot Bq$ $\quad E_{abs3H} := \frac{0.0186}{3} \cdot MeV$ $\quad E_{abs3H} = 9.933 \cdot 10^{-16} \cdot joule$

$R_{14C} := 2.848 \cdot 10^3 \cdot Bq$ $\quad E_{abs14C} := \frac{0.1565}{3} \cdot MeV$ $\quad E_{abs14C} = 8.358 \cdot 10^{-15} \cdot joule$

$R_{40K} := 4.388 \cdot 10^3 \cdot Bq$ $\quad E_{abs40K} := \frac{1.31 \cdot 0.8933}{3} \cdot MeV$ $\quad E_{abs40K} = 6.25 \cdot 10^{-14} \cdot joule$

$R_{Ra} := 0.37 \cdot Bq$ $\quad$ Data for the decay chain are found in Fig. 5.1. and/or a nuclide chart, etc.

The main decay chain:

$^{226}Ra(\alpha)^{222}Rn(\alpha)^{218}Po(\alpha)^{214}Pb(\beta^-)^{214}Bi(\beta^-)^{214}Po(\alpha)^{210}Pb(\beta^-)^{210}Bi(\beta^-)^{210}Po(\alpha)$

$E_{\alpha 226Ra} := 4.784 \cdot MeV$ $\quad Q_{226Ra} := E_{\alpha 226Ra} \cdot \frac{226}{222}$ $\quad Q_{226Ra} = 4.87 \cdot MeV$

$E_{\alpha 222Rn} := 5.490 \cdot MeV$ $\quad Q_{222Rn} := E_{\alpha 222Rn} \cdot \frac{222}{218}$ $\quad Q_{222Rn} = 5.591 \cdot MeV$

$E_{\alpha 218Po} := 6.003 \cdot MeV$ $\quad Q_{218Po} := E_{\alpha 218Po} \cdot \frac{218}{214}$ $\quad Q_{218Po} = 6.115 \cdot MeV$

Neglect the recoil energy of the daughter for the beta emitting daughters, but include γ:s

$E_{\beta 214Pb} := 0.7 \cdot MeV$ $\quad E_{\gamma 214Pb} := 0.352 \cdot MeV$

$Q_{214Pb} := E_{\beta 214Pb} \cdot \frac{1}{3} + 37 \cdot \% \cdot E_{\gamma 214Pb}$ $\quad Q_{214Pb} = 0.364 \cdot MeV$

$E_{\beta 214Bi} := 3.3 \cdot MeV$ $\quad E_{\gamma 214Bi} := 1.508 \cdot MeV$ $\quad$ Average for main γ:s from Table of Isotopes

$Q_{214Bi} := E_{\beta 214Bi} \cdot \frac{1}{3} + E_{\gamma 214Bi}$ $\quad Q_{214Bi} = 2.608 \cdot MeV$

$E_{\alpha 214Po} := 7.687 \cdot MeV$ $\quad Q_{214Po} := E_{\alpha 214Po} \cdot \frac{214}{210}$ $\quad Q_{214Po} = 7.833 \cdot MeV$

Include the assumption that the 5 daughters have 0.3 decays for each decay of ^{226}Ra in the energy sum

$$E_{absRa} := Q_{226Ra} + 0.3 \cdot \left(Q_{222Rn} + Q_{218Po} + Q_{214Pb} + Q_{214Bi} + Q_{214Po}\right)$$

$$Q_{tot} := t_{irr} \cdot \left(R_{3H} \cdot E_{abs3H} + R_{14C} \cdot E_{abs14C} + R_{40K} \cdot E_{abs40K} + R_{Ra} \cdot E_{absRa}\right)$$

$N_{damaged} := Q_{tot} \cdot G_{value}$ $\quad N_{damaged} = 2.924 \cdot 10^{-9} \cdot mole$

$m_{damaged} := N_{damaged} \cdot M_w$ $\quad m_{damaged} = 2.92 \cdot 10^{-4} \cdot gm$