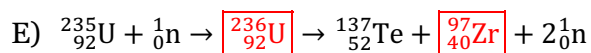
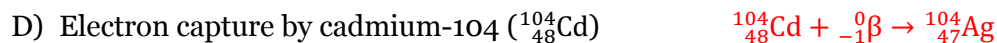
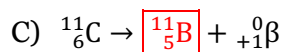
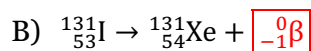
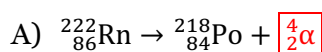


1. Consider a radioactive nuclide of element X with mass number A and atomic number Z. Write a general nuclear equation for each type of decay in the table below.

Decay Type	General Nuclear Equation	Description
β decay	${}^A_ZX \rightarrow {}^A_{Z+1}Y + {}^0_{-1}\beta$	Neutron-rich
positron emission	${}^A_ZX \rightarrow {}^A_{Z-1}Y + {}^0_{+1}\beta$	Neutron-poor
electron capture	${}^0_{-1}\beta + {}^A_ZX \rightarrow {}^A_{Z-1}Y$	Neutron-poor
α decay	${}^A_ZX \rightarrow {}^{A-4}_{Z-2}Y + {}^4_2\alpha$	Neutron-rich ($Z > 83$)

2. Complete each nuclear reaction given below.



3. Both carbon-14 and potassium-40 can be used for radiometric dating. The half-life of ${}^{14}\text{C}$ is 5730 years and the half-life of ${}^{40}\text{K}$ is 1.28×10^9 years.

$$\text{Rate} = kN \quad t_{1/2} = \frac{\ln 2}{k} \quad t = -\frac{1}{k} \ln \frac{N_t}{N_0}$$

- A) Which radioisotope is preferred for radiodating a rock that is 20,000 years old?

${}^{14}\text{C}$ because more half-lives have past and so there is a more appreciable/measurable ratio.

- B) Neither method is good for a 200,000-year-old rock. Calculate the fraction of ${}^{14}\text{C}$ and ${}^{40}\text{K}$ remaining in the rock to determine why this is so.

$$\frac{N_t}{N_0} = 0.5^{t/t_{1/2}} \rightarrow {}^{14}\text{C}: \frac{N_t}{N_0} = 0.5^{\frac{200,000}{5730}} = 3.1 \times 10^{-11} \quad {}^{40}\text{K}: \frac{N_t}{N_0} = 0.5^{\frac{200,000}{1.28 \times 10^9}} = 1.00$$

Too many half-lives have passed for ${}^{14}\text{C}$ and too few for ${}^{40}\text{K}$ for any measurable ratio.

4. Mercury-197 has a half-life of 65 hours. What fraction of a mercury sample remains after 6 days?

$$t = -\frac{1}{k} \ln \frac{N_t}{N_0} \qquad 6 \text{ days} \times \frac{24 \text{ hr}}{1 \text{ day}} = -\frac{65 \text{ hr}}{\ln 2} \ln \frac{N_t}{N_0}$$

$$\ln \frac{N_t}{N_0} = -1.536$$

$$\frac{N_t}{N_0} = 0.22 \text{ (22 \%)}$$

5. Iron-56 is often considered the most stable nuclide although it is actually the third-most stable. Nickel-62 is the most stable nuclide. Given the mass of a proton, neutron, and measured mass of ${}^{62}_{28}\text{Ni}$ below, calculate the binding energy *per nucleon* for ${}^{62}_{28}\text{Ni}$.

$$m_{\text{proton}} = 1.0073 \text{ amu}$$

$$m_{\text{neutron}} = 1.0087 \text{ amu}$$

$$m_{{}^{62}_{28}\text{Ni}} = 61.9283 \text{ amu}$$

Recall $\Delta E = \Delta mc^2$ where $c = 3.00 \times 10^8 \text{ m/s}$, $1 \text{ amu} = 1.66 \times 10^{-27} \text{ kg}$, and $1 \text{ J} = 1 \text{ kg} \cdot (\text{m/s})^2$.

${}^{62}_{28}\text{Ni}$ has 28 protons and 34 neutrons, a total of 62 nucleons. So, the mass defect is:

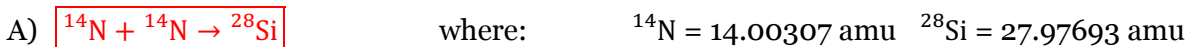
$$\begin{aligned} \Delta m &= (\text{measured mass}) - (\text{expected mass}) \\ &= m_{{}^{62}_{28}\text{Ni}} - [28 \times m_{\text{protons}} + 34 \times m_{\text{neutrons}}] \\ &= 61.9283 \text{ amu} - [28 \times (1.0073 \text{ amu}) + 34 \times (1.0087 \text{ amu})] \\ \Delta m &= -0.5719 \text{ amu} \end{aligned}$$

Therefore, the binding energy per nickel-62 nucleus is:

$$\begin{aligned} \text{BE} &= |\Delta m|c^2 \\ &= \left| -0.5719 \text{ amu} \times \frac{1.66 \times 10^{-27} \text{ kg}}{1 \text{ amu}} \right| \times \left(3.00 \times 10^8 \frac{\text{m}}{\text{s}} \right)^2 \\ \text{BE} &= 8.544 \times 10^{-11} \text{ J} \end{aligned}$$

And, the binding energy per nucleon is $1.378 \times 10^{-12} \text{ J/nucleon}$.

6. Silicon-28 can be made by many different nuclear fusion reactions. Which of the two fusion reactions, A or B, releases the greater amount of energy?



The magnitude of the mass defect ($|\Delta m|$) is proportional to the energy released.

A) $\Delta m = m_{\text{Si}} - 2 \times m_{\text{N}} = 27.97693 \text{ amu} - 2 \times (14.00307 \text{ amu}) = -0.02921 \text{ amu}$

B) $\Delta m = m_{\text{Si}} - [m_{\text{O}} + m_{\text{C}}] = 27.97693 \text{ amu} - [15.99491 + 12.00000] \text{ amu} = -0.01798 \text{ amu}$

Computing the energies released directly is also okay:

A) $\Delta E = \left(-0.02921 \text{ amu} \times \frac{1.66 \times 10^{-27} \text{ kg}}{1 \text{ amu}} \right) \times \left(3.00 \times 10^8 \frac{\text{m}}{\text{s}} \right)^2 = -4.364 \times 10^{-12} \text{ J}$

B) $\Delta E = \left(-0.01798 \text{ amu} \times \frac{1.66 \times 10^{-27} \text{ kg}}{1 \text{ amu}} \right) \times \left(3.00 \times 10^8 \frac{\text{m}}{\text{s}} \right)^2 = -2.686 \times 10^{-12} \text{ J}$

Propose an alternative fusion reaction to produce ${}^{28}\text{Si}$.

