Aim: Why do unstable isotopes undergo nuclear reactions?

Do Now: Draw Bohr models of three different isotopes of carbon in the boxes below. Include the electron configuration and isotopic notation.

<table>
<thead>
<tr>
<th>Carbon-12</th>
<th>Carbon-13</th>
<th>Carbon-14</th>
</tr>
</thead>
<tbody>
<tr>
<td>e\textsuperscript{-} configuration: ______</td>
<td>e\textsuperscript{-} configuration: ______</td>
<td>e\textsuperscript{-} configuration: ______</td>
</tr>
<tr>
<td>Isotopic notation:</td>
<td>Isotopic notation:</td>
<td>Isotopic notation:</td>
</tr>
<tr>
<td># of protons: ____</td>
<td># of protons: ____</td>
<td># of protons: ____</td>
</tr>
<tr>
<td># of electrons: ____</td>
<td># of electrons: ____</td>
<td># of electrons: ____</td>
</tr>
<tr>
<td># of neutrons: ____</td>
<td># of neutrons: ____</td>
<td># of neutrons: ____</td>
</tr>
</tbody>
</table>

Recall: Isotopes are atoms of the same element that have the same number of _______ but a different number of _________ (and therefore different _________).
Determining the neutron to proton ratio: Look up the atomic number on the Periodic Table. Subtract the atomic number from the mass number to get the number of neutrons. Divide neutrons by protons to get the \( \frac{n}{p} \) ratio.

<table>
<thead>
<tr>
<th>Ex: K-39 (“small”)</th>
<th>Ex: K-42 (“large”)</th>
<th>Ex: Gold-197 (“large”)</th>
<th>Ex: Uranium-235 (large)</th>
</tr>
</thead>
<tbody>
<tr>
<td>mass # = _______</td>
<td>mass # = _______</td>
<td>mass # = _______</td>
<td>mass # = _______</td>
</tr>
<tr>
<td>atomic # = _______</td>
<td>atomic # = _______</td>
<td>atomic # = _______</td>
<td>atomic # = _______</td>
</tr>
<tr>
<td># of neutrons = ___</td>
<td># of neutrons = ___</td>
<td># of neutrons = ___</td>
<td># of neutrons = ___</td>
</tr>
<tr>
<td>( \frac{n}{p} ) ratio = _____</td>
<td>( \frac{n}{p} ) ratio = _____</td>
<td>( \frac{n}{p} ) ratio = _____</td>
<td>( \frac{n}{p} ) ratio = _____</td>
</tr>
<tr>
<td>[ stable / unstable ]</td>
<td>[ stable / unstable ]</td>
<td>[ stable / unstable ]</td>
<td>[ stable / unstable ]</td>
</tr>
</tbody>
</table>

**Which Nuclei Are Stable and Which Nuclei Are Unstable?**

Elements with atomic # 1-82

Elements with atomic # 83 or greater

Radioactivity:

When an element is unstable, its nucleus will undergo transmutation to attain a more stable state.

Nuclear chemistry:

<table>
<thead>
<tr>
<th>Nuclear Chemistry</th>
<th>Other Branches of Chemistry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Involves the outermost electrons</td>
<td>Elements can't change (proton number unaltered)</td>
</tr>
<tr>
<td>Involves relatively smaller amounts of energy transfer</td>
<td>Rate of reaction affected by changes in temperature, pressure, and/or presence of catalysts.</td>
</tr>
</tbody>
</table>

In both types of chemistry, atoms become more stable.
Aim: What are the different types of nuclear decay?

**NATURAL TRANSMUTATION**

\[ ^{234}_{92}Th \rightarrow ^{234}_{90}Pa + ^{0}_{-1}e \]

(“Radioactive Decay” – ONE reactant, only!)

**ARTIFICIAL TRANSMUTATION**

\[ ^{4}_{2}He + ^{14}_{7}N \rightarrow ^{17}_{8}O + ^{1}_{1}H \]

(MORE THAN ONE reactant, only!)

**ALPHA**

- **Type (Symbol):** Alpha
- **Notation:** \([^{A}_{Z} Th \rightarrow ^{A-4}_{Z-2} Pa + ^{0}_{-1} e}\)
- **Penetrating Power:** WEAK (can be stopped by a sheet of paper)
- **What happens to the atom when it undergoes this type of decay?**
  - The nucleus loses 2 protons (atomic number decreases by 2) and 4 total particles (mass decreases by 4).
  - Ex: ___________________________

**BETA**

- **Type (Symbol):** Beta
- **Notation:** \([^{A}_{Z} Pa \rightarrow ^{A}_{Z+1} Pa + ^{0}_{-1} e}\)
- **Penetrating Power:** INTERMEDIATE (can be stopped by a few millimeters of aluminum foil)
- **What happens to the atom when it undergoes this type of decay?**
  - A neutron in the nucleus decays to form a proton (atomic number increases by 1, but mass stays the same) and an electron (the beta particle).
  - Ex: ___________________________

**POSITRON**

- **Type (Symbol):** Positron
- **Notation:** \([^{A}_{Z} Pa \rightarrow ^{A}_{Z-1} Pa + ^{0}_{1} e]\)
- **Penetrating Power:** HIGH (can be stopped by a concrete)
- **What happens to the atom when it undergoes this type of decay?**
  - A proton in the nucleus decays to form a neutron (atomic number decreases by 1, but mass stays the same) and a positron (the antimatter form of an electron).
  - Ex: ___________________________

**GAMMA**

- **Type (Symbol):** Gamma
- **Notation:** \([^{A}_{Z} Pa \rightarrow ^{A}_{Z} Pa + ^{0}_{0} \gamma}\)
- **Penetrating Power:** HIGH (can be stopped by a concrete)
- **What happens to the atom when it undergoes this type of decay?**
  - A high-energy photon emitted as a nucleus becomes more stable. It does not change the identity of the element because it has no mass or charge. Gamma can be given off by itself, or it can be given off with any of the other types of decay, such as alpha or beta decay.
  - Ex: \(^{234}_{92}Th \rightarrow \) ___________________________
Examples of Different Types of Radiation

Practice: Complete the following Uranium Decay Sequence.

U-238 is unstable and decays into more stable nuclei. It takes 14 decay steps until a stable, non-radioactive nucleus is finally reached. The daughter nuclide of one step becomes the parent nuclide of the next. REMEMBER: In nuclear reactions, both mass and charge are conserved. This means that the sum of the mass numbers (superscripts) on the right must equal the sum on the left. The same is true for the atomic numbers (subscripts).

<table>
<thead>
<tr>
<th>Step</th>
<th>Decay Mode</th>
<th>Parent Nuclide</th>
<th>Emission Particle + Daughter Nuclide</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td>$^{238}_{92}U$</td>
<td>$^{4}<em>{2}He + ^{234}</em>{90}Th$</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>$^{234}_{90}Th$</td>
<td>$^{0}<em>{-1}e + ^{234}</em>{91}Pa$</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>$^{234}_{91}Pa$</td>
<td>$^{0}<em>{-1}e + ^{234}</em>{92}U$</td>
</tr>
<tr>
<td>4</td>
<td>$\alpha$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>$\alpha$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>$\alpha$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>$\alpha$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>$\alpha$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>$\beta^-$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>$\beta^-$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>$\alpha$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>$\beta^-$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>$\beta^-$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>$\alpha$</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Practice Test Questions

1. Look up how each of the following isotopes undergoes decay on Reference Table N and then write the complete decay equation for each isotope.

<table>
<thead>
<tr>
<th>Parent Nuclide</th>
<th>Decay Type</th>
<th>Decay Equation</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{233}\text{U}$</td>
<td>$\alpha$</td>
<td>$^{92}2_{\text{He}} + 3_{9}^{229}\text{Th}$</td>
</tr>
<tr>
<td>$^{137}\text{Cs}$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$^{220}\text{Fr}$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$^{239}\text{Pu}$</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2. A U-238 atom decays to a Pb-206 atom through a series of steps. Each point on the graph below represents a nuclide and each arrow represents a nuclear decay mode.

a) Based on this graph, what particle is emitted during the nuclear decay of a Po-218 atom? ______

b) Explain why the disintegration series ends with the nuclide Pb-206. ________________________________________

3. Which nuclear emission has the greatest mass?
   (1) $\alpha$ (2) $\beta$ (3) $\gamma$ (4) positron

4. Which isotope will spontaneously decay and emit particles with a charge of +2? (Hint: Consult Reference Table N!)
   (1) $^{53}\text{Fe}$ (2) $^{137}\text{Cs}$ (3) $^{198}\text{Au}$ (4) $^{220}\text{Fr}$

5. Atoms of one element are converted to atoms of another element through
   (1) fermentation (2) oxidation (3) polymerization (4) transmutation

6. Which equation represents the radioactive decay of $^{226}_{88}\text{Ra}$?
   (1) $^{226}_{88}\text{Ra} \rightarrow ^{226}_{86}\text{Rn} + ^{4}_{2}\text{He}$
   (2) $^{226}_{88}\text{Ra} \rightarrow ^{226}_{86}\text{Ac} + ^{0}_{-1}\text{e}$
   (3) $^{226}_{88}\text{Ra} \rightarrow ^{226}_{87}\text{Fr} + ^{0}_{+1}\text{e}$
   (4) $^{226}_{88}\text{Ra} \rightarrow ^{225}_{86}\text{Ra} + ^{1}_{0}\text{n}$
7. Which equation represents positron decay?

\[
\begin{align*}
(1) & \quad ^{87}_{37}\text{Rb} \rightarrow ^{0}_{-1}\text{e} + ^{87}_{36}\text{Sr} \\
(2) & \quad ^{227}_{92}\text{U} \rightarrow ^{223}_{90}\text{Th} + ^{4}_{2}\text{He} \\
(3) & \quad ^{27}_{13}\text{Al} + ^{4}_{2}\text{He} \rightarrow ^{30}_{15}\text{P} + ^{1}_{0}\text{n} \\
(4) & \quad ^{11}_{6}\text{C} \rightarrow ^{0}_{-1}\text{e} + ^{11}_{5}\text{B}
\end{align*}
\]

8. Which nuclear equation represents a natural transmutation? (Hint: Have you noticed that all natural transmutations (in Regents-level chemistry) have only 1 reactant?)

\[
\begin{align*}
(1) & \quad ^{9}_{4}\text{Be} + ^{1}_{0}\text{H} \rightarrow ^{6}_{3}\text{Li} + ^{4}_{2}\text{He} \\
(2) & \quad ^{27}_{13}\text{Al} + ^{4}_{2}\text{He} \rightarrow ^{30}_{15}\text{P} + ^{1}_{0}\text{n} \\
(3) & \quad ^{14}_{7}\text{N} + ^{4}_{2}\text{He} \rightarrow ^{17}_{8}\text{O} + ^{1}_{1}\text{H} \\
(4) & \quad ^{235}_{92}\text{U} \rightarrow ^{231}_{90}\text{Th} + ^{4}_{2}\text{He}
\end{align*}
\]

9. Radioactive cobalt-60 is used in radiation therapy treatment. Cobalt-60 undergoes beta decay. This type of nuclear reaction is called

(1) natural transmutation
(2) artificial transmutation
(3) nuclear fusion
(4) nuclear fission

10. The chart below shows the spontaneous nuclear decay of U-238 to Th-234 to Pa-234 to U-234. Which is the correct order of nuclear decay modes from U-238 to U-234?

\[
\begin{align*}
(1) & \quad \beta^- \text{ decay, } \gamma \text{ decay, } \beta^- \text{ decay} \\
(2) & \quad \beta^- \text{ decay, } \beta^- \text{ decay, } \alpha \text{ decay} \\
(3) & \quad \alpha \text{ decay, } \alpha \text{ decay, } \beta^- \text{ decay} \\
(4) & \quad \alpha \text{ decay, } \beta^- \text{ decay, } \beta^- \text{ decay}
\end{align*}
\]

11. Describe how α, β, and γ rays each behave when they pass through an electric field. Use the diagram below to illustrate your answer.

\[\text{Diagram of radioactive source and electric field with rays passing through lead block} \]
Aim:
How can we use HALF-LIFE as an archaeological clock?

The half-life of a radioactive isotope is defined as the period of time that must go by for half of the nuclei in the sample to undergo decay.

Do Now: Use the graphic at right to answer the questions that follow.

<table>
<thead>
<tr>
<th>Total # of Years Elapsed</th>
<th># of Half-Lives Elapsed</th>
<th>Mass of Sample Remaining</th>
<th>% of Original Sample Remaining</th>
</tr>
</thead>
<tbody>
<tr>
<td>5,730 years</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11,460 years</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17,190 years</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>22,920 years</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

During one half-life period:

- Half of the radioactive nuclei in the sample decay into new, more stable nuclei.
  - Ex: If a sample contains 1000 nuclei of a radioactive isotope now, ____ will undergo decay over the course of one half-life.

- Half the mass of the radioactive isotope is converted into a new, more stable isotope.
  - Ex: If a sample contains 4.0 grams of a radioactive isotope now, after one half-life, ____ grams will remain undecayed; the other 2.0 grams will be made up of a new, more stable isotope.

- After one half-life, half (50%) of the original amount of the sample will have undergone radioactive decay.
  - After a second half-life, ____ of the original sample will remain undecayed.
  - After a third half-life, ____ of the original sample will remain undecayed.

- A Geiger-Müller counter’s count-per-time period will be half of what it started at.
  - Ex: If a Geiger-Müller counter is showing 400 counts per minute now, after one half-life, the counter will show ____ counts per minute after one half-life has elapsed.

The half-life of many radioactive isotopes can be found on Reference Table N.
Solving Half-Life Problems

1. You know how much of the isotope you have now, and you want to find out how much will be left after a certain amount of time (going into the future).

- **Step 1**: Determine how many half-lives have gone by. Take how much time has gone by and divide it by the duration of the half-life.
- **Step 2**: Cut the amount (mass, percent, fraction, number of nuclei) in half as many times as there are half-lives.

**Examples:**

1. The half-life of Rn-222 (a carcinogenic house pollutant) is 3.8 days. If today your basement contains 20.0 grams of Rn-222, how much will remain after 19 days assuming no more leaks in?

2. A laboratory sample of $^{32}$P triggers 400 clicks per minute in a Geiger-Mueller counter. How many days will it take for the $^{32}$P to decay enough so that there are only 50 clicks per minute?

3. A cylinder contains 5.0 L of pure radioactive $^{19}$Ne. If the cylinder is left to sit for 103.2 seconds, what percent of our original sample of $^{19}$Ne will remain?

2. You know how much of the isotope you have now, you want to find out how there was a certain amount of time ago (going into the past).

- **Step 1**: Determine how many half-lives have gone by. Take how much time has gone by and divide it by the duration of the half-life.
- **Step 2**: Double the amount (mass, percent, fraction, number of nuclei) as many times as there are half-lives.

**Examples:**

1. The half-life of Tc-99m (used to locate brain tumors) is 6.0 hours. If 10. micrograms are left after 24 hours, how much Tc-99m was administered originally?

2. A laboratory sample of $^{32}$P triggers 100. clicks per minute in a Geiger-Mueller counter. How many days ago did the $^{32}$P decay enough to produce 1600. clicks per minute?
3. You want to find out how long the half-life is, knowing how much a sample has decayed over a given amount of time.

- **Step 1:** Determine how many times you can cut your original amount in half in order to get to your final amount. This is the number of half-lives that have gone by.
- **Step 2:** Divide the time that has elapsed by the number of half-lives that have passed.

**Examples:**

1. A radioactive sample is placed next to a Geiger counter and monitored. In 20.0 hours, the counter's reading goes from 500 counts per minute to 125 counts per minute. How long is the half-life?

2. A sample of pure radioactive isotope is left to decay. After 40.0 days, the sample is placed in a mass spectrometer, and it is determined that the sample only 25% of the original isotope remains. How long is the half-life?

4. Radioactive Dating: used to determine the age of a substance that contains a radioactive isotope of known half-life.

- **Step 1:** Determine how many times you can cut your original amount in half in order to get to your final amount. This is the number of half-lives that have gone by.
- **Step 2:** Multiply the number of half-lives by the duration of a half-life (found on Table N).

**Examples:**

1. The oldest rocks on Earth have been found to contain 50% U-238 and 50% Pb-206 (what U-238 ultimate decays into). What is the age of these rocks?

2. An ancient scroll is discovered, and it is found that only 25% percent of the original concentration of C-14 (a radioactive isotope found in equal concentration in all living beings) remains. How old is the scroll?
Calculating Half-Life: Independent Practice

Directions: Show all of your work in the space provided under each question, and draw a box around your final answer, including g units.

1. What is the half-life of a radioactive isotope if 25% of the original mass of the isotope remains after 20. days?

2) A Geiger counter is used to monitor the radioactivity level of a certain isotope. During a 30-hour period, the count rate dropped from 600. counts/minute to 150. counts/minute. What is its half-life?

3) The half-life of cesium-137 is 30. years. How much $^{137}\text{Cs}$ was present originally if, after 120. years, 6.0 g remained?

4) The half-life of barium-131 is 12.0 days. How many grams of $^{131}\text{Ba}$ remain after 60. days, if the initial sample weighed 10.0 g?

5) How much $^{32}\text{P}$ was present originally if, after 71.5 days, 2.0 grams remain (the half-life of $^{32}\text{P}$ is 14.3 days)?

6) A Geiger counter detects 300. counts per minute when a sample of neon-19 is placed under it. Based on Reference Table N, how long will it take for the Geiger counter to drop to 75 counts per minute?

7) A nuclear bomb test 56.2 years ago generated Sr-90, which dispersed into the surrounding environment. A soil test today shows 20 micrograms of Sr-90 in a 1-kg sample of soil. How many micrograms of Sr-90 per kg of soil must have been present right after the test blast? Use Reference Table N.
Flipped Lesson - Uses of Radioisotopes

Instructions: The radioisotopes referenced in this flipped lesson are useful and ubiquitous in modern society. Please be sure to become familiar with their uses, as this content is testable on both the unit exam and the Regents exam. To complete this assignment, you will need Reference Tables N and O, Periodic Table, glossary, and links provided via QR code.

I. Radioisotopes in Medicine:
Radioisotopes ("radioactive isotopes") are used in medical diagnosis and treatment. Isotopes that have very short half-lives and are quickly eliminated from the body are preferable for this purpose.

Using your glossary, define **tracers**.

<table>
<thead>
<tr>
<th>Radioisotope</th>
<th>Nuclear Decay Equation</th>
<th>Half-Life</th>
<th>Uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tc-99</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I-131</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ra-226</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Co-60</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Practice Regents Questions:

1. Nuclear radiation is harmful to living cells, particularly to fast-growing cells, such as cancer cells and blood cells. An external beam of the radiation emitted from a radioisotope can be directed on a small area of a person to destroy cancer cells within the body. Cobalt-60 is an artificially produced radioisotope that emits gamma rays and beta particles. One hospital keeps a 100.0-gram sample of cobalt-60 in an appropriate, secure storage container for future cancer treatment.

a. State one risk to human tissue associated with the use of radioisotopes to treat cancer.

____________________________________________________________________
____________________________________________________________________
____________________________________________________________________

b. A radioisotope is called a **tracer** when it is used to
   (1) kill bacteria in food
   (2) kill cancerous tissue
   (3) determine the age of animal skeletal remains
   (4) determine the way in which a chemical reaction occurs

c. Compare the penetrating power of the two emissions from the Co-60.

____________________________________________________________________
____________________________________________________________________
____________________________________________________________________


d. Complete the nuclear equation below for the beta decay of the Co-60 by writing an isotopic notation for the missing product.

\[ \text{Co}^{60} \rightarrow \text{B}^{0} + \text{________} \]

e. Determine the total time that will have elapsed when 12.5 grams of the original Co-60 sample at the hospital remains unchanged.
II. Radioisotopes in Geology and Archaeology

The decay of radioisotopes provides a consistently reliable method for dating rocks, fossils, and geologic events. Using your glossary, define carbon dating.

<table>
<thead>
<tr>
<th>Radioisotope</th>
<th>Nuclear Decay Equation</th>
<th>Half-Life</th>
<th>Uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-14</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>U-238</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Practice Regents Questions:
1. The dating of geological formations is an example of a beneficial use of
   (1) isomers (2) electrolytes (3) organic compounds (4) radioactive nuclides

2. Which radioisotope is used in dating geological formations?
   (1) I-131 (2) U-238 (3) Ca-37 (4) Fr-220

3. The radioactive isotope carbon-14 can be used for
   (1) determining the age of a sample (2) determining medical disorders
      (3) controlling fission reactions (4) controlling speeds of neutrons
III. Radioisotopes in Food & Agriculture

More than 40 countries have approved the use of radiation to help preserve nearly 40 different varieties of food. In agriculture, radiation has eradicated approximately 10 species of pest insects.

<table>
<thead>
<tr>
<th>Radio isotope</th>
<th>Nuclear Decay Equation</th>
<th>Half-Life</th>
<th>Uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Co-60</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Practice Regents Questions:

1. Radiation used in the processing of food is intended to
   (1) increase the rate of nutrient decomposition
   (2) kill microorganisms that are found in the food
   (3) convert ordinary nutrients to more stable forms
   (4) replace chemical energy with nuclear energy

2. Which isotope is used to treat cancer and irradiate food?
   (1) U-238       (2) Pb-206   (3) Co-60   (4) C-14
Aim: How can nuclear reactions be used to produce energy?

The foundation of nuclear energy is harnessing the power of atoms. Both fission and fusion are nuclear processes by which atoms are altered to create energy, but what is the difference between the two? Simply put, fission is the division of one atom into two, and fusion is the combination of two lighter atoms into a larger one. They are opposing processes, and are therefore very different.

<table>
<thead>
<tr>
<th>Fission</th>
<th>Fusion</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Fission Diagram" /></td>
<td><img src="image2" alt="Fusion Diagram" /></td>
</tr>
</tbody>
</table>

Instructions: Watch the videos below using your iPad or smartphone. Work with your group to sort the phrases into two categories: fission or fusion. You may use the internet as a resource if you get stuck.

Once your group reaches a consensus, check with a teacher before recording the properties of each respective reaction on the following page. The teacher will only tell you whether there is an error, not what the error is.
<table>
<thead>
<tr>
<th><strong>Fission</strong></th>
<th><strong>Fusion</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Definition:</strong></td>
<td><strong>Definition:</strong></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Nuclear Equation:</strong></td>
<td><strong>Nuclear Equation:</strong></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Natural occurrence of the process</td>
<td></td>
</tr>
<tr>
<td>Byproducts of the reaction</td>
<td></td>
</tr>
<tr>
<td>Conditions</td>
<td></td>
</tr>
<tr>
<td>Energy Requirement</td>
<td></td>
</tr>
<tr>
<td>Energy Released</td>
<td></td>
</tr>
<tr>
<td>Energy Production</td>
<td></td>
</tr>
<tr>
<td>Fuel</td>
<td></td>
</tr>
<tr>
<td>Nuclear Weapon</td>
<td></td>
</tr>
</tbody>
</table>
Artificial Transmutation (Fission & Fusion) Practice Regents Questions

1. Which equation is an example of natural transmutation?
   1) $\frac{10}{5}$B + $\frac{4}{2}$He → $\frac{13}{7}$N + $\frac{1}{0}$n
   2) $\frac{14}{6}$C → $\frac{14}{7}$N + $\frac{0}{-1}$e
   3) S + 2e⁻ → S²⁻
   4) Na → Na⁺ + e⁻

2. Which equation is an example of artificial transmutation?
   1) $\frac{9}{4}$Be + $\frac{4}{2}$He → $\frac{12}{6}$C + $\frac{1}{0}$n
   2) U + 3F₂ → UF₆
   3) Mg(OH)₂ + 2HCl → 2H₂O + MgCl₂
   4) Ca + 2H₂O → Ca(OH)₂ + H₂

3. The change that is undergone by an atom of an element made radioactive by bombardment with high-energy protons is called
   1) natural transmutation
   2) artificial transmutation
   3) natural decay
   4) radioactive decay

4. Which balanced equation represents nuclear fusion?
   1) $\frac{2}{1}$H + $\frac{2}{1}$H → $\frac{4}{2}$He
   2) 2H₂ + O₂ → 2H₂O
   3) $\frac{6}{3}$Li + $\frac{1}{0}$n → $\frac{3}{1}$H + $\frac{4}{2}$He
   4) CaO + CO₂ → CaCO₂

5. In which type of reaction do two lighter nuclei combine to form one heavier nucleus?
   1) combustion
   2) reduction
   3) nuclear fission
   4) nuclear fusion

6. What occurs in both fusion and fission reactions?
   1) Small amounts of energy are converted into large amounts of matter.
   2) Small amounts of matter are converted into large amounts of energy.
   3) Heavy nuclei are split into lighter nuclei.
   4) Light nuclei are combined into heavier nuclei.
7. The diagram below represents a nuclear reaction in which a neutron bombards a heavy nucleus. Which type of reaction does the diagram illustrate?
1) Fission
2) Fusion
3) Alpha decay
4) Beta decay

8. An uncontrolled chain reaction takes place during the
1) operation of a fission nuclear reactor
2) explosion of an atomic bomb
3) production of energy by the Earth’s Sun
4) fusion of light nuclei into heavier nuclei

9. Nuclear fusion differs from nuclear fission because nuclear fusion reactions
1) form heavier isotopes from lighter isotopes
2) form lighter isotopes from heavier isotopes
3) convert mass to energy
4) convert energy to mass

10. High energy is a requirement for fusion reactions to occur because the nuclei involved
1) attract each other because they have like charges
2) attract each other because they have unlike charges
3) repel each other because they have like charges
4) repel each other because they have unlike charges
Nuclear Reactors (Power Plants)
(Produce Energy Via Nuclear Fission Rxns)

Word Bank:

- Moderator
- Coolant
- Fuel Elements
- Shielding
- Control Rods

1. __________ The fissionable material in the reactor (ex: U-235, U-238, Pu-236, or Th-232).
2. __________ Slow down the neutrons produced during the fission process (ex: graphite (C), beryllium (Be), water (H₂O))
3. __________ Absorb neutrons to slow down or stop fission reactions from occurring; can be raised or lowered to control rate of reaction (ex: Cd, B)
4. __________ Prevents radiation from being released from entering the environment (ex: lead, concrete)
5. __________ Absorbs heat produced in the reactor to prevent nuclear meltdown (ex: water, carbon dioxide, liquid Na)

Pros & Cons of Nuclear Energy

<table>
<thead>
<tr>
<th>Benefits (+)</th>
<th>Drawbacks (-)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Diagram of a nuclear power plant showing containment structure, reactor, steam generator, turbine, generator, and cooling towers.
Nuclear Reactor Practice Regents Questions

1. Which materials are commonly used for shielding in a nuclear fission reactor?
   1) uranium and plutonium  2) boron and cadmium
   3) steel and concrete      4) beryllium and heavy water

2. Which components of a fission reactor are used to slow neutrons during a fission reaction?
   1) control rods          2) coolants
   3) shields              4) moderators

3. Which substance can be used as both a coolant and a moderator in a nuclear reactor?
   1) heavy water           2) carbon dioxide
   3) graphite             4) helium

4. Water and molten sodium are used in nuclear reactors as
   1) coolants              2) moderators
   3) control rods          4) fuels

5. Which two substances are most commonly used for shielding in a nuclear reactor?
   1) water and heavy water 2) beryllium and graphite
   3) molten sodium and molten lithium 4) steel and high-density concrete

6. The diagram below represents a nuclear reactor. The arrows indicate the direction of the flow of water. Which structure is indicated by letter A?
   1) turbine
   2) moderator
   3) control rod
   4) internal shield

7. Which substances are used in the control rods of nuclear reactors?
   1) water and concrete    2) graphite and beryllium
   3) cadmium and boron     4) sodium and carbon dioxide

8. Which pair of isotopes can serve as fissionable nuclear fuels?
   1) U-235 and Pb-208      2) U-235 and Pu-239
   3) Pb-208 and Pu-239     4) Pb-206 and U-235

9. The fission process in a reactor can be regulated by adjusting the number of neutrons available. This is done by the use of
   1) moderators            2) control rods
   3) coolants              4) shielding