1. 15-11, p.378

Energy from natural radioactivity in rock helps keep things hot well below ground. I don't think this is the only source of heat ... but it contributes in the mantle of the earth.

2. 15-12, p.378

The particles produced in radioactive decay interact with surrounding matter by ionizing atoms. When electrons are captured by the ionized atoms, light is emitted.

3. 15-16, p.378  Find residual nucleus in \( \beta \) decay of \( ^3H \)

\[
^3H \rightarrow ^3He + e^- + \nu \quad \beta = e^- \\
Z \rightarrow Z+1 \quad A \text{ unchanged}
\]

\[
^{222}_{86}\text{Rn} \rightarrow ^{218}_{84}\text{Po} + \alpha
\]

\[
Z \rightarrow Z-2, \quad A \rightarrow A-4
\]

\[
\text{Rn} = Z \text{ of } 86 \rightarrow Z = 84 \text{ Po}
\]
15-19, p. 378

If isotope has 6-month half-life — what fraction remains after 5 years

5 years = 10 half lives

\[
\text{fraction remaining} = \frac{1}{2} \times \frac{1}{2} \times \frac{1}{2} \times \frac{1}{2} \times \frac{1}{2} \times \frac{1}{2} \times \frac{1}{2} \times \frac{1}{2} = \left(\frac{1}{2}\right)^{10}
\]

\[= 9.7 \times 10^{-9} \approx 0.001\]

15-24, p. 378

Start with 1 gram of pure \(^{14}C\)

How much left after 12,000 yro?

\(2,12\) for \(^{14}C\) ~ 6,000 yrs from Table 15-1 p. 363

12,000 yrs = 2 half-lives

\[
\text{fraction remaining} = \left(\frac{1}{2}\right) \times \left(\frac{1}{2}\right) = \frac{1}{4}
\]

Amount of \(^{14}C\) remaining is \(\frac{1}{4}\) gram.
6  15-25  p 378

Starting with 2 grams of radon, how much remains after 12 days?

\[ t_{1/2} \text{ radon} = 4 \text{ days} \]

12 days = 3 half-lives of radon

Fraction remaining = \( \frac{1}{2} \times \frac{1}{2} \times \frac{1}{2} = \frac{1}{8} \)

(2 grams) \( \frac{1}{8} = \frac{1}{4} \text{ gram radon remaining} \)

7  15-27, p 378

Most stable \( \rightarrow \) isotope with longest half life \( \rightarrow 238U \)

Least stable \( \rightarrow \) isotope with shortest half life \( \rightarrow ^{214}Pb \)

8  15-34, p 378

No, the dead sea scrolls could not have been dated using \(^{14}C\)
if they were carved in stone —

1) We don’t know the original amount of \(^{14}C\) in a stone.
2) Stones were likely formed so long ago that the \(^{14}C\) would have decayed away.
3) The dating would provide the date of the stone rather than the date that the writing was carved on the stone.
have 1 gram each of $^{131}$I and $^{234}$Th

how much do you have of each after 24 days?

t$_{1/2}$ of $^{131}$I = 8 days from Table 15.1

t$_{1/2}$ of $^{234}$Th = ? Not in Table 15.1

= 24.1 days from Wikipedia

At end of 24 days

\[
\begin{align*}
\text{3 half-lives for } ^{131}\text{I} \\
\text{Fraction left is } \frac{1}{2} \times \frac{1}{2} \times \frac{1}{2} = \frac{1}{8} \\
\text{1/8 gram of } ^{131}\text{I remains}
\end{align*}
\]

\[
\begin{align*}
\text{1 half-life of } ^{234}\text{Th} \\
\text{Fraction left is } \frac{1}{2} \\
\text{1/2 gram } ^{234}\text{Th remains}
\end{align*}
\]
How old is axe?

After 1 half-life 50% remains
After 2 half-lives 25% remains
After 3 half-lives 12.5% remains

$T_{1/2}^{14C} \approx 6000 \text{ yrs}$

So, sample is $\approx 14,000 \text{ years old}$

---

$P_{100}$ does not need to know how to do it this way. Can do a bit more carefully using more complicated/precise formulation.

\[ N = N_0 e^{-\lambda t} \]
\[ \lambda = \frac{0.693}{T_{1/2}} = 1.1 \times 10^{-4} \text{ yr}^{-1} \]
\[ t = \frac{-\ln 0.5}{\lambda} = 1.46 \times 10^4 \text{ yrs} \]

So, if 20% remains sample must be a bit over 2 half-lives old.
15-5 and 15-6, p 379

$^{238}\text{U}$ has $t_{1/2} = 4.5 \times 10^9$ yrs

$^{235}\text{U}$ has $t_{1/2} = 0.7 \times 10^9$ yrs

Earth ~ 4.5 billion yrs old

1 billion = $1 \times 10^9$ yrs

Approx $\frac{1}{2}$ of $^{238}\text{U}$ left (1 half-life)

6.5 half-lives have passed for $^{235}\text{U}$

Fraction left $^6$ 6 half-lives $= \left(\frac{1}{2}\right)^6 = 0.016$

""" 7 """ $= \left(\frac{1}{2}\right)^7 = 0.008$

After 6.5 half-lives ... expect fraction remaining

to be ~ 0.011
\[ \frac{4}{2} \text{He} + \frac{8}{4} \text{Be} \rightarrow \frac{12}{6} \text{C} \]

Carbon \rightarrow \text{release energy of fusion}

Gold \rightarrow \text{"..." fission}

Iron \rightarrow \text{neither}

He has a charge of +2. Temp needs to be higher so that nuclei can approach close enough together for fusion to happen. The higher the nuclear charge - the harder it is to overcome nuclear repulsion.