

ALPHAS, BETAS AND GAMMAS OH, MY!

Teacher's Notes

OBJECTIVE:

*Understanding
radioactive decay.*

Grade: 8 – 12

Intended Learning Outcome(s): To develop energy literate students.

Subjects: Physics, Physical Science, Integrated Earth Systems, Geology, Chemistry

Materials: Periodic Table of the Elements for each student (included)
Decay Event Table worksheet (included)
Nuclear Reactions and Atomic Notation worksheet (included)
Mass Number/Atomic Number chart for each student (included)
Pen or pencil

Teaching Time: One class period

Number of Players: Entire class

Teacher Information: This activity gives students a mathematical/logical or graphing/charting activity that helps develop math, science and technology skills on a conceptual level and includes mathematical reasoning and processes. This activity allows the student to explore the bigger picture. Mass can become energy through a process known as the natural transmutation of elements. More specifically, students will explore the concept of “radioactive decay” as it relates to the natural transmutation of elements. Radioactive decay of unstable elements through fission reactions appears to be an ever present and ongoing process that generates the thermal energy that keeps Earth’s mantle fluid and generates the heat that leads to the beauty of Yellowstone’s geysers and relaxing hot springs. Another source for this activity is found in Scott Foresman Addison Wesley’s publication of Paul G. Hewitt’s Conceptual Physics Concept Development Practice Book, page 143-144. Students often struggle learning and applying the concept of “alpha decay, beta decay and gamma decay or emission,” as it relates to the natural transmutation of elements or radioactivity. This activity allows students to explore “particle or energy emissions” and allows them to map the resulting isotopes or nuclides until the decay events result in a “stable” element.

This can be followed up with activities that apply the concepts of “half-life,” or radioactivity. Some follow-up “application” activities, for example, could be measuring geologic time based on the “half-life” of known nuclides or isotopes, or measuring the age of carbon-based items (tools, papers and other items) useful in archeology or paleontology. There are many such activities to be found on the Department of Energy web-site (www.energy.gov) under the “for educators” quick clicks.

“Alphas, Betas and Gammas Oh, My!” is meant to be an activity that is inexpensive and efficient. It is based on a similar activity from Scott Foresman Addison Wesley’s publication of Paul G. Hewitt’s Conceptual Physics Concept Development Practice Book, page 143-144.

Simply stated, we believe that mass is converted into energy through two main processes. One of these “mass-to-energy” converting processes is fusion. Stars are huge fusion reactors, converting hydrogen into helium (and later in their waning lives, into all of the heavier elements). During the fusion process a very small amount of mass is “lost” or better stated, is not accounted for. We now believe that this mass is not “lost” at all but converted into energy. Paraphrasing the First Law of Thermodynamics, “energy is neither created nor destroyed, but always exists in one form or another.” Simply stated, energy and mass exist in either form, mass or energy.

Fission is another naturally occurring process that converts mass into energy. On Earth and other planets, a phenomenon known as the natural transmutation of elements converts mass into energy. Fission reactions convert mass that is “left-over” when massive “unstable” or radioactive elements decay. This decay is either an alpha decay up or a beta decay down the Periodic Table of Elements. The ultimate destination of this decay in most cases, is the generation of two less massive “daughter” elements that are usually more stable (less radioactive) than the original element. The amount of time it takes for these alpha and beta decay events to occur is known as “half life.” Through the use of modern technologies like super computers and particle accelerators, scientists and engineers reasonably believe they know the “half-life” of most of the nuclides or isotopes of each element.

Nuclide is the physicists’ term for what chemists call isotopes. These are naturally occurring forms of an element that has more or less nucleons (neutrons in this case) than the average amount of neutrons an element has statistically. It is believed that all elements will eventually alpha or beta decay, even the nuclides or isotopes that we term “stable.” These events related to fission reactions appear to be ever present and ongoing processes that generate the thermal energy that, for example, keeps Earth’s mantle fluid and generates the heat that leads to the beauty of Yellowstone’s geysers and relaxing hot springs. The energy released through fission and natural transmutation occurs when mass is converted into energy as predicted by Einstein’s $E=mc^2$ (where E = energy, m = mass and c = velocity of light). Energy in the form of electromagnetic radiation is released as a gamma decay. Because gamma radiation is a form of light or electromagnetic radiation, it exhibits a particle/wave duality. It is a wave and a particle. The reasons for gamma decay are complex and myriad. Suffice it to say for now, gamma emissions occur in conjunction with alpha and beta decays.

It is important that students understand and can use the notation that physicists use in labeling nuclides or isotopes. The following instruction is important in successfully completing this activity and for use in future research or accurate reporting or discussion of nuclear energy concepts.

Procedure:

1. Read or have students read the overview and the Mass Number/Atomic Number Chart to this activity. They may also research alpha, beta and gamma decays online or from their textbooks.
2. Have students complete the Nuclear Reactions and Atomic Notation worksheet.
3. Have the students complete the Decay Event Table worksheet. Have students complete the graph by following a sequence of alpha and beta decays.

Data Collection:

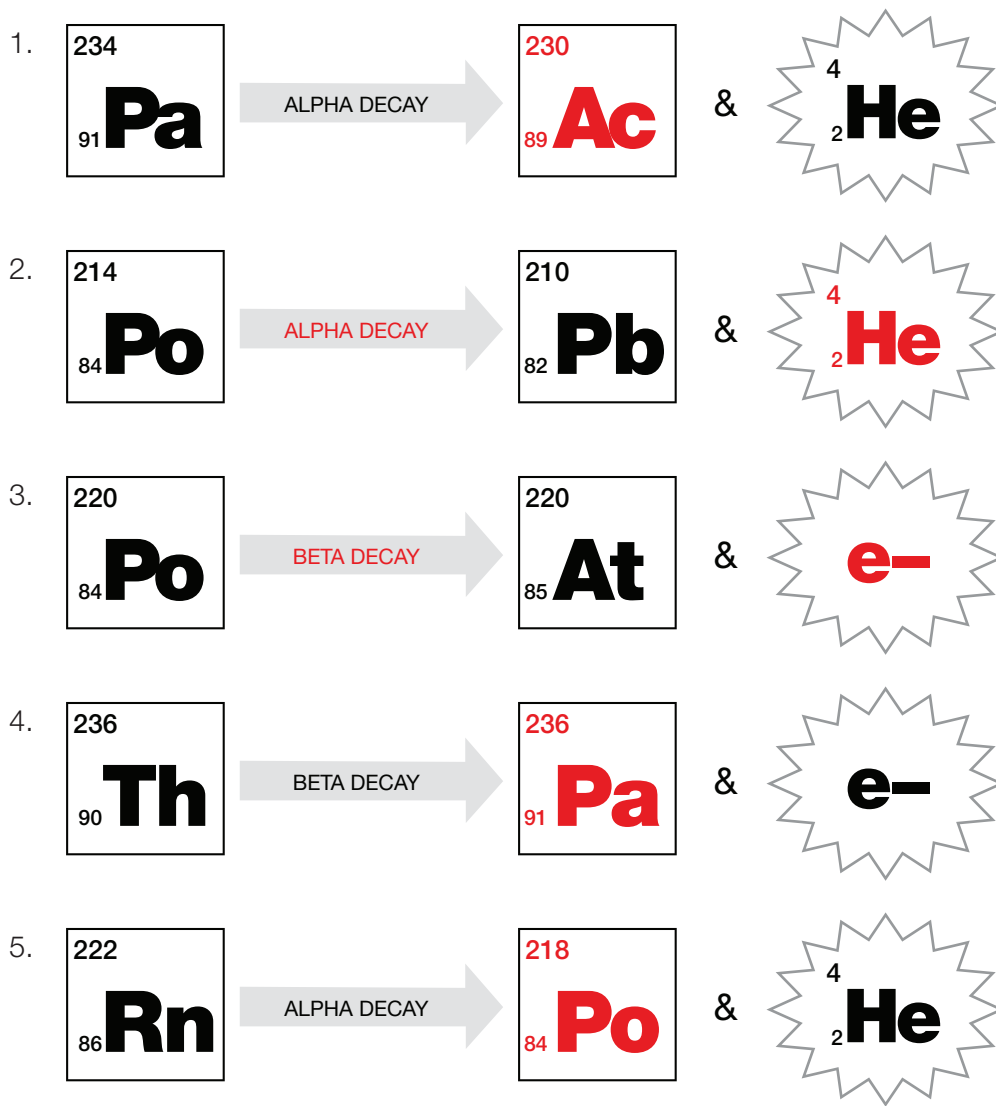
1. Using the correct atomic physics notation, complete the worksheet on nuclear reactions.
 - a. See teacher answer worksheet
2. Following the set of alpha and beta decays, graph the path of decays by drawing an arrow and writing the correct atomic symbol for each mass number per atomic number event.
 - a. See teacher answer worksheet

AUTHOR BIO:

Curtis Craig teaches biology for Utah Electronic High School. He received his zoology & botany degree from Brigham Young University (BYU) and earned his Master's of Education in particle astrophysics from Westminster College and the University of California/Berkeley. He is a co-founder of Hands On Universe. He is the recipient of numerous teaching awards including the United States Department of Energy's Top Ten Science Educators, the BYU Physical Science & Mathematics Teacher of the Year; the Tandy Technology Teacher of the Year; and the Presidential Awardee for Excellence in Math and Science Teaching. He is also past President of the Utah Science Teachers Association, and was awarded the Technology and Engineering Teacher of the Year award by the Utah Association of Career and Technical Education in 2008.

Nuclear Reactions and Atomic Notation

Data Analysis: *Teacher Answer Worksheet*



You may use a periodic table or a chart of the nuclides.

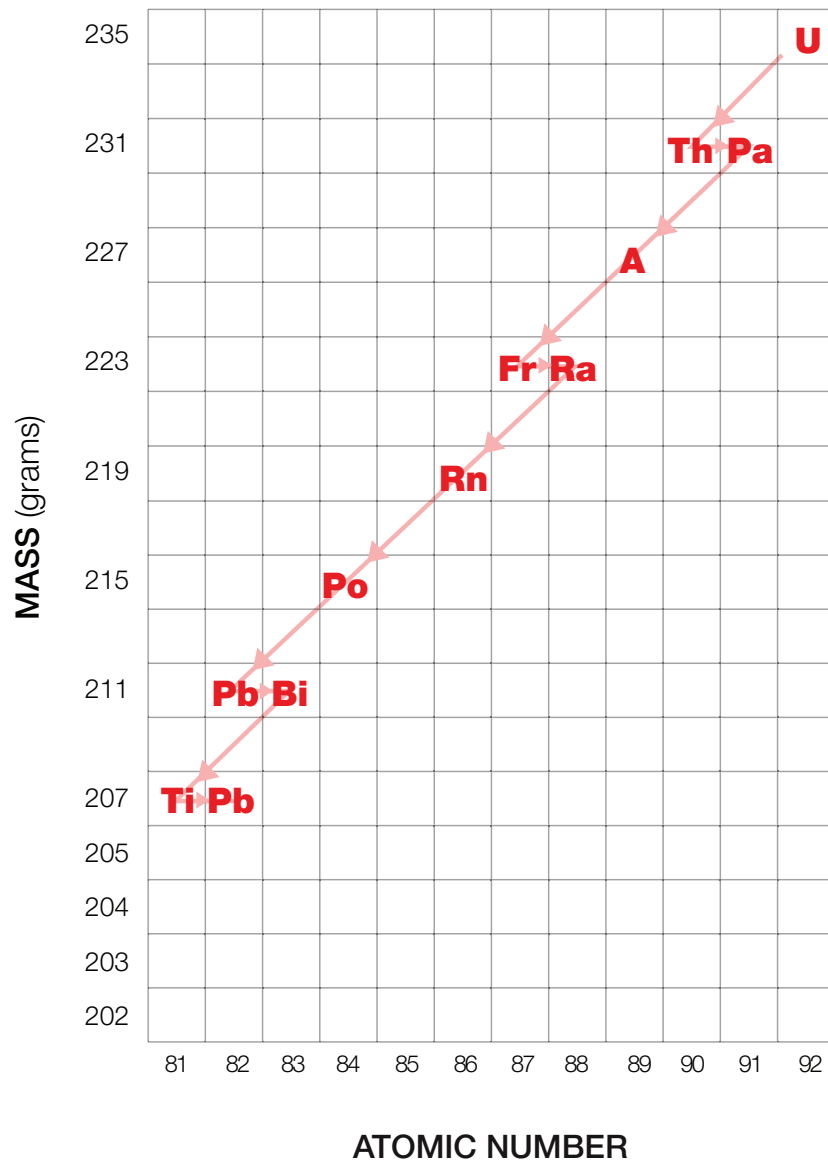
6. Use atomic notation like the problems above and create an **alpha decay** with the nuclide of your choice.
 - a. See above
7. Use atomic notation like the problems above and create a **beta decay** with the nuclide of your choice.
 - a. See above

Decay Event Table

Instructions: *Teacher Answer Worksheet*

Complete the graph by following the sequence of alpha and beta decays that actually occurs in nature from the decay event table. Start with U235 and Follow the steps (in order) of alpha and beta decays. Graph the path of decays by drawing an arrow tracing the mass number per atomic number and writing the correct atomic symbol for each mass number per atomic number event.

STEP #	DECAY EVENT
1	ALPHA
2	BETA
3	ALPHA
4	ALPHA
5	BETA
6	ALPHA
7	ALPHA
8	ALPHA
9	BETA
10	ALPHA
11	BETA
12	STABLE



ALPHAS, BETAS AND GAMMAS OH, MY!

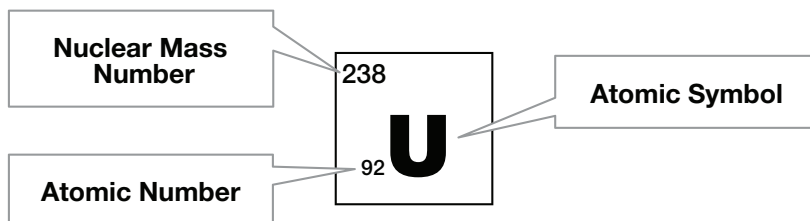
Student Activity

OBJECTIVE:

Complete the Nuclear Reactions Notation worksheets.

Overview:

Scientists and energy industry engineers use the following notation in describing the name of an element, its mass number and its atomic number:



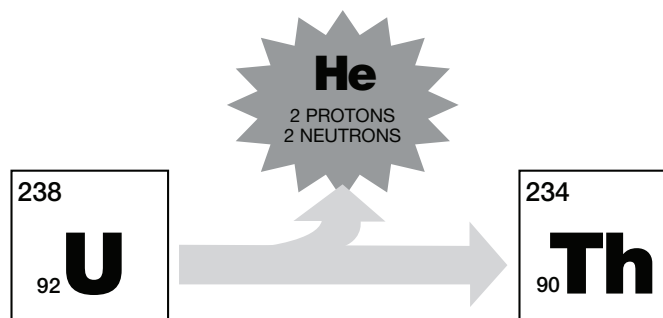
The **atomic symbol** is the notation used to “abbreviate” the name of an element, taken from the Periodic Table of Elements. For example: U is the atomic symbol for the element Uranium, Pb the atomic symbol for Lead.

The **nuclear mass number** written in the upper left corner of the atomic symbol is the number/mass of nucleons (protons & neutrons) in the nucleus of an atom of an element, including the mass of the electrons (*which is very small relative to the mass of the nucleons and is relatively negligible*). For example the mass number for the nuclide or isotope Uranium 238 is 238. To determine the exact number of neutrons in a given nuclide’s nucleus is to subtract the atomic number from the mass number. For example: the number of neutrons in U238 is $(238 - 92 = 146)$ so there are 146 neutrons in the nuclide of Uranium, U238.

The **atomic number** is the number of protons found in the nucleus of an atom of an element. For example the atomic number or number of protons in the nucleus of an atom of an element of Uranium is 92. An element is defined by its atomic number. In other words, you are the element you are because of the number of protons you have in the nucleus of your atom.

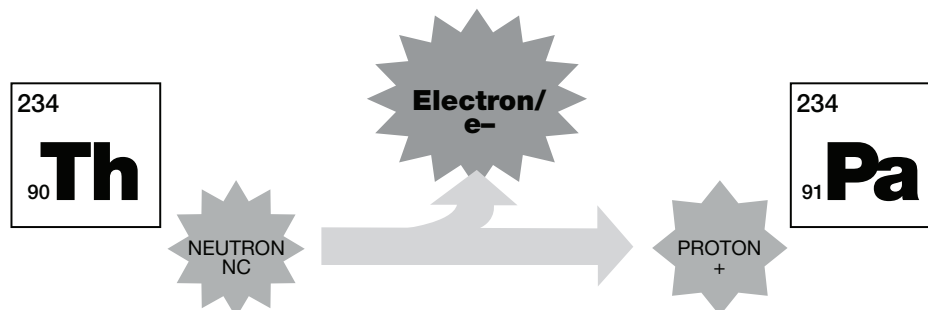
Now that students can read the notation, they are ready to play with alpha and beta decays as well as gamma decays or emissions. Like most games there are rules as to how nuclides decay.

Rule #1: Alpha decay is essentially the “emission” of a helium nucleus. So when an atom emits two protons and two neutrons, the atom alpha decays down the periodic table two elements (because of the ‘emission’ of two protons). For example: Uranium 238 whose atomic number is 92, becomes Thorium 234, Th, whose atomic number is 90. See the example below:



NOTE: In the above example of an alpha decay, it is intuitive to note that the emission of 2 protons will decrease the atomic number by 2, because of the emission of 2 protons. Less obvious or simply overlooked is the decrease in the mass number by 4 nucleons (2 protons and 2 neutrons in total)!

Rule #2: Beta decay is essentially the “emission” of charged particles. In our simple model we will use negatively charged particles, called electrons. In beta decay, unstable nuclides emit electrons. This occurs when a neutron in the nucleus of an atom becomes a proton and emits an electron. This happens because a neutron is just slightly more massive than a proton and electron. (Do not misinterpret this data, a neutron is not made of a proton and an electron) So when an element Beta decays its nuclide moves up the periodic table one element. For example: Thorium 234 whose atomic number is 90, becomes Paladium 234, Pa, whose atomic number is 91. See the following example:



NOTE: Another perhaps obvious observation is that there is an increase by 1 of the number of protons in the new nuclide. Not so intuitive is that the mass number does not change. The total number of nucleons remains the same.

Nuclear Reactions and Atomic Notation

Student Worksheet #1

Fill in the blanks with the correct notation, *atomic symbols*, *mass number*, *atomic number*, *decay type*, and/or *emission particles*.

1. $\begin{array}{|c|} \hline 234 \\ \hline \mathbf{Pa} \\ \hline 91 \\ \hline \end{array}$ $\xrightarrow{\text{ALPHA DECAY}}$ \square & $\begin{array}{|c|} \hline 4 \\ \hline \mathbf{He} \\ \hline 2 \\ \hline \end{array}$

2. $\begin{array}{|c|} \hline 214 \\ \hline \mathbf{Po} \\ \hline 84 \\ \hline \end{array}$ $\xrightarrow{\hspace{2cm}}$ $\begin{array}{|c|} \hline 210 \\ \hline \mathbf{Pb} \\ \hline 82 \\ \hline \end{array}$ & $\begin{array}{|c|} \hline \square \\ \hline \square \\ \hline \square \\ \hline \end{array}$

3. $\begin{array}{|c|} \hline 220 \\ \hline \mathbf{Po} \\ \hline 84 \\ \hline \end{array}$ $\xrightarrow{\hspace{2cm}}$ $\begin{array}{|c|} \hline 220 \\ \hline \mathbf{At} \\ \hline 85 \\ \hline \end{array}$ & $\begin{array}{|c|} \hline \square \\ \hline \square \\ \hline \square \\ \hline \end{array}$

4. $\begin{array}{|c|} \hline 236 \\ \hline \mathbf{Th} \\ \hline 90 \\ \hline \end{array}$ $\xrightarrow{\text{BETA DECAY}}$ \square & $\begin{array}{|c|} \hline \mathbf{e-} \\ \hline \square \\ \hline \square \\ \hline \end{array}$

5. $\begin{array}{|c|} \hline 222 \\ \hline \mathbf{Rn} \\ \hline 86 \\ \hline \end{array}$ $\xrightarrow{\text{ALPHA DECAY}}$ \square & $\begin{array}{|c|} \hline 4 \\ \hline \mathbf{He} \\ \hline 2 \\ \hline \end{array}$

You may use a periodic table or a chart of the nuclides.

- Use atomic notation like the problems above and create an **alpha decay** with the nuclide of your choice.
- Use atomic notation like the problems above and create a **beta decay** with the nuclide of your choice.

Decay Event Table

Student Worksheet #2

Complete the graph by following the sequence of alpha and beta decays that actually occurs in nature from the decay event table. Start with U235 and follow the steps (in order) of alpha and beta decays. Graph the path of decays by drawing an arrow tracing the mass number per atomic number and writing the correct atomic symbol for each mass number per atomic number event.

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7	ALPHA
8	ALPHA
9	BETA
10	ALPHA
11	BETA
12	STABLE

