1) The half-life of $^{14}$C is 5730 years. A mummified body is found high in the Andes and determined to have 32% of the amount of $^{14}$C that it had when alive. How old is the body in years? (4 pts)

$$N(t) = N_0 e^{-\lambda t}$$

where \( \lambda = \frac{\ln 2}{T_{1/2}} \)

$$\frac{N(t)}{N_0} = e^{-\frac{\lambda t}{T_{1/2}}} = \frac{32}{100} = 0.32$$

\(\downarrow\)

$$e^{-\frac{\lambda t}{T_{1/2}}} = 0.32 = e^{\ln 0.32}$$

\(\downarrow\)

$$-\frac{\lambda t}{T_{1/2}} = \ln 0.32 \Rightarrow \frac{t}{T_{1/2}} = \frac{T_{1/2}}{\ln 2} \ln 0.32 = 9419 \text{ yr}$$

2) There are $3 \times 10^7$ radon atoms ($T_{1/2} = 3.83 \text{ days} = 3.3 \times 10^5 \text{ s}$) trapped in a basement. What is the activity, in units of Bq, after 31 days? (4 pts)

$$N(t) = N_0 e^{-\lambda t}$$

where \( \lambda = \frac{\ln 2}{T_{1/2}} \)

$$N(31 \text{ days}) = N_0 e^{-\frac{\lambda t}{T_{1/2}}} = 3 \times 10^7 e^{-\frac{31 \text{ days}}{3.3 \times 10^5\text{s}}} = 1.09 \times 10^5$$

Activity = \( \frac{\Delta N}{\Delta t} = \lambda N = \frac{\ln 2}{T_{1/2}} \cdot N = \frac{\ln 2}{3.3 \times 10^5} \cdot 1.09 \times 10^5 \)

= 0.23 s\(^{-1}\) = 0.23 Bq

(CONTINUED ON OTHER SIDE)

Rewrite and sign the honor pledge: “I pledge my honor that I have not violated the Honor Code during this examination.”

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3) In 1 kg of seawater, there are $1 \times 10^{22}$ deuterium nuclei (1 proton, 1 neutron). If each nucleus produces 7.2 MeV in a fusion reaction, how many kilograms of seawater would be needed to supply the energy needs of the US for one year? The annual energy consumption is estimated to be $9 \times 10^{19}$ J. (2 pts)

$$\text{Number of Kgs} = \frac{\text{Annual Energy Consumption}}{\text{Fission energy per Kg of seawater}}$$

$$= \frac{9 \times 10^{19} \text{ J}}{4.2 \times 10^6 \text{ eV/nucleus} \times 1 \times 10^{22} \text{ nuclei/Kg}}$$

$$= 1.25 \times 10^{-9} \text{ Kg/J} \cdot \frac{1 \text{ eV}}{1.6 \times 10^{-19} \text{ J}}$$

$$= 7.8 \times 10^9 \text{ Kg}$$