The following atoms all undergo alpha particle emission. Write the complete nuclear equation.

\[ ^{210}_{84}\text{Po} \rightarrow \frac{4}{2}\text{He} + ^{196}_{82}\text{Pb} \]
\[ ^{238}_{92}\text{U} \rightarrow \frac{4}{2}\text{He} + ^{234}_{90}\text{Th} \]
\[ ^{238}_{90}\text{Th} \rightarrow \frac{4}{2}\text{He} + ^{234}_{88}\text{Ra} \]
\[ ^{222}_{86}\text{Rn} \rightarrow \frac{4}{2}\text{He} + ^{198}_{84}\text{Po} \]

The following atoms all undergo beta decay. Write the complete nuclear equation.

\[ ^{14}_{6}\text{C} \rightarrow \text{e}^- + ^{14}_{7}\text{N} \]
\[ ^{90}_{38}\text{Sr} \rightarrow \text{e}^- + ^{90}_{39}\text{Y} \]
\[ ^{40}_{19}\text{K} \rightarrow \text{e}^- + ^{40}_{20}\text{Ca} \]
\[ ^{13}_{7}\text{N} \rightarrow \text{e}^- + ^{13}_{8}\text{O} \]

The following all undergo electron capture. Write the complete nuclear equation.

\[ ^{106}_{47}\text{Ag} + \text{e}^- \rightarrow ^{106}_{46}\text{Pd} \]
\[ ^{116}_{50}\text{Sn} + \text{e}^- \rightarrow ^{116}_{49}\text{In} \]
\[ ^{190}_{78}\text{Pt} + \text{e}^- \rightarrow ^{190}_{77}\text{Ir} \]
\[ ^{123}_{53}\text{I} + \text{e}^- \rightarrow ^{123}_{52}\text{Te} \]
The following all undergo positron emission. Write the complete nuclear equation.

\[ ^{116}_{50}\text{Sn} \rightarrow \,^{49}_{33}\text{In} \,^{+1}_{0}\text{e} \]

\[ ^{61}_{29}\text{Cu} \rightarrow \,^{28}_{18}\text{Ni} \,^{+1}_{0}\text{e} \]

\[ ^{30}_{16}\text{S} \rightarrow \,^{15}_{7}\text{P} \,^{+1}_{0}\text{e} \]

\[ ^{85}_{38}\text{Sr} \rightarrow \,^{37}_{17}\text{Rb} \,^{+1}_{0}\text{e} \]

Complete the missing information in the reactions. Then, label the reaction one of the following:
- Alpha Decay \((\alpha)\)
- Beta Decay \((-\beta)\)
- Electron Capture \((EC)\)
- Positron Emission \((+\beta)\)

\[ ^{14}_{6}\text{C} \rightarrow \,^{7}_{7}\text{N} \,^{0}_{-1}\text{e} \]

Type: \(-\beta\)

\[ ^{238}_{92}\text{U} \rightarrow \,^{234}_{90}\text{Th} \,^{4}_{2}\text{He} \]

Type: \(\alpha\)

\[ ^{15}_{8}\text{O} \rightarrow \,^{7}_{7}\text{N} \,^{0}_{+1}\text{e} \]

Type: \(+\beta\)

\[ ^{32}_{15}\text{P} \rightarrow \,^{16}_{8}\text{S} \,^{0}_{-1}\text{e} \]

Type: \(-\beta\)

\[ ^{105}_{47}\text{Ag} + \,^{0}_{-1}\text{e} \rightarrow \,^{105}_{46}\text{Pd} \]

Type: \(EC\)

\[ ^{40}_{21}\text{Sc} \rightarrow \,^{20}_{18}\text{Ca} \,^{0}_{+1}\text{e} \]

Type: \(+\beta\)

\[ ^{244}_{94}\text{Pu} \rightarrow \,^{2}_{2}\text{He} \,^{92}_{4}\text{U} \]

Type: \(\alpha\)
Use the half-lives of elements to learn about radioactive dating.

Most elements found in nature are stable; they do not change over time. Some elements, however, are unstable—that is, they change into a different element over time. Elements that go through this process of change are called radioactive, and the process of transformation is called radioactive decay. Because radioactive decay happens very steadily, scientists can use radioactive elements like clocks to measure the passage of time. By looking at how much of a certain element remains in an object and how much of it has decayed, scientists can determine an approximate age for the object.

So why are scientists interested in learning the ages of objects? By looking at very old things, such as rocks and fossils, and determining when they were formed, scientists learn about the history of the Earth and the plants and animals that have lived here. Radioactive dating makes this history lesson possible! A half-life is the time that it takes for half a certain amount of a radioactive material to decay, and it can range from less than a second to billions of years. The chart below lists the half-lives of some radioactive elements.

### Table of Half-lives

<table>
<thead>
<tr>
<th>Element</th>
<th>Half-life</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bismuth-212</td>
<td>60.5 minutes</td>
</tr>
<tr>
<td>Carbon-14</td>
<td>5730 years</td>
</tr>
<tr>
<td>Chlorine-36</td>
<td>400,000 years</td>
</tr>
<tr>
<td>Cobalt-60</td>
<td>5.26 years</td>
</tr>
<tr>
<td>Iodine-131</td>
<td>8.07 days</td>
</tr>
<tr>
<td>Phosphorous-24</td>
<td>14.3 days</td>
</tr>
<tr>
<td>Polonium-215</td>
<td>0.0018 seconds</td>
</tr>
<tr>
<td>Radium-226</td>
<td>1600 years</td>
</tr>
<tr>
<td>Sodium-24</td>
<td>15 hours</td>
</tr>
<tr>
<td>Uranium-238</td>
<td>4.5 billion years</td>
</tr>
</tbody>
</table>

1. Use the data in the table above to complete the following chart:

<table>
<thead>
<tr>
<th>Number of years after formation</th>
<th>0</th>
<th>1600</th>
<th>3200</th>
<th>6400</th>
<th>12,800</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percent of radium-226 remaining</td>
<td>100%</td>
<td>50%</td>
<td>25%</td>
<td>12.5%</td>
<td>6.25%</td>
</tr>
</tbody>
</table>

2. If 1 g of sodium-24 has decayed from a sample that was originally 2 g, how old is the sample?

Because half of the sample has decayed, we know that one half-life has passed, which is 15 hours.

The sample is 15 hours old.

3. What fraction of chlorine-36 remains undecayed after 200,000 years?

200,000 is one-half of 400,000, so one-half of the half-life has passed. Therefore, one-quarter of the sample has decayed, leaving three-quarters of the sample undecayed.
4. As uranium-238 decays, it becomes lead-206. After 3.5 g of uranium-238 decays for \(1.125 \times 10^9\) years, how many grams of the sample will be lead-206?

\[
(1.125 \times 10^9) \div (4.5 \times 10^9) = 0.25 \text{ of the half-life has passed. Therefore, 0.125 g of the sample has decayed. 0.125} \times 3.5 = 0.438; \text{ 0.438 g of the sample has decayed into lead-206.}
\]

5. A scientist has a 2.5 g sample of radium-226. How many grams of the sample will decay in 800 years?

\[
800 \div 1600 = 0.5; \text{ 0.5 of the half-life passes in 800 years. Therefore, 0.25 of the sample decays in this time. 0.25} \times 2.5 = 0.625 \text{ g of radium-226 will decay in 800 years.}
\]

6. An archaeologist finds a piece of old bone that she believes may be 2000 years old. The lab technician tells her that the carbon-14 in the bone has completed 25 percent of its first half-life. Does this finding support her belief about the age of the bone? Why or why not?

\[
25\% \text{ of the half-life of carbon-14 is } 0.25 \times 5730 \text{ years} = 1432.5 \text{ years}; \text{ Because the bone is less than 2000 years old, this finding does not support her belief.}
\]

7. A technician does a test on an unidentified radioactive element and discovers that it has a half-life of \(4.5 \times 10^9\) years. What element do you think it is, and why?

\[
4.5 \times 10^9 \text{ years is 4.5 billion years; The substance may be uranium-238, which has the same half-life.}
\]

8. A paleontologist unearths the remains of a *Tyrannosaurus rex*. We know that these dinosaurs became extinct about 65 million years ago. Therefore, would it be reasonable to expect that the carbon-14 in the fossil has completed 15,000 half-lives? Why or why not?

\[
15,000 \times 5730 = 85,950,000 \text{ years; Yes, it would be reasonable because the } T. \text{ rex had not yet become extinct 85 million years ago.}
\]