

(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 $G(\text{damage})$ value is $3.1 \cdot 10^{-7} \text{ mol/J}$? Assume $E_{\text{abs}}(\beta) = E_{\text{max}}/3$.

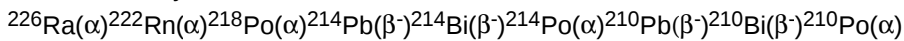
Constants, units, and data:

$$\begin{aligned} Bq &:= \text{sec}^{-1} & eV &:= 1.6021773 \cdot 10^{-19} \cdot \text{joule} & MeV &:= 10^6 \cdot eV \\ N_A &:= 6.022137 \cdot 10^{23} \cdot \text{mole}^{-1} & M_w &:= 10^5 \cdot \text{gm} \cdot \text{mole}^{-1} & G_{\text{value}} &:= 3.1 \cdot 10^{-7} \cdot \text{mole} \cdot \text{joule}^{-1} \\ t_{\text{irr}} &:= 1 \cdot \text{yr} & t_{\text{irr}} &= 3.156 \cdot 10^7 \cdot \text{sec} & m_{\text{body}} &:= 70 \cdot \text{kg} \end{aligned}$$

Calculations:

$$\begin{aligned} R_{3H} &:= 163.548 \cdot Bq & E_{\text{abs}3H} &:= \frac{0.0186}{3} \cdot \text{MeV} & E_{\text{abs}3H} &= 9.933 \cdot 10^{-16} \cdot \text{joule} \\ R_{14C} &:= 2.848 \cdot 10^3 \cdot Bq & E_{\text{abs}14C} &:= \frac{0.1565}{3} \cdot \text{MeV} & E_{\text{abs}14C} &= 8.358 \cdot 10^{-15} \cdot \text{joule} \\ R_{40K} &:= 4.388 \cdot 10^3 \cdot Bq & E_{\text{abs}40K} &:= \frac{1.31 \cdot 0.8933}{3} \cdot \text{MeV} & E_{\text{abs}40K} &= 6.25 \cdot 10^{-14} \cdot \text{joule} \\ R_{Ra} &:= 0.37 \cdot Bq & \text{Data for the decay chain are found in Fig. 5.1. and/or a nuclide chart, etc.} & & & \end{aligned}$$

The main decay chain:



$$\begin{aligned} E_{\alpha 226\text{Ra}} &:= 4.784 \cdot \text{MeV} & Q_{226\text{Ra}} &:= E_{\alpha 226\text{Ra}} \cdot \frac{226}{222} & Q_{226\text{Ra}} &= 4.87 \cdot \text{MeV} \\ E_{\alpha 222\text{Rn}} &:= 5.490 \cdot \text{MeV} & Q_{222\text{Rn}} &:= E_{\alpha 222\text{Rn}} \cdot \frac{222}{218} & Q_{222\text{Rn}} &= 5.591 \cdot \text{MeV} \\ E_{\alpha 218\text{Po}} &:= 6.003 \cdot \text{MeV} & Q_{218\text{Po}} &:= E_{\alpha 218\text{Po}} \cdot \frac{218}{214} & Q_{218\text{Po}} &= 6.115 \cdot \text{MeV} \end{aligned}$$

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

$$\begin{aligned} E_{\beta 214\text{Pb}} &:= 0.7 \cdot \text{MeV} & E_{\gamma 214\text{Pb}} &:= 0.352 \cdot \text{MeV} \\ Q_{214\text{Pb}} &:= E_{\beta 214\text{Pb}} \cdot \frac{1}{3} + 37\% \cdot E_{\gamma 214\text{Pb}} & Q_{214\text{Pb}} &= 0.364 \cdot \text{MeV} \\ E_{\beta 214\text{Bi}} &:= 3.3 \cdot \text{MeV} & E_{\gamma 214\text{Bi}} &:= 1.508 \cdot \text{MeV} & \text{Average for main } \gamma\text{'s from Table of Isotopes} \\ Q_{214\text{Bi}} &:= E_{\beta 214\text{Bi}} \cdot \frac{1}{3} + E_{\gamma 214\text{Bi}} & Q_{214\text{Bi}} &= 2.608 \cdot \text{MeV} \\ E_{\alpha 214\text{Po}} &:= 7.687 \cdot \text{MeV} & Q_{214\text{Po}} &:= E_{\alpha 214\text{Po}} \cdot \frac{214}{210} & Q_{214\text{Po}} &= 7.833 \cdot \text{MeV} \end{aligned}$$

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

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

$$Q_{\text{tot}} := t_{\text{irr}} \cdot (R_{3H} \cdot E_{\text{abs}3H} + R_{14C} \cdot E_{\text{abs}14C} + R_{40K} \cdot E_{\text{abs}40K} + R_{Ra} \cdot E_{\text{abs}Ra})$$

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

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