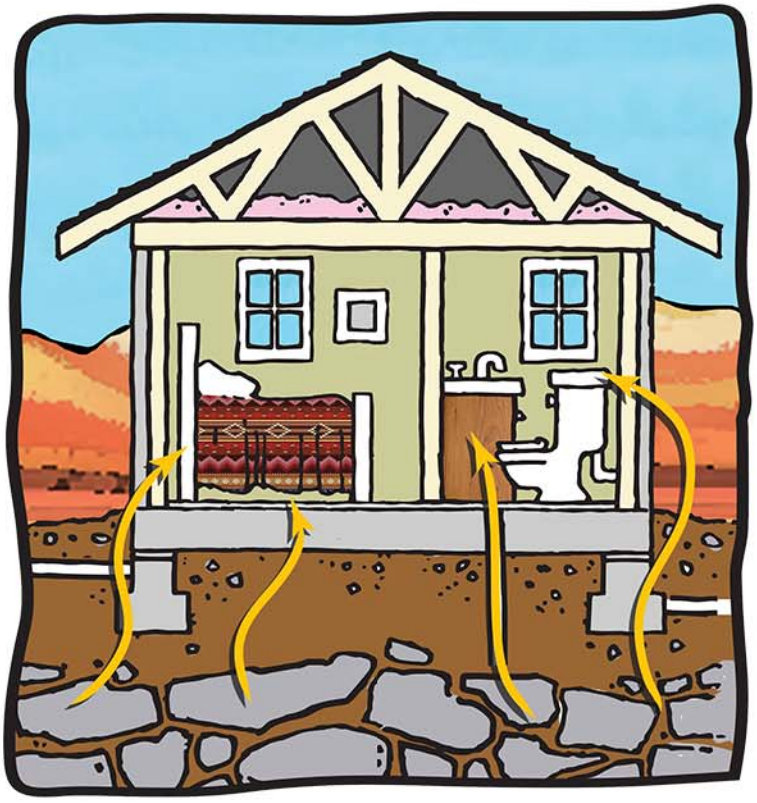
U.S. EPA Radiation Education Activities:

Radon



United States Environmental Protection Agency

U.S. EPA Radiation Education Activities: **Radon**

Radon is one of the most serious environmental health threats in the nation. Exposure to radon causes almost 21,000 deaths each year. This makes it the number one cause of lung cancer for non-smokers and the second leading cause of lung cancer for the nation as a whole. Nationally, one out of every fifteen U.S. homes has a problem. You cannot see radon, but it's not hard to find out if radon is a problem in your home. Radon can be detected with a simple test and elevated radon levels can be lowered with straightforward, proven methods. Testing is quick, easy and inexpensive.

Target Audience and Activity Topics

The Radon activities introduce middle and high school students to radon's physical properties and its health effects. The activities encourage students to test their homes and implement ways to reduce their exposure to radon.

Students will examine how radon moves through the ground and enters homes and buildings through cracks and gaps. The students will learn about solutions available to reduce elevated radon levels. Students will evaluate sample radon readings and determine if fixes need to be made to the home or building. Students are encouraged to test their homes using a short-term test kit and analyze their readings. These activities also examine radon's decay chain, the half-life of radon and how these by-products can get trapped in the lungs and cause cancer.

NOTE: The term "radiation" used in these activities refers to ionizing radiation unless otherwise indicated.

Activity Times

All U.S. Environmental Protection Agency (EPA) Radiation Education Activities can be used individually or modified and combined to create multiple lessons. Activity options allow you to customize the activities to fit the time you have available (e.g., 1–2 class periods) and meet the needs and interests of your students.

The time needed to complete activities is between 45-60 minutes, not including optional activities or extensions.

Next Generation Science Standards

The concepts within these activity sets can be used to support the following science standards:

- ESS2. Earth's Systems
- ESS3. Earth and Human Activity
- ETS1. Engineering Design
- PS1. Structure and Properties of Matter

Common Core State Standards (CCSS)

The concepts in the Vocabulary Activities align with the following CCSS English Language Arts Standards for Literacy in History/Social Studies, Science, & Technical Subjects:

- Key Ideas and Details: CCSS.ELA-LITERACY.RST.6-12.2
- Craft and Structure: CCSS.ELA-LITERACY.RST.6-12.4
- Vocabulary Acquisition and Use: CCSS.ELA-LITERACY.L.6-12.6

Table of Contents

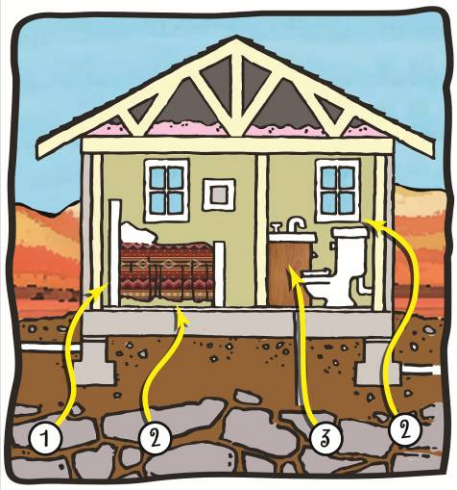
Radon: Teacher Background Information

You can't see radon. You can't smell it or taste it either, but it may be a problem in your home or school. Radon is a radioactive gas found in rock, soil and water. Radon is found all over the U.S. It can get into any type of building — homes, offices and schools — and result in a high indoor radon level. You and your family are most likely to get your greatest exposure at home, where you spend most of your time. The only way to know if your home or school has a radon problem is to test for it.

Breathing radon increases your risk of lung cancer. Radon is the number one cause of lung cancer among people who do not smoke. It is the second leading cause of lung cancer for people who do.

Radon in Homes or Buildings

Radon comes from the decay of uranium that is found in nearly all soils. It typically moves up through the ground to the air above and into your home through cracks and other holes in the foundation. Your home traps radon inside, where it can reach dangerous levels. Any home may have a radon problem. This means new and old homes, well-sealed and drafty homes, and homes with or without basements.



Radon can get into homes through:

1. Construction joints
2. Cracks and gaps in floors and walls
3. Gaps around service pipes and through water supply lines

Sometimes radon enters the home through well water. Compared to radon entering the home through water, radon entering your home through the soil is usually a much larger risk. In a small number of homes, the building materials can give off radon, too.

Radon in Water

Radon in water supplies poses an inhalation risk and an ingestion risk. Research has shown that the risk of lung cancer from breathing radon in air is much larger than the risk of stomach cancer from swallowing water with radon in it. Most of your risk from radon in water comes from radon released into the air when water is used for showering and other household purposes.

Radon in your home's water is not usually a problem when it comes from surface water. A problem is more likely when the radon source is ground water, such as a private well or a public water supply system that uses ground water. If you are concerned about radon coming from a public water supply, contact your water supplier or the EPA's Safe Drinking Water Hotline at 1-800-426-4791.

Uranium Mining and Radon

Uranium mining releases radon from the ground into the atmosphere. Underground mines could pose a higher radon risk to both the public and workers. Mines and mining waste can release radioactive elements, including radon, and other pollutants to streams and other bodies of water. Federal and state agencies have set limits and drinking water standards, and continue to monitor these sites for public safety.

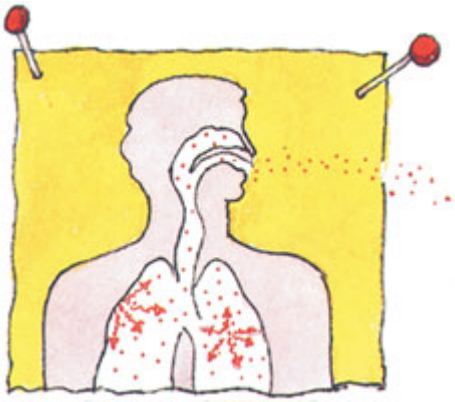
Uranium miner.
Source: National Institute of Environmental Health Sciences

Uranium mine waste from operations that closed before the mid-1970s are of particular concern. Many abandoned uranium mines are located in the western U.S. and near Native American communities where uranium is generally found. In some cases, these mines were abandoned and the waste piled near the mine. Weathering can cause radioactive dust to be blown by the wind and seep into surface and ground water. There are also cases of uranium mine waste being used for house construction, which creates significant radon and radiation hazards for the people living in those homes.

Living with Radon

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. However, not everyone exposed to elevated levels of radon will develop lung cancer. The amount of time between exposure and the onset of the disease may be many years.

Like other environmental pollutants, there is some uncertainty about radon health risks. However, we know more about radon risks than risks from most other cancer-causing substances, due to studies of cancer in humans (including underground miners).



Smoking combined with radon is an especially serious health risk. If people stop smoking and lower radon levels in their home, they can reduce their lung cancer risk significantly.

Radon Testing

Radon is measured in picocuries per liter of air (pCi/L), a measurement of radioactivity. In the United States, the average indoor radon level is about 1.3 pCi/L. The average outdoor level is about 0.4 pCi/L. The U.S. Surgeon General and the U.S. Environmental Protection Agency (EPA) recommend fixing homes with radon levels at or above 4 pCi/L. EPA also recommends that people consider fixing their homes for radon levels between 2 pCi/L and 4 pCi/L.

Testing your house for radon is easy. A simple test will tell you if your home has a high radon level. It's as easy as opening a package and putting the test kit in the right place for several days. After sending the test kit back to the address in the package, the company will send your radon test results in about 2 weeks. Fixing a radon problem reduces the risk of lung cancer for you and your family.

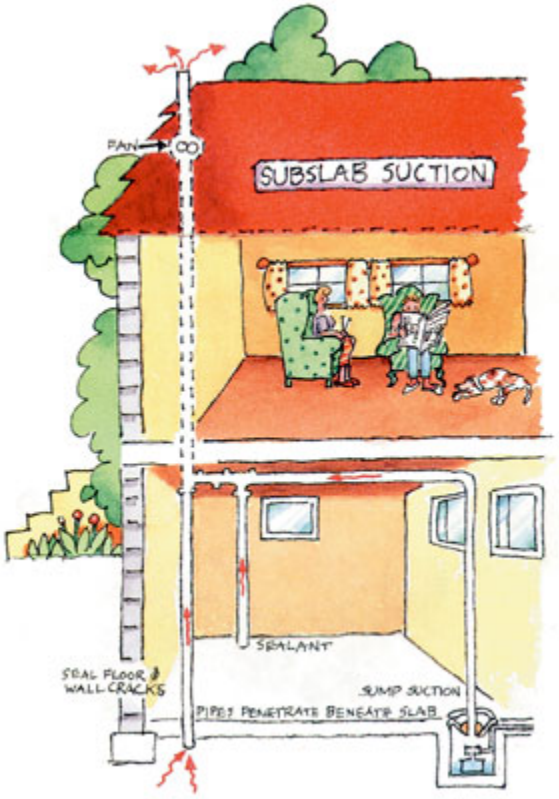
How to Get Radon Test Kits

To get an easy-to-use radon test kit you can:

- Buy a test kit online or at your local home improvement or hardware store. Many kits are priced under $25.00.
- Order a test kit at www.sosradon.org or by calling 1-800-SOS-RADON (1-800-767-7236); customizable radon test kit coupons are available too.
- Request a test kit from your state radon program. Visit http://www2.epa.gov/radon/find-information-about-local-radon-zones-and-radon-programs to see radon levels measured across the country.
- Hire a qualified tester to do a radon test for you. Your state radon program may keep a list of these professionals.

Fixing and Avoiding Radon Problems

Buildings with high levels of radon have been found in every state. In fact, radon levels can vary greatly from building to building or home to home, even in close proximity. There are several proven methods to reduce radon in buildings, but the one primarily used is a vent pipe system and fan which pulls radon from beneath the house and vents it to the outside. This system, known as a soil suction radon reduction system, does not require major changes to the home or building. Sealing foundation cracks and other openings makes this kind of system more effective and cost-effective. Similar systems can also be installed in houses with crawl spaces.



If radon in water is a problem, it can be fixed. Water supply treatments can be used to remove radon from the water before it enters your home, or at the tap. Treating water at the tap only treats a small portion of the water you use and is not effective in reducing the risk from breathing radon released into the air from all water used in the home.

Building new homes with simple and cost-effective radon-resistant features can reduce radon. Contact your builder or visit http://www2.epa.gov/radon/building-new-home-have-you-considered-radon for more information. Every home should be tested before, or soon after, you move in. Even homes built with radon-resistant construction features should be tested. If high radon levels are found, it is easier and costs less to reduce radon levels in homes that are built radon-resistant.

Additional Resources:

- RadTown USA: www3.epa.gov/radtown
- Radon (Rn): http://www2.epa.gov/radon
- Radon Information for Kids, Students and Teachers: http://www2.epa.gov/radon/radon-information-kids-students-and-teachers
- A Citizen's Guide to Radon: http://www2.epa.gov/radon/citizens-guide-radon-guide-protecting-yourself-and-your-family-radon

Radon Vocabulary Activities

The concepts surrounding radiation can be complex. By conducting a vocabulary activity before beginning an activity or series of activities, students will have a shared base knowledge.

Materials and Resources

- *Vocabulary Materials* document.
- Materials noted in activity suggestions.

Common Core State Standards (CCSS)

The concepts in this activity align with the following CCSS English Language Arts Standards for Literacy in History/Social Studies, Science, & Technical Subjects:

- Key Ideas and Details: CCSS.ELA-LITERACY.RST.6-12.2
- Craft and Structure: CCSS.ELA-LITERACY.RST.6-12.4
- Vocabulary Acquisition and Use: CCSS.ELA-LITERACY.L.6-12.6

Vocabulary by Activity

Activity 1: Ground Up	• Ionizing radiation • Radiation • Radioactive atom	• Radioactive decay • Radon • Uranium
Activity 2: Radon Vacuum	• Ionizing radiation • Radiation	• Radon • Uranium
Activity 3: Indoor Radon Levels	• Ionizing radiation • Radiation	• Radon • Uranium
Activity 4: The Half-Life of Radon	• Alpha particles • Half-life • Ingestion • Inhalation • Ionizing radiation	• Radiation • Radioactive atom • Radioactive decay • Radon • Uranium

Activity Suggestions

- **Identifying images.**
  - Print the applicable images from the *Vocabulary Materials* document.
  - Display the images around the room or spread them out in an open area on the floor.
  - Pronounce the vocabulary words one at a time. NOTE: You can provide the definition of the given word at this time or after students have identified the words.
  - Have students take turns identifying the words in an active manner. Suggestions include having students move to and identify the correct image, use a flashlight to point to the correct image (review safety rule: never shine the light in another person's eyes), drive a remote control car to the correct image, or throw a bean bag to land on the correct image.
- **Matching words and images.**
  - Print the applicable words and images from the *Vocabulary Materials* document.
  - Give each student a vocabulary word or image. Options: Fold or ball up the copies and let each student select one. Have students trade their copy with another student once or twice. NOTE: You may need to participate to have an even number of participants.
  - Direct students to find the person with the matching word or image.
  - Review the matches to confirm they are correct.
  - Pronounce each word and provide a definition.
- **Spelling the words.**
  - Print the applicable words and images from the *Vocabulary Materials* document.
  - Display the words and images.
  - Pronounce each word and provide a definition.
  - Conduct a spelling activity:
    - Have students create a word scramble or word find activity, trade papers and complete the activity.
    - Play spelling basketball. Divide the class into two teams. Pronounce a vocabulary word. Have a student (alternating between teams) spell or write the word on the board. Students that spell the word correctly are given an opportunity to shoot a basket (use a trash can) with a ball of paper (ball) from a designated distance (or varying distances for a different number of points). The team that scores the most points wins. You can have students provide a definition for extra points.
- **Creating definitions.**
  - Print the applicable words and images from the *Vocabulary Materials* document.
  - Display the vocabulary words and images.
  - Pronounce the vocabulary words.
  - Have students work in pairs or small groups to hypothesize and create a definition for each vocabulary word.
  - Options: Direct one student from each pair/group to rotate and join another pair/group or have two pairs/groups join together. Direct the newly formed groups to compare their definitions and modify them if desired.
  - Review each pair/group's definitions, have students discuss what they agree/disagree with and share the accurate definition.

Activity 1: Ground Up

Objectives

Students will:

- Predict whether they live in an area where the potential average indoor radon levels are low, moderate or high.
- Investigate why indoor radon levels vary.
- Conduct experiments to investigate the movement of radon through the ground.

Next Generation Science Standards

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

- ESS2. Earth's Systems.
- ESS3. Earth and Human Activity.

Materials and Resources

- *Radon: Teacher Background Information*.
- *Vocabulary Materials*.
- *Radon Zones Map* and state radon zones map (display with computer and projector, copy for students, or allow them to access the maps with student computers):
  - EPA Map of Radon Zones: http://www2.epa.gov/radon/find-information-about-local-radon-zones-and-radon-programs#radonmap
- *Ground Up Worksheet* (one per student, pair or group) and teacher answer key.
- *Ground Up Data Sheet* (one per student, pair or group).
- Containers, such as small, clear plastic tubs or clear plastic cups (at least one per pair or group or one for each type of rock and soil per pair or group).
- Rocks and soil representative of the local geology (enough of each type so pairs or groups can partially fill the tubs or cups).
- Straws (at least one per student).
- Beakers (one per pair or group).
- Water.
- Droppers (one per pair or group).

Time

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

Vocabulary

- Ionizing radiation
- Radiation
- Radioactive atom
- Radioactive decay
- Radon
- Uranium

Directions

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

2. Explain that radon is a naturally occurring radioactive gas that comes from the decay of uranium found in rocks and soils. Human activities, such as uranium mining, can increase the risk of radon exposure. During the mid-1940s to 1970s, the U.S. was in a race with the Soviet Union to develop and test nuclear weapons. Nuclear power was also introduced during this time. Thousands of uranium mines were in operation, primarily in the Western part of the U.S., and nuclear testing was taking place in the West and in Alaska. When the demand for uranium decreased, uranium mines and testing areas were abandoned; leaving contaminated soil and water with high radon levels that has affected Native Americans and Alaska Natives.

   Radon is a threat to health because it tends to collect indoors in homes and buildings, sometimes to very high levels, and can cause lung cancer.

3. Ask students to predict whether they live in an area where the potential average indoor radon levels are low, moderate or high and explain their reasoning.

4. Display or provide students with a copy of the *Radon Zones Map* and their state map. State maps are web-accessible through http://www2.epa.gov/radon/find-information-about-local-radon-zones-and-radon-programs#radonmap. Explain that the maps show potential average indoor radon levels by three zones: Zone 1 (red) is predicted to have high indoor radon levels, Zone 2 (orange) moderate indoor radon levels, and Zone 3 (yellow) low indoor radon levels.

5. Ask students to hypothesize why certain areas (or the area where they live) have greater potential for higher indoor radon levels or why two houses side by side can have very different radon levels. **This is due to the geology below the individual homes. It may be that the rock and soil has a higher uranium (and therefore, radon) content or that the type of rock and soil and presence of cracks and fissures that might allow radon to move up more easily through the ground. How well the homes are built, including how well floors, walls and gaps are sealed or how ventilated the home is, may be other factors.**

6. Distribute the *Ground Up Worksheet*. Provide rock and soil samples of the local geology and identify each. Direct students to answer the questions.

7. Distribute the *Ground Up Data Sheet.* Direct students in completing the experiments and documenting their findings.

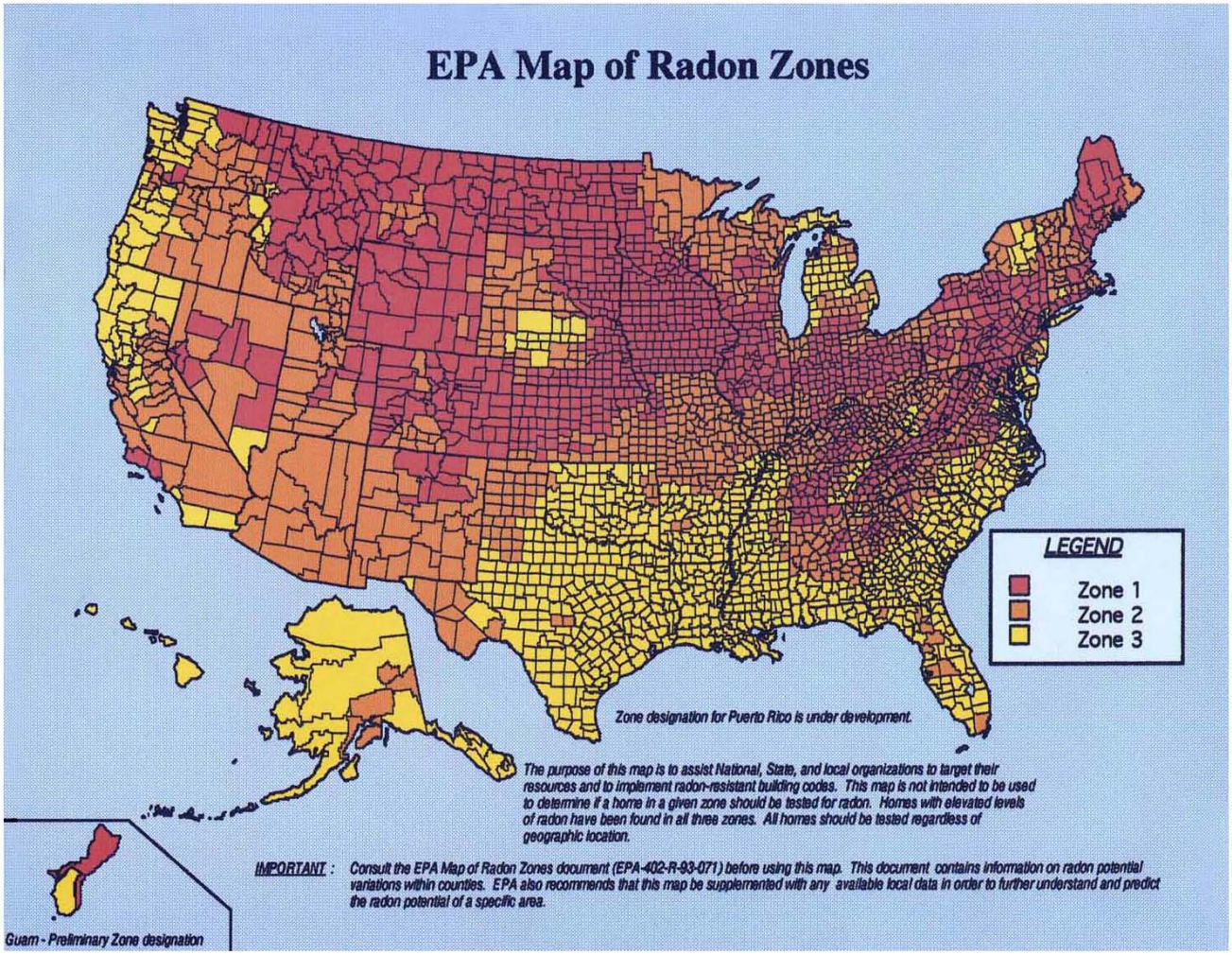
8. Review students' findings and conclusions when complete. *The Ground Up Teacher Answer Key* may serve as a guide.

9. Conclude by asking students if they should rely solely on radon maps to determine whether they should test their home for radon. **Students should recognize the importance of testing all homes because uranium exists in nearly all rock and soil and the movement of radon can vary greatly based on the formation of the earth or the presence of cracks and fissures below individuals' homes.**

10. Optional activities or extensions: Have students:
    - Investigate how scientists collect soil air samples to determine the radon content.
    - Investigate local soil air data (check with your state's radon program), chart the data and identify areas of concern.
    - Examine the local rock and soil types. Plot on a map the geological breakdown of the area with low, medium and high radon potential. Have students test different areas using short-term test kits. Plot the results on the map, determine which results correlate with the radon potential of area and provide possible explanations if the data doesn't correlate.

Radon Zones Map

The U.S. Environmental Protection Agency (EPA) created this map to identify areas with the potential for elevated indoor radon levels. The EPA Map of Radon Zones helps national, state, and local organizations implement radon-resistant building codes. The map should not be used to determine if a home in a given zone should be tested for radon. Homes with elevated levels of radon have been found in all three zones. All homes should be tested for radon.



What do the colors mean?

	Zone 1 (red zones)	Highest potential; average indoor radon levels may be greater than 4 pCi/L (picocuries per liter)
	Zone 2 (orange zones)	Moderate potential; average indoor radon levels may be between 2 and 4 pCi/L
	Zone 3 (yellow zones)	Low potential; average indoor radon levels may be less than 2 pCi/L

Ground Up Worksheet

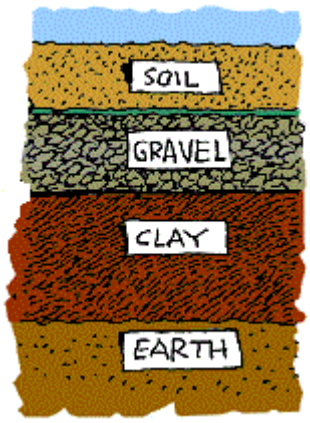
Name: _____ Date: _____

Radon is a radioactive gas that comes from the decay of uranium found in nearly all rock and soil types. Radon moves from the ground up into homes and other buildings.

Read the following questions. Form a hypothesis in response to each question.

1. How does radon move up through rock and soil?

   _____
   _____
   _____



2. Examine rock and soil samples that are representative of the local geology. Which rock and soil types might slow or block radon's movement?

   _____
   _____
   _____

3. How might ground water or the moisture content of soil affect radon's movement?

   _____
   _____
   _____

Ground Up Teacher Answer Key

1. How does radon move up through rock and soil?
   Students should find that radon can move through porous or permeable rocks, spaces between rocks and gravel, and cracks in rocks and soil. Sandstone tends to be permeable, and uranium is generally found in sandstone deposits.

2. Examine the rock and soil samples that are representative of the local geology. Which rock and soil types might slow or block radon's movement?
   Students should find that radon may be blocked by less permeable rock and soil types like clay, slate and granite. Radon that is trapped in the soil will decay to form lead.

3. How might ground water or the moisture content of soil affect radon's movement?
   Students should find that ground water or moist soil slows radon movement.

Ground Up Data Sheet

Name: _____ Date: _____

Follow the directions and record your observations and conclusions.

Directions	Observations and Conclusions
1. Fill one or more container(s) one-half to three-quarters full of individual types of rock and soil. 2. Insert a straw so it nearly touches the bottom of the container and blow. Take note of how easy or hard it is to blow air in the straw and how gas might travel through the soil. 3. Record your observations. 4. Form a conclusion about how radon, a radioactive gas, might move up through the different types of rock and soil.	
5. Fill a beaker with water. 6. Fill a dropper with water from the beaker. 7. Place several drops of water on the individual types of rock and soil. Observe whether the rock and soil absorb the water. Permeable rocks and soil allow liquids and gases to pass through them. 8. Record your observations. 9. Form a conclusion about which types of rock and soil might slow or block radon's movement.	
10. Fill a beaker with water. 11. Pour the water over the different types of rock and soil in the container. 12. Insert a straw so it nearly touches the bottom of the container and blow. Take note of how easy or hard it was to blow air in the straw and how the gas might travel through the soil. 13. Record your observations. 14. Form a conclusion about how ground water might impact radon's movement up through the ground.	

Activity 2: Radon Vacuum

Objectives

Students will:

- Hypothesize how their home can act like a vacuum, drawing radon in.
- Conduct an experiment and demonstrate how homes act like a vacuum.
- Hypothesize or demonstrate ways to prevent radon from entering the home or ways to vent the radon out of the home.

Next Generation Science Standards

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

- ESS3. Earth and Human Activity.
- ETS1. Engineering Design.

Materials and Resources

- *Radon: Teacher Background Information*.
- *Vocabulary Materials*.
- *Radon* image (display using a computer and projector).
- *Radon Vacuum Worksheet* (one per student, pair or group).
- Option A for Step 5(per pair or group):
  - Empty plastic bottle, 20-ounce or 2-liter.
  - Straws (one per student).
  - Clay to seal opening of 2-liter bottles.
  - Water.
  - A container to set under the bottle and collect water.
- Option B for Step 5 (per pair or group):
  - Two shoe boxes or small boxes.
  - Scissors.
  - Masking or duct tape.
  - Plastic tubing or paper towel tubes.
  - Fog machine or materials for a do-it-yourself fog machine with glycerin or dry ice.

Time

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

Vocabulary

- Ionizing radiation
- Radiation
- Radon
- Uranium

Directions

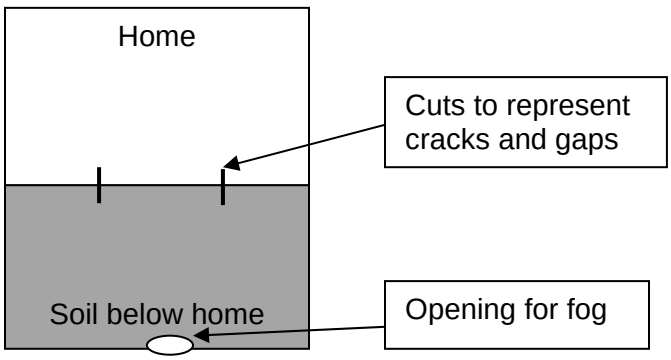
1. Start with a vocabulary activity if students are not familiar with radon and the terms used in this activity.

2. Show the *Radon* image and distribute the *Radon Vacuum Worksheet* to students.

3. Ask students to hypothesize in question 1 how their home can act like a vacuum, drawing radon in, and the ways in which radon can enter their home. **Answers may vary; however, the air pressure inside homes is usually lower than pressure in the soil around foundations. Because of this difference in pressure, your home acts like a vacuum, drawing radon in through foundation cracks and other openings.**

4. Explain that students will have the opportunity to conduct an experiment and demonstrate how homes act like a vacuum because of lower pressure in the house drawing in radon. Conversely, the higher pressure of the soil around a home's foundation will force the radon inside of the home where the pressure is lower.

5. Select an activity for students to complete and provide them with directions.
   - Option A: Direct students to fill the plastic bottle one half to two-thirds full and set the bottle in the container. Insert a straw into the mouth of the bottle and seal the mouth of the bottle, around the straw, with clay. Direct students to blow hard and then step back. Student should see liquid move as the pressure changes in the bottle when they blow into the straw. *NOTE: This activity can be conducted outside.*
   - Option B: Direct students to secure two boxes together. The bottom box will represent soil below your home's foundation and should be sealed shut. The top box will represent your home and can be open on one side so students can see in. Where the two boxes are secured together, make several cuts to represent cracks and gaps that might exist in floors, in walls and around service pipes. Cut a small hole in the bottom box so that fog can be pumped into the bottom box. Students should see the fog coming through the cracks and collect in the "home."



6. Ask students to share their observations and conclusions. Students should recognize that the higher pressure will force radon through cracks and crevices and into homes and buildings (Option A) or that radon can enter homes through cracks and gaps (Option B).

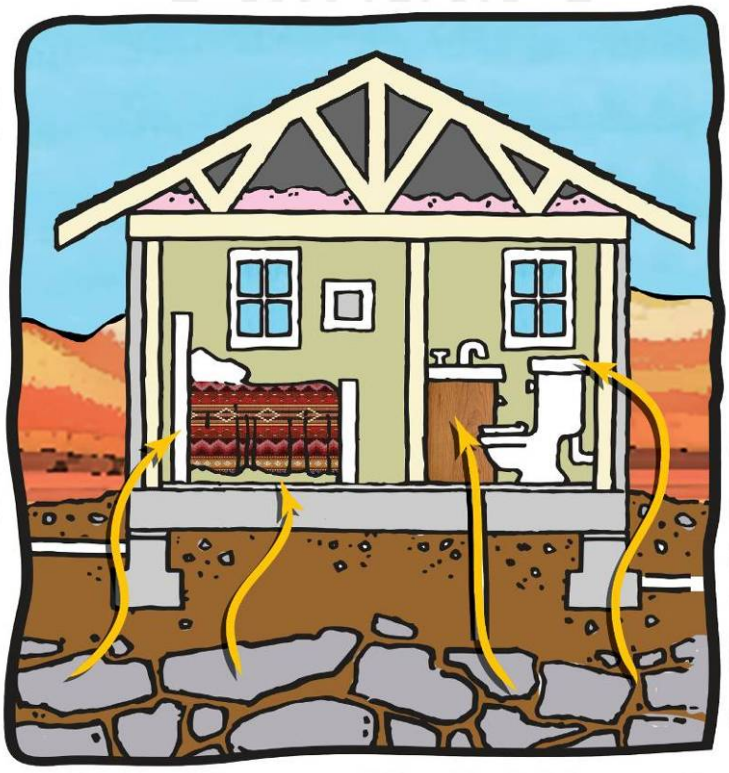
7. Ask students to investigate and demonstrate ways to prevent radon from entering the home or ways to vent the radon out of the home. With Option A, students can cut a hole or window in the bottle to show how ventilation improves air pressure inside the bottle. With Option B, students can seal up cracks with tape and use plastic tubing or paper towel tubes to take

radon directly from the bottom box (soil below the home) straight up and out so that it never goes into the home. Other options include cutting out/opening windows in the home and using tubing, vents or exhaust fans to take the radon out of the home.

8. Conclude by having students share at least one thing they have learned about radon.

9. Optional activities or extensions:
   - Have students examine radon reduction systems and their costs.
   - Invite a radon professional to speak about radon in the area, the importance of testing homes and ways to reduce radon levels.
   - Have students create posters for the National Radon Poster Contest: www.sosradon.org/poster-contest

Radon



Radon Vacuum Worksheet

Name: _____ Date: _____

Radon is a radioactive gas that comes from the decay of uranium found in nearly all rock and soil types. Radon moves up from the ground into homes and other buildings.

1. Read the question and form a hypothesis. How can your home act like a vacuum, drawing radon in? What are some ways radon can enter your home?

   _____

   _____

   _____

2. Describe the materials and procedure(s) used to test your hypothesis.

   _____

   _____

   _____

   _____

   _____

   _____

   _____

3. Summarize your observations and findings.

   _____

   _____

   _____

4. Hypothesize and demonstrate ways to prevent radon from entering the home or ways to vent the radon out of the home.

   _____

   _____

   _____

   _____

   _____

   _____

5. Summarize your observations and findings.

   _____

   _____

   _____

Activity 3: Indoor Radon Levels

Objectives

Students will:

- Learn about types of radon testing.
- Analyze radon testing data.
- Compare the data with the Environmental Protection Agency's (EPA) recommendations.
- Recommend whether to fix the radon levels based on the average indoor radon level.

Next Generation Science Standards

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

- ESS2. Earth's Systems.
- ESS3. Earth and Human Activity.

Materials and Resources

- *Radon: Teacher Background Information*.
- *Vocabulary Materials*.
- *Radon Testing* image.
- Computer and projector to display the *Radon Testing* image.
- *Radon Testing Worksheet* (one per student, pair or group) and teacher answer key.
- Radon test kit information:
  - *Where Can I Get a Radon Test Kit?*: http://www2.epa.gov/radon/find-radon-test-kit-or-measurement-and-mitigation-professional#where

Time

30-45 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. Explain that radon is a radioactive gas that comes from the decay of uranium in rock and soil. Human activities, such as uranium mining, can increase the risk of radon exposure. During the mid-1940s to 1970s, the U.S. was in a race with the Soviet Union to develop and test nuclear weapons. Nuclear power was also introduced during this time. Thousands of uranium mines were in operation, primarily in the Western part of the U.S., and nuclear testing was taking place in the West and in Alaska.

   When the demand for uranium decreased, uranium mines and testing areas were abandoned; leaving contaminated soil and water with high radon levels.

   Radon is a threat to health because it tends to collect inside homes and buildings, sometimes to very high levels, and can cause lung cancer. Any home or building may have a radon problem, including new and old homes, well-sealed and drafty homes, and homes with or without basements. On average, one out of every fifteen U.S. homes has a problem.

3. Ask students how they can test radon levels in their home. Students should be able to state that they can purchase a test kit or have a professional test their home for radon. Radon testing is necessary because we cannot detect radon by smell or sight. Students can visit *Where Can I Get a Radon Test Kit?:* http://www2.epa.gov/radon/find-radon-test-kit-or-measurement-and-mitigation-professional#where.

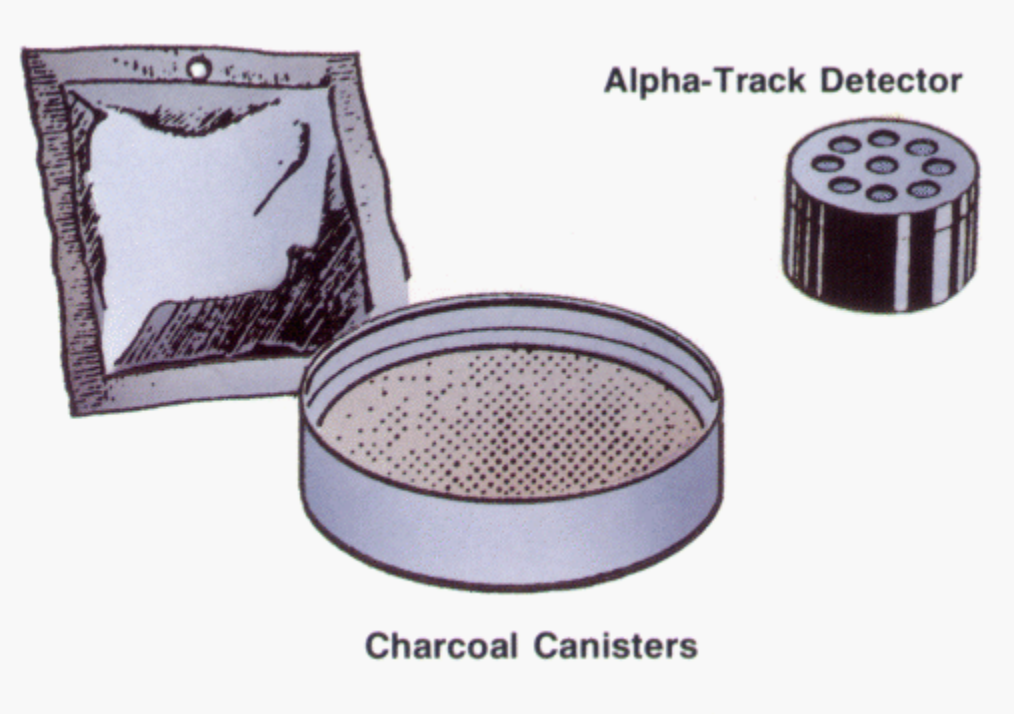
4. Display the *Radon Testing* image. Explain that there are short-term and long-term testing options. Short-term tests remain in a home for 2 to 90 days, depending on the device. Long-term tests remain in your home for more than 90 days. A short-term test is less likely than a long-term test to tell you your year-round average radon level so you may want to follow up with a second short-term test to confirm the results of the first. Short-term charcoal canister tests are left in the home for 2 to 7 days to capture radon levels whereas long-term alpha track detectors can be left in the home for 90 days to a year.

5. Distribute the *Radon Testing Worksheet*. Have students completed the worksheet and share their responses. The *Radon Testing Teacher Answer Key* is provided.

6. Conclude by discussing the importance of testing homes for radon.

7. Optional activities or extensions:
   - Contact your state radon program or the regional EPA office and see if it has radon data from your area that can be charted and analyzed by students.
   - Determine if you can get radon test kits and the analyses paid for so that each student can test their home for radon. Have students compile and analyze the data.
   - Have students create posters, raps, videos or other media messages to stress the importance of radon testing.
   - Have students create posters for the National Radon Poster Contest: www.sosradon.org/poster-contest

Radon Testing Devices



Radon Testing Worksheet

Name: _____ Date: _____

The lower the radon levels in your home, the lower your family's risk of lung cancer. The amount of radon in the air is measured in picocuries per liter (pCi/L). The U.S. Environmental Protection Agency (EPA) recommends fixing your home if the results of one long-term test or the average of short-term tests show radon levels of 4 pCi/L or higher. You may also want to consider fixing if the level is between 2 and 4 pCi/L.

Review the test results for each home. Calculate the average of each pair of readings and determine whether the homeowner should consider fixing the home.

Home A:

Winter reading	Summer reading
3.5 pCi/L	1.0 pCi/L

Average radon level: _____

Does this home's radon level need to be fixed? Explain your answer.

_____

_____

_____

Home B:

Reading during rainy season	Reading during dry, windy weather
5 pCi/L	10.0 pCi/L

Average radon level: _____

Does this home's radon level need to be fixed? Explain your answer.

_____

_____

_____

When testing your home for radon, why is it important to get a year-round average radon level?

_____

_____

Radon Testing Teacher Answer Key

Name: _____ Date: _____

Home A:

Winter reading	Summer reading
3.5 pCi/L	1.0 pCi/L

Average radon level: **3.5 + 1 = 4.5 / 2 = 2.25 pCi/L**

Does this home's radon level need to be fixed? Explain your answer.
Answers may vary. This homeowner may want to consider lowering the indoor radon level, especially since the reading was higher during the winter.

Home B:

Reading during rainy season	Reading during dry, windy weather
5.0 pCi/L	10.0 pCi/L

Average radon level: **5 + 10 = 15 / 2 = 7.5 pCi/L**

Does this home's radon level need to be fixed? Explain your answer.
This homeowner should definitely consider lowering the indoor radon level. It is well above EPA's action level of 4 pCi/L or higher.

When testing your home for radon, why is it important to get a year-round average radon level?
Radon levels tend to vary from day to day and season to season. For example, rainfall may slow radon's movement through soil so that less gets into the home. In dry periods radon has an easier time moving to the surface through cracks and crevices. Weather extremes when homes are closed and heat and air conditioning are turned on, or windy weather may lead to a lower pressure in the home which creates a vacuum and draws radon in from a higher pressure area in the soil under the home.

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.

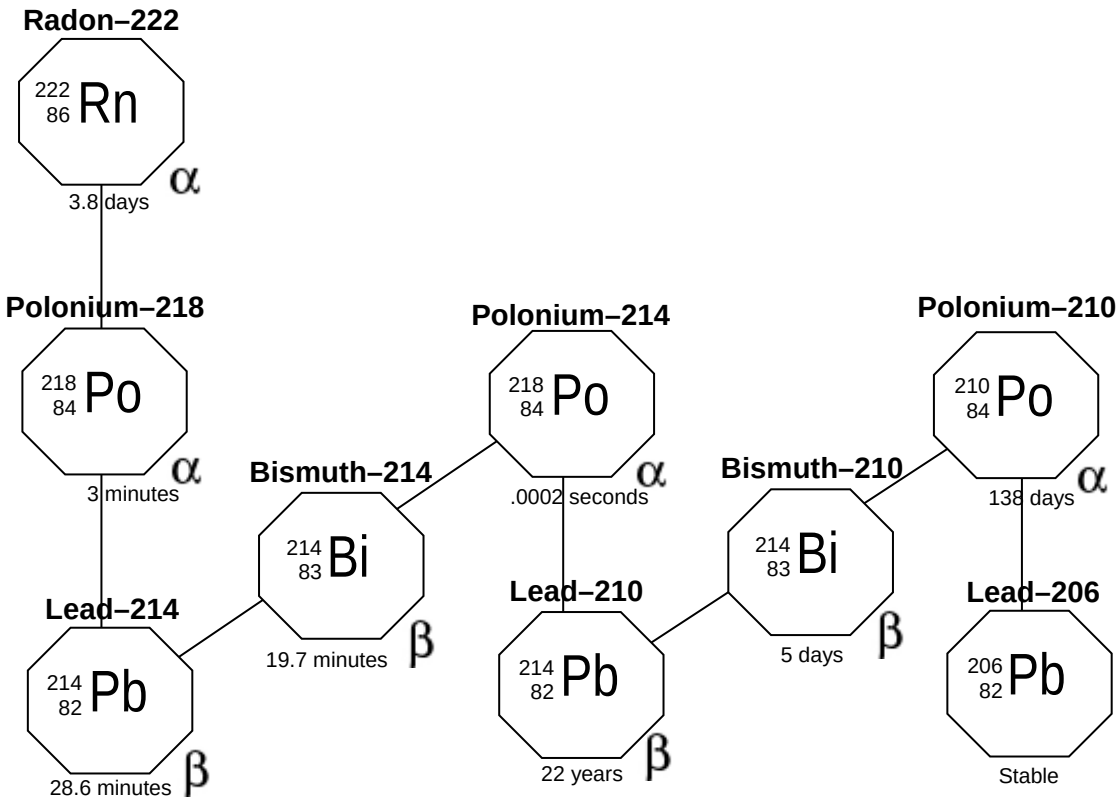
6. Direct students to complete the remainder of the *Half-Life Data Sheet*. The use of calculators is optional.

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.

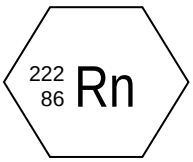
Radon-222 Decay Chain



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:

_____

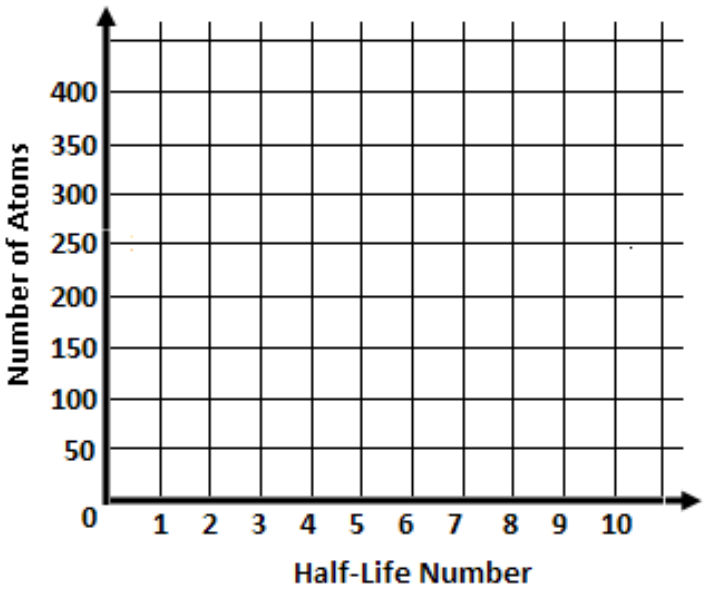
_____

_____

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:

_____

_____

2. Conclusions:

_____

_____

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

_____

_____

_____

_____

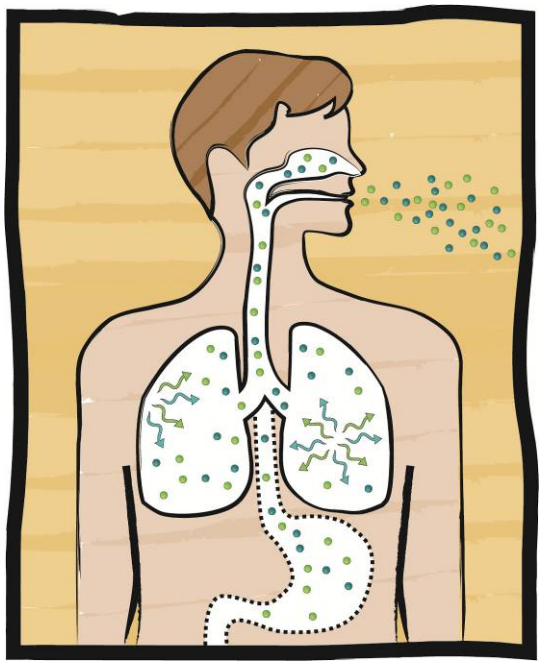
4. Radon is the second leading cause of lung cancer. How does the half-life of radon and its decay products cause damage to lung tissue that can lead to lung cancer over the course of a lifetime?

_____

_____

_____

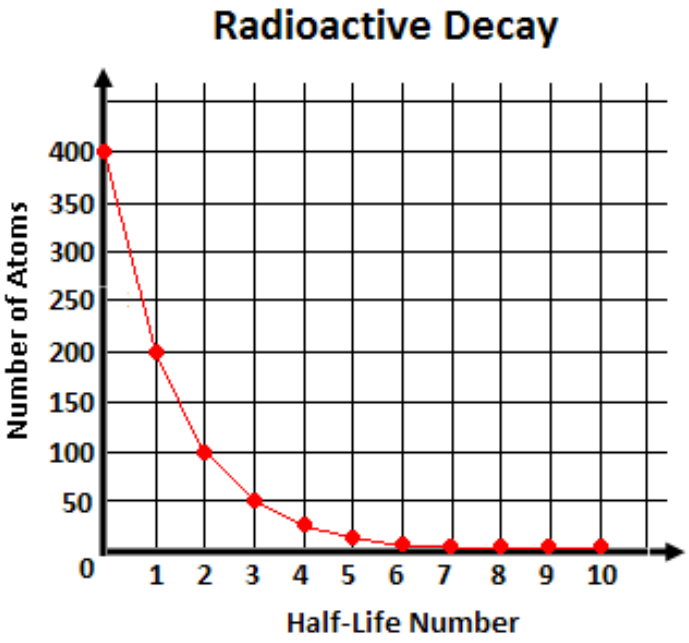
_____



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.**