Teaching Activity: Using Radioactive Decay to Determine Geologic Age

Introduction: Up until the late 18th century, science was covered by a haze of fantasy and mysticism about the real nature of life on Earth. Careful studies by scientists on the origins of rocks (petrology), coupled with the study of rock-layering (stratigraphy) and the evolution of life (paleontology) helped scientists reconstruct the sequence of events that shaped the Earth's surface. However, lack of exact dates allowed for dating only on a relative scale, and while Earth history was organized into units of geologic time (eras, period, etc.) scientists could only refer to approximate and not definite time periods.

In the late 1800s, Henri Becqueral, a French physicist, discovered the natural radioactive decay of uranium and opened new vistas in science. His work was followed by the research in n1905 of Lord Rutherford, a British physicist who made the first clear suggestion for using radioactivity as a tool for measuring geologic time directly In 1907, B.B. Boltwood of Yale University presented the first list of geologic ages based on radioactivity. The next 40 years was a period of unending research in the development and refinement of the methods and techniques used to measure the age of the Earth and since 1950 precise dating methods have been used extensively.

Radioactive decay is a spontaneous process in which an isotope (the parent element) loses particles from its nucleus to form a new element (the daughter). The rate of decay is expressed in terms of the isotope's half-life - the period of time it takes for ½ of a particular radioactive substance to decay. Most have rapid rates of decay (short half-lives) and lose their radioactivity within a few days or years. Some isotopes, however, decay slowly and several are used as "geologic clocks". The parent isotopes and the corresponding daughter products most commonly used to determine the ages of ancient rocks are listed below.

PARENT ISOTOPE	STABLE DAUGHTER ISOTOPE	HALF-LIFE VALUE
Uranium -238	Lead - 206	4.5 Billion years
Uranium -235	Lead - 207	704 Million years
Thorium -232	Lead - 208	14.0 Billion years
Rubidium - 87	Strontium -87	48.8 Billion years
Potassium - 40	Argon -40	1,25 Billion years
Samarium -147	Neodymium - 143	106 Billion years

Dating rocks using these radioactive timekeepers is simple in theory, but the laboratory procedures are very complex. The numbers of parent and daughter isotopes in each specimen are determined by various analytical methods. The principal difficulty lies in measuring precisely very small amounts of isotopes. Literally thousands of dated materials are now available for use to bracket the various episodes in Earth history within specific time zones. However, as the behavior of isotopes in the Earth's crust is more clearly understood, revisions and modifications will be forthcoming as research continues to improve our knowledge of Earth history.

Objectives:

- To understand the concept of radiactivity and radiaactive decay;
- To simulate the radioactive decay process using the imaginary chemical element "Zorkium";

Materials:

(Per group) : Shoe box with lid
100 cubes (Any cube shaped objects will work-sugar cubes, dice, etc.)

(Per student): **Student Data Table/Analysis Sheet**

Important Terms: **Radioactivity, isotope, radioactive decay, parent element, daughter element, stable element, half-life, relative/absolute time;**

Procedure:

1. Be sure that students understand the concepts of relative time, absolute time , radioactivity and rates of radioactive decay.
2. Arrange students into groups of 2-3.

3 . Introduce the activity by having students participate in the following introductory activity:

- Have one student list the names of in his/her immediate family (parents, siblings) in order from the oldest to the youngest. Tell students not to list the ages of any member.
- Ask the remainder of the class if there is any way to know from the available information the exact age of any family member. They will realize that it is not possible. The information they have can only be used to determine *relative age*, i.e., father is older than son or daughter, etc.,
- Explain that relative age is often used in the study of rocks. As scientists recognize that layers of rock had been deposited in sequence, one on top of another, they derived the principle of *stratigraphic supposition*, which says that in any sequence of strata, not later disturbed, the order in which they were deposited is from top to bottom. Therefore, the rocks on the bottom of the sequence of undisturbed strata are older than rocks at the top of the sequence.
- Have students identify the type of information they would need to determine the *absolute age* of any family member.

4. Explain to the class that they are going to participate in a simulation - an activity that will demonstrate to them how scientists determine the absolute age of rocks, mineral, and many other substances using radioactive decay as the tool. Give the following instructions to students or write them on the chalkboard:
   a. **The cubes you have been given represent the imaginary element "Zorkium".**
   b. **Mark only one side of each cube with a felt-tip pen.**

c. Put the cubes into the shoe box. Hold the lid tightly and turn the box over twice. Remove the lid.

d. Take out all the cubes that have the marked - side up. These cubes represent atoms that have decayed into the daughter element "DOZ" (Daughter of Zorkium).

e. In the Data Table beside Trial 1, record the number of cubes removed and the number of cubes remaining.

f. Repeat the procedures "d" and "e" until you have completed twelve trials of until all the cubes have been removed.

5. Have students use the data collected in the chart to construct a graph.

- On the vertical axis they should plot the number of cubes remaining.
- On the horizontal axis they should plot the trial numbers.
- They should connect the points they have plotted and draw a best- fit line for these points.

6. Students should then answer the questions in the **Analysis** section.

NOTES: Below is a table of some popular dating materials in use and the approximate age in years they are capable of dating.

Sample	Approximate Age in Years
Cloth wrappings from a mummified bull. [Samples taken from a pyramid in Dashur, Egypt. This date agrees with the age of the pyramid as estimated from historical records.]	2,050
Charcoal. [Sample, recovered from bed of ash near Crater Lake, Oregon, is from a tree burned in the violent eruption of Mount Mazama which created Crater Lake. This eruption blanketed several States with ash, providing geologists with an excellent time zone.]	6,640
Charcoal. [Sample collected from the "Marmes Man" site in southeastern Washington. This rock shelter is believed toe among the oldest known inhabited sites in North America.]	10,130
Spruce Wood. [Sample from the Two Creeks forest bed near Milwaukee, Wisconsin, dates one of the last advances of the continental ice sheet into the United States.]	11, 640
Bishop Tuff.[Samples collected from volcanic ash and pumice that overlie glacial debris in Owens Valley, California. This volcanic episode provides an important reference datum in the glacial history of North America.]	700,000
Volcanic ash. [Samples collected from strata in Olduvai Gorge, East Africa, which sandwich the fossil remains of Zinjanthropus and Homo habilisÑpossible precursors of modern man.]	1,750,000
Monzonite. [Samples of copper-bearing rock from vast open-pit mine at Bingham Canyon, Utah.]	37,500.000
Quartz monzonite. [Samples collected from Half Dome, Yosemite National Park, California.]	80,000,000
Conway Granite. [Samples collected from Redstone Quarry in the White Mountains of New Hampshire.]	180,000,000
Rhyolite. [Samples collected from Mount Rogers, the highest point in Virginia.]	820,000,000
Pikes Peak Granite. [Samples collected on top of Pikes Peak, Colorado.]	1,030,000,000
Gneiss. [Samples from outcrops in the Karelian area of eastern Finland are believed to represent the oldest rocks in the Baltic Region.]	2,700,000,000
The Old Granite. [Samples from outcrops in the Transvaal, South Africa. These rocks intrude even older rocks that have not been dated.]	3,200,000,000
Morton Gneiss. [Samples from outcrops in southwestern Minnesota are believed to represent some of the oldest rocks in North America.]	3,600,000,000

Student Activity Sheet #1

DATA TABLE: ZORKIUM DECAY DATA

TRIAL NUMBER	Number of daughter atoms	Number of Zorkium atoms remaining
	0	100
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		

Student Activity Sheet #2

ANALYSIS/COMPREHENSION

1. Explain the radioactive decay of an element. ______________________________
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2. Define half - life of a radioactive element and how it can be used as an "Atomic clock". ____
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3. Compare relative and absolute dating. Discuss differences in these two ways of dating materials. ____
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4. How many trials did it take for the Zorkium to decay? ______________________

5. Suppose each trial equals 1000 years, what is the half-life of Zorkium?____

6. After half (50) of the Zorkium cubes were removed from the box, how long did it take for half of the remaining cubes to decay? This amount of time represents the half-life of Zorkium. __________________________________

7. Does your graph look like your neighbors? Why or why not? ________________
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Student Activity Sheet #2

ANALYSIS/COMPREHENSION

8. Imagine that you have a radioactive sample containing both Zorkium and DOZ. After analysis you find that it contains 25 atoms of Zorkium and 75 atoms of DOZ. How old is your sample? (HINT: You must use the half-life of Zorkium determined earlier in the activity). ________________________

ENRICHMENT:

1. Have students research two early methods for determining the age of Earth based on the salinity of the oceans and the cooling history of the Earth.

2. Have students research methods scientists used to date rocks that were brought back from the moon.

3. Have students research the term *isotope*. How does this relate to and what are the hazards associated with Radon.

4. Have students research real chemical elements used as atomic clocks - Carbon-14, Potassium-40, etc., and how each is used to determine the ages of particular kinds of rocks or minerals of a given time span.