Activity 4: The Half-Life of Radon

Objectives

Students will:

- Learn about radioactive decay, decay chains and how radon forms radioactive products or particles that can be harmful.
- Demonstrate the concept of half-life.
- Calculate and chart the half-life of a given sample.
- Discuss the significance of knowing the half-life of radioactive elements.

Next Generation Science Standards

The concepts in this activity can be used to support the following science standards:

- PS1. Structure and Properties of Matter.
- ESS3. Earth and Human Activity.

Materials and Resources

- *Radon: Teacher Background Information*.
- *Vocabulary Materials*.
- *Radon Exposure* image (display or copy for students).
- Computer and projector for displaying information.
- *Half-Life Data Sheet* (one per student, pair or group) and *Half-Life Teacher Answer Key*.
- Student calculators (optional).
- *Radon-222 Decay Chain* (optional; display or copy for students).

Time

45-60 minutes, not including optional activities or extensions.

Vocabulary

- Ionizing radiation
- Radiation
- Radon
- Uranium

Directions

1. Start with a vocabulary activity if students are not familiar with radon and the terms used in this activity.

2. Display the *Radon-222 Decay Chain* image. Explain that radioactive elements are made up of atoms with an unstable nucleus. The nucleus is unstable because of strong forces or extra energy built up inside. As the nucleus tries to become stable, it gives off (emits) energy or radiation in the form of alpha particles, beta particles, gamma radiation or a combination of the three. When radiation is emitted, the nucleus forms a new, more stable, nucleus of a different element. This process continues until the nucleus becomes stable and is no longer radioactive. Radon is a radioactive gas. Its decay products (polonium, bismuth and lead) are metals that can easily attach to dust and other particles in the air. Those particles can be circulated and transported in air and inhaled. Note that radioactive elements are constantly giving off radiation as they decay, not just in single bursts.

3. Explain that each radioactive element has a half-life. **Half-life is the amount of time it takes for half of the radioactive atoms in a sample to decay into a more stable form. In the decay chain, students can see that radon has a half-life of 3.8 days. Polonium-218 has a half-life of 3 minutes.**

4. Provide students with the *Half-Life Data Sheet*. Have them read the initial statement and form a hypothesis.

5. Demonstrate the concept of half-life with the class by choosing from the following options:
   - Select three volunteers. Have the volunteers stand at a distance from an easily identifiable location (e.g., a wall or the classroom door). Direct each volunteer to move at varying rates (fast, moderate and slow) to represent half-lives of different elements. For example, radon has a half-life of 3.8 days, radium has a half-life of 1600 years, and uranium has a half-life of 4.5 billion years. Direct each volunteer to walk halfway toward the identifiable location at their designated rate and stop before continuing to the next halfway point between them and the identifiable location. They will continue this process until they cannot go any farther. You can mark the halfway points with string or paper if students need the guidance.
   - Ask for 12 volunteers. Have the volunteers line up in the front of the room. Provide each volunteer with two different colored sheets of paper to represent radon and polonium. Have all of the volunteers hold the radon paper out front facing the students. Have half of the volunteer (any 6 of the 12) place the polonium colored paper out front to represent half of the atoms that transformed to polonium. Then have the next half (3 of the 6 volunteers showing radon) place the polonium paper out front. In the next half-life, have one volunteer place the polonium paper out front and have another volunteer show half radon and half polonium by folding one or both of the papers in half. The remaining volunteer should then place the polonium paper out front and the volunteer showing half radon, half polonium should fold one or both papers to represent ¾ radon and ¼ polonium.
   - Show an online video or demonstration of half-life. Sources may include TeacherTube, other allowed Internet sources, or Colorado University's online applet that demonstrates half-life and radioactive decay.

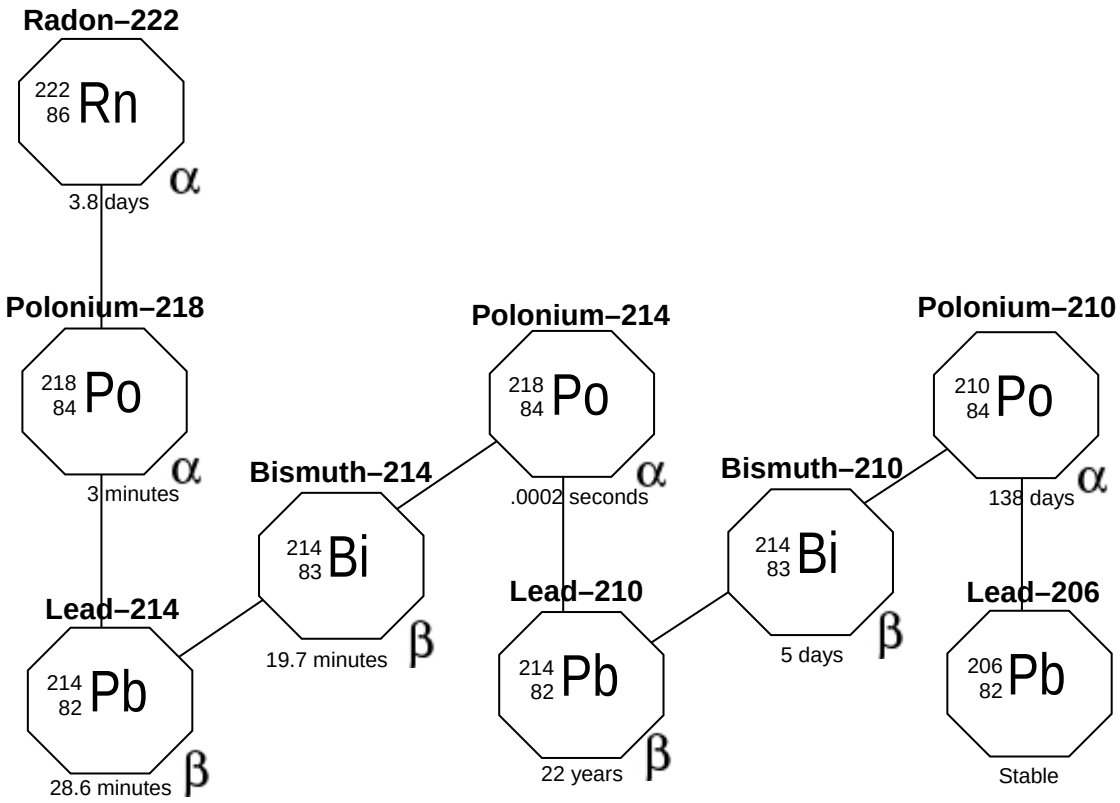
6. Direct students to complete the remainder of the *Half-Life Data Sheet*. The use of calculators is optional.

7. Ask students to share their observations and conclusions from the activity. The *Half-Life Teacher Answer Key* is provided.

8. Conclude by sharing that radon is naturally present in our world. The chances of getting lung cancer from radon depends mostly on:
   - The indoor radon level of the places where a person spends most of their time. The U.S. Environmental Protection Agency (EPA) recommends fixing or lowering radon levels that are 4 picocuries per liter (pCi/L) or higher.
   - The amount of time a person is exposed to higher levels of radon.
   - Whether a person is also exposed to cigarette smoke (which can also cause lung cancer).

9. Optional activities or extensions:
   - Have students create posters for the National Radon Poster Contest: www.sosradon.org/poster-contest
   - Draw a diagram of lungs or locate a video showing the progression of lung cancer as the lungs go from healthy to damaged over a span of years.
   - Construct a model of the lungs providing a breakaway of the lung to show its inner tissue (bronchioles, alveoli and bronchial tubes) to show how radon products can stick to lung tissue and cause damage.
   - Invite a nurse, doctor or health care professional to come in and talk about radon exposure and lung cancer.

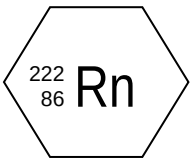
Radon-222 Decay Chain



Key

Alpha particle: α

Beta particle: β



In the example, Rn is the atomic symbol for the element Radon. The number 222 indicates the atomic mass of the element (or isotope). The number 86 respresents the element's atomic number.

Half-Life Data Sheet

Name: _____ Date: _____

Each radioactive (unstable) element has a different half-life. Hypothesize what half-life is:

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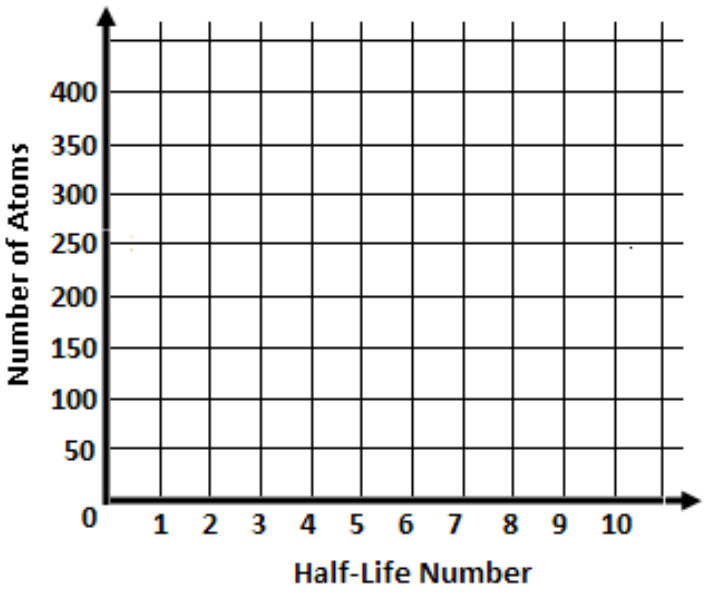
Complete the half-life demonstration as directed by your teacher.

Calculate the number of radon atoms remaining after each half-life starting with a radon sample of 400 atoms. Write the number of atoms in the "Number of Remaining Radon Atoms" column. Round decimals to the nearest hundredth (For example: .474 = .47). Plot the number of radioactive atoms on the graph according to the half-life number.

Half-Life Number	Number of Radon Atoms
0	400
1 (3.8 days)	
2 (7.6 days)	
3 (11.4 days)	
4 (15.2 days)	
5 (19 days)	
6 (22.8)	
7 (26.6 days)	
8 (30.4 days)	
9 (34.2 days)	
10 (38 days)	



1. Observations:

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2. Conclusions:

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3. Why is it useful to know the half-life of radioactive materials?

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4. Radon is the second leading cause of lung cancer. How does the half-life of radon and its decay products cause damage to lung tissue that can lead to lung cancer over the course of a lifetime?

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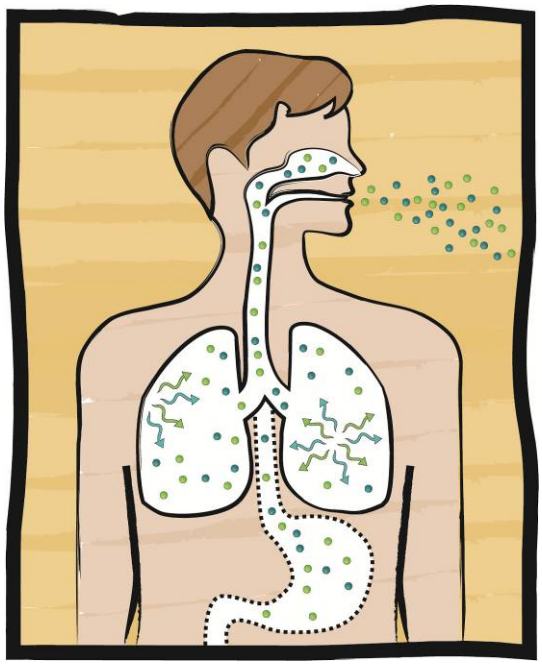
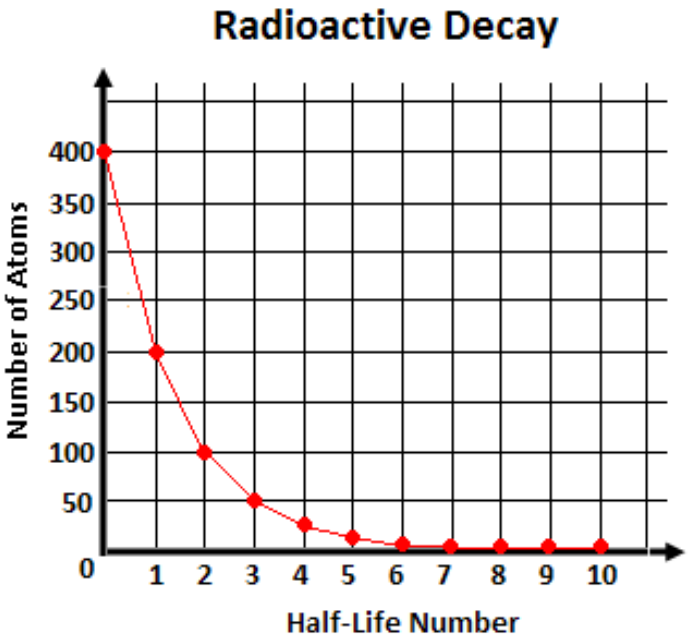


Half-Life Teacher Answer Key

Each radioactive (unstable) element has a different half-life. Hypothesize what half-life is: **The amount of time it takes for half of the radioactive atoms in a sample to decay into a more stable form.**

Half-Life Number	Number of Remaining Radon Atoms
0	400
1 (3.8 days)	*200*
2 (7.6 days)	*100*
3 (11.4 days)	*50*
4 (15.2 days)	*25*
5 (19 days)	*12.5*
6 (22.8)	*6.25*
7 (26.6 days)	*3.13*
8 (30.4 days)	*1.57*
9 (34.2 days)	*.79*
10 (38 days)	*.40*



1. Observations: **Students should observe that the more time that passes, the more radioactive decaying takes place. After each half-life number, the number of radon atoms is decreased by half.**

2. Conclusions: **Students should reach the conclusion that over time, radioactive atoms become more and more stable as they decay.**

3. Why is it useful to know the half-life of radioactive materials? **It helps in determining how long radioactive material must be safely stored, when radioactive material will be safe to handle, or how long a source will remain radioactive. For example, radioactive dye (called a tracer) or radioactive seeds are used in medical imagery and cancer treatment. Knowing the half-life helps doctors and patients know how long the radioactive material will be effective and when it will stop producing radiation.**

Radium is used in industrial radiography devices (a technology similar to x-ray imaging) to inspect for flaws in metal parts. Radium also has been added to the tips of lightning rods, improving their effectiveness by ionizing the air around it.
We do not generally use radon for any useful purposes.

4. Radon is the second leading cause of lung cancer. How does the half-life of radon and its decay products cause damage to lung tissue that can lead to lung cancer over the course of a lifetime? **Radon gas decays into radioactive particles that can get trapped in your lungs when you breathe. As they break down further, these particles release small bursts of energy. This can damage lung tissue and lead to lung cancer over the course of your lifetime. The amount of time between exposure and the onset of the disease may be many years.**