What is Radon? – Vocabulary

Use web resources to define the following terms:

Sublimation:

Deposition:

Infiltration:

Ambient:

Picocurie:

Mitigation:

Aerosols:

Teacher Comments:

 Name

Lab 1: Where is Radon?

Guiding Questions: Is Radon gas evenly distributed everywhere? Or is it preferentially concentrated in certain areas?

Radon gas concentrations can be easily measured utilizing either radon test kits or passive radon monitors such as the **Safety Siren Pro Series 3 Radon Gas Detector.** Using as few as two and as many as four radon monitors, a simple experiment can be performed to assess whether radon gas accumulates in specific areas or is evenly distributed throughout an air space. Using the Safety Siren Pro Series 3 Radon Gas Detector Protocol and collect data for the radon level in the following areas: 1) basement or crawl-space, 2) the main floor that is at ground level, 3) a second floor that is above ground level, and 4) an outdoor site 1 to 2 meters above the ground, and at least 3 meters away from any building. Indicate in the first column what type of foundation the house is built on and whether or not a radon mitigation system is installed. Record all data in the following data table:

Data Table 1: (This data set can be used if no radon measuring equipment is available.)

Dwelling: ***Fill in name and check one foundation type. Indicate if a mitigation system is installed.***	***Measured Radon Level (piC/L)***			
	Basement or crawlspace	***Main floor (at ground level)***	***Second floor (above ground level)***	***Outdoor (1 to 2 meters off the ground)***
Name: *Foundation Type* ☐ Basement ☐ Crawl Space ☐ Slab-on-grade ☐ Other *Mitigation system?* ☐ Yes ☐ No				
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Name: *Foundation Type* ☐ Basement ☐ Crawl Space ☐ Slab-on-grade ☐ Other *Mitigation system?* ☐ Yes ☐ No				

Processing the data:

1. *Use the data from the above table to find the maximum, minimum, and average radon levels for the various dwelling categories that are represented. Use the following table to record the calculated averages:*

Dwelling category	*Average Measured Radon Level (piC/L)*			
	Basement or crawlspace	*Main floor (at ground level)*	*Second floor (above ground level)*	*Outdoor (1 to 2 meters off the ground)*
*Homes **with** mitigation system installed and foundation type is:*				
Basement Maximum Minimum Average				
Crawl space Maximum Minimum Average				

Slab-on-grade Maximum Minimum Average				
Other Maximum Minimum Average				
*Homes **without** mitigation system installed and foundation type is:*				
Basement Maximum Minimum Average				
Crawl space Maximum Minimum Average				
Slab-on-grade Maximum Minimum Average				
Other Maximum Minimum Average				

Processing the data (continued):

2. What do the data suggest about the relationship between the radon level in a dwelling versus the radon level outside the dwelling (ambient air)?

3. Which dwelling type do the data suggest are the highest concentrations of radon found? The lowest?

4. Do the data suggest that radon concentrates in any specific location within a house?

5. Do the data suggest any sort of radon concentration gradient? If "yes," answer question 6.

6. Can an origin of radon gas be inferred based on this gradient?

7. Based on the data, is radon gas evenly distributed or preferentially concentrated in the environment?

8. Two different farmers utilize two different water sources for their irrigation requirements. One uses a well that pumps groundwater, and one uses surface water diverted from a nearby river. Would you expect either water source to have a higher concentration of radon dissolved? If so why and if not why not?

Teacher Comments:

 Name

Lab 2: What on Earth is Radioactive?

Student Directions

1. Following the teacher's directions, complete column 1 of the student observation sheet. **IMPORTANT:** Stand at least of minimum of three feet from each sample when recording your observations and do not spend more than one minute viewing each sample. Do not touch any of the samples.
2. When you have completed column 1 of your table, return to your desk.
3. When everyone is seated at their desks, your teacher will use a Geiger counter to measure the radioactivity of each sample in counts per minute (CPM). Record the readings for each sample in column 2 and indicate if each sample is radioactive in column 3 below.

Student Observations

Sample Description	Counts per Minute (CPM)	Radioactive?	Notes
1.		☐ Yes ☐ No	
2.		☐ Yes ☐ No	
3.		☐ Yes ☐ No	
4.		☐ Yes ☐ No	
5.		☐ Yes ☐ No	
6.		☐ Yes ☐ No	
7.		☐ Yes ☐ No	
8.		☐ Yes ☐ No	
9.		☐ Yes ☐ No	
10.		☐ Yes ☐ No	

1. Compared to the samples that were not radioactive, are there any identifiable characteristics present in the radioactive samples? Please explain.

2. Is it possible to determine if a mineral or other sample is radioactive without the use of advanced technology? Why or why not?

3. If any of the samples were found to be radioactive, your teacher will cover those samples with aluminum foil and/or within a plastic container. Do you think covering the samples will reduce the amount of radioactivity emitted from the sample? Explain your prediction(s) below.

4. Record the sample number(s) and the counts per minute of the shielded sample(s) below. How do these numbers compare to the Geiger counter readings recorded earlier?

5. Thinking back to what you know about alpha, beta, and gamma radiation, explain these results.

6. Uranium ore (Uranium-238) is a naturally occurring radioactive material often present in the earth's crust, in a variety of rock materials, and the soil. The decay series of Uranium-238 includes a number of decay products and the emission of alpha, beta, and gamma radiation. Radon-222 is one of the decay products of Uranium-238 and considered to pose a significant health risk compared to the other decay products.

   Review the "Uranium Decays Series Chart" and determine how radon is different from the other decay products of Uranium-238.

7. Explain why the characteristics of radon make it a hazard to human health indoors. How does this differ from the other decay products of Uranium?

8. If radon only emits alpha radiation, why is it a health concern? Would radon be less or more of a health concern if its half-life was shorter?

Teacher Comments:

COMPREHENSION 1

What is Radon?

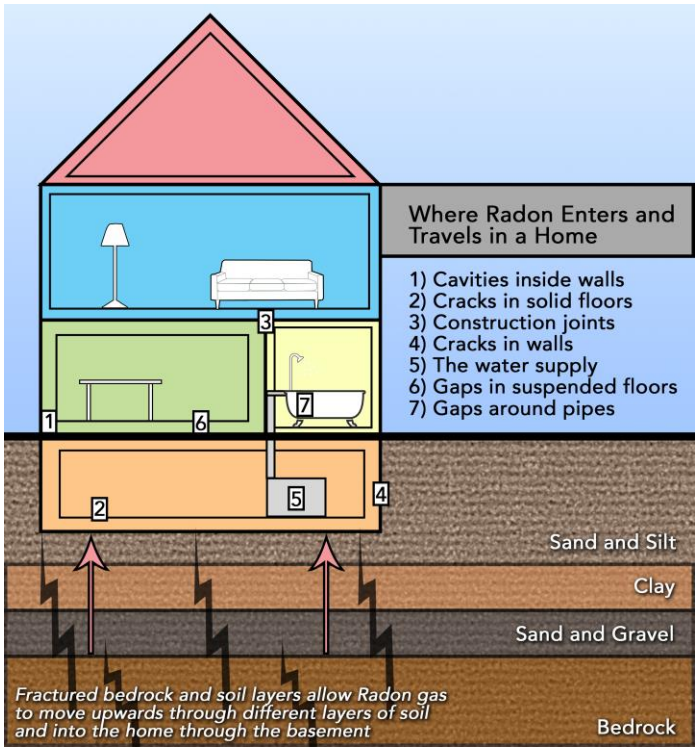
INTRODUCTION

Radon is a chemical element, whose element symbol is Rn, with an atomic number of 86. Radon's most stable isotope is Radon-222. Radon is a naturally occurring radioactive gas, which is odorless, colorless, tasteless, and chemically nonreactive. Radon's half-life is 3.8 days meaning that half of the given quantity decays every 3.8 days. When radon decays it emits ionizing radiation in the form of alpha particles.

HOW DOES RADON ENTER AMBIENT AND INDOOR AIR?

Radon is produced in the rock and soil from the decay of Radium-226 to Radon-222 within the Uranium-238 decay series. Radon then moves within the rock and soil through spaces between mineral grains and into the groundwater and the ambient (outside) air.

Radon is commonly found throughout the Earth's crust, with most soils in the US containing between 200 and 2,000 picocuries of radon per liter (pCi/L) of (soil) air. However, it is estimated that only 10 to 50% of radon escapes into the ambient air (the other 50% remains in the mineral grains). Exposures to radon in ambient air are typically low, with average concentrations of 0.4 (pCi/L) of air. In buildings, radon can migrate through cracks in foundations or other avenues, potentially accumulating in high concentrations.



Radon is not typically found in municipal water sources because these systems aerate water, allowing radon to escape.

HOW DOES RADON EXPOSURE OCCUR AND WHAT ARE THE HEALTH EFFECTS?

Radon is ubiquitous in the environment; therefore, exposures occur both in ambient and indoor environments. Radon's main exposure pathway for humans is via inhalation. Although most of the radon gas that is inhaled gets

exhaled, some of radon's solid decay products, or progeny, can attach to aerosols and dust from the air and end up in the lungs. All of radon's progeny are metallic solids. Your body's natural defenses, swallowing and coughing, can clear out a portion of these particles. The decay of radon's progeny will continue to occur, with each step releasing radiation until its non-radioactive progeny (Lead-206) is formed. As radon's progeny decay, small amounts of energy are released which can damage tissue and can lead to health problems later in life. Additionally, a small portion of radon's decay products from the lungs gets absorbed into the bloodstream.

"In a small number of homes, the building materials — such as granite and certain concrete products — can give off radon, although building materials rarely cause radon problems by themselves."

- EPA's Consumer's Guide To Radon Reduction

Exposure to radon can also occur through water. Radon in groundwater is most common in homes that are not connected to a municipal water supply (e.g., homes with their own well). When radon is present in groundwater, there is a potential for it to be released into the air when showering, doing dishes, etc. Radon can also be ingested when drinking water. Luckily, radon in water contributes less than 5% of the total radon in the air and is therefore not typically a significant health concern.

HOW DO DIFFERENT BUILDING CONDITIONS AFFECT RADON LEVELS?

There are three basic types of building foundations: basements, slab-on-grade, and crawlspaces. Although all types of buildings can have high levels of radon, basements may have a higher potential for radon exposures. This is due to the living space being located beneath the earth where radon is present in soil and rock, the tendency for basements to have less ventilation than other areas of a building, and cracks in the foundation where radon can enter the indoor environment. Similar to basements, radon can also enter slab-on-grade houses through cracks in the foundation.

The permeability of soil also affects the movement of radon. For example, radon can move quickly through coarse sand and gravel, while clay can decrease the movement of radon.

Crawlspaces are also prone to high levels of radon as these areas are primarily open to the earth below. Contrary to a basement, these spaces are not inhabited and are often ventilated which reduces the amount of radon that enters a home or building. It is important to note that regardless of foundation type, any building can have high levels of radon. The only way to know for sure if a building has high levels of radon is to conduct a test and collect some data.

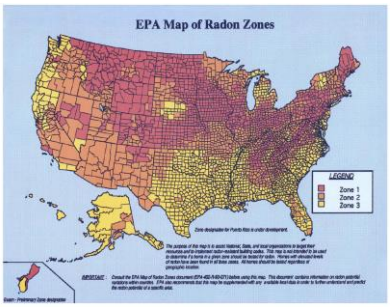
HOW DOES AIR PRESSURE IMPACT THE INFILTRATION OF RADON?

Another important factor that contributes to the infiltration of radon into indoor spaces is pressure. Generally, buildings have lower pressure inside compared to the outdoor air and soil. These differences in pressure can exist due to mechanical ventilation (e.g., exhaust fans) moving conditioned indoor air to the outside and when temperatures outside are lower than inside, resulting in warm air rising up and out of the building. Mechanical systems such as furnaces or air conditioners can also contribute to pressure differences. When air is moved outside of a building through these processes, it must be replaced. As air moves from areas of higher

pressure (i e., outside) to areas with lower pressure, radon is drawn from the soil and into a building through cracks or other openings.

HOW IS THE POTENTIAL FOR RADON TO EXIST IN THE SOIL DETERMINED?

Although most rocks contain some uranium, certain types have higher than average uranium concentrations. These rocks include light-colored volcanic rocks, dark shales, granites, sedimentary rocks containing phosphate, as well as metamorphic rocks formed from these rocks. These rocks and the soil they produce contain as much as 100 parts per million (ppm) uranium and exist in layers underneath portions of the United States. Usually, the higher the uranium concentrations in an area, the higher the chances are for elevated radon levels. However, some houses in high uranium areas have low levels of indoor radon and some houses with high concentrations of radon exist in areas with low levels of uranium. This phenomenon is possible because many factors play a role in whether a home has an elevated level of radon. The EPA has developed a map of radon potential for the US (see sidebar). The factors that were taken into consideration when developing this map included: 1) indoor radon measurements; 2) geology; 3) aerial radioactivity; 4) soil permeability; and 5) foundation type.



Source: Environmental Protection Agency

State-specific radon maps are also available from the EPA at: http://www.epa.gov/radon/zonemap.html

HOW CAN A HOME OR BUILDING BE TESTED FOR RADON?

The Environmental Protection Agency (EPA) recommends that every home be tested for radon. There are various "do-it-yourself" methods for testing radon levels indoors. Radon testing kits are often available from your local health department, home improvement stores, or from online vendors.

The two most common types of radon tests include short-term and long-term tests. Short-term tests run from two to 90 days, providing quick results. Long-term tests run for 90 days or longer and are used to gain a better understanding of yearly exposures to radon as levels can fluctuate from day to day or with the seasons.

The EPA recommends the following steps for testing a home for radon:

Step 1. Perform a short-term test. If your result is 4 pCi/L or higher, perform a follow-up test (Step 2) to be sure.

Step 2. Follow up with either a long-term test or a second short-term test:

- For a better understanding of your year-round average radon level, perform a long-term test.
- If you need results quickly, perform a second short-term test.

The higher your initial short-term test result, the more certain you can be that you should do a short-term rather than a long-term follow up test. If your first short-term test result is more than twice EPA's 4 pCi/L action level, you should do a second short-term test immediately.

Step 3. If you followed up with a long-term test: fix your home if your long-term test result is 4 pCi/L or more. If you followed up with a second short-term test: The higher your short-term results, the more certain you can be that you should fix your home. Consider fixing your home if the average of your first and second test is 4 pCi/L or higher.

Listen to the podcast, "Keeping Your Home Safe from Radon" available at: http://1.usa.gov/13mhSqk

Note: The National Radon Proficiency Program (RPP) closed in 1998, so companies should not promote their products as "EPA Listed," "EPA Approved," or "Meets EPA Requirements." The radon detector used in this lesson is for educational purposes only. If radon levels observed are above the EPA's action level, it is recommended that follow-up testing be conducted as described above.

WHAT ARE THE MITIGATION OPTIONS FOR RADON?

Mitigation of radon is recommended when the levels in a home are 4 pCi/L or higher. Some methods of radon mitigation reduce the amount of radon that enters a home, while other methods reduce radon concentrations once it has entered the home. Typically, the EPA advises homeowners to use a mitigation method that prohibits radon from entering the home. However, many factors need to be taken into consideration when choosing the best mitigation method for reducing radon levels in the home. These factors include: 1) the foundation type; 2) the size of the home; 3) the initial concentration of radon in the home; and 4) the cost of installation and system operation.

One of the most common techniques for reducing radon in homes is soil suction. This technique is used frequently in houses with basements or slab-on grade construction. Soil suction prevents radon from entering the indoor environment by pulling air from under the home and venting it through a pipe to the outside. To achieve this, a fan vent is attached to a suction pipe that draws the radon gas from below the home and releases it in the outdoor air, producing a negative pressure or vacuum beneath the slab. To achieve similar results in a home with a crawlspace, a dense plastic sheet is used to cover the earth floor, while a vent pipe and a fan draw the radon from under the sheet and vent it to the outside of the house. Many other mitigation options also exist, but choosing the best method will depend on the home construction and the four factors mentioned above. In many situations, a home can be mitigated for radon for a cost of $800 - $2,000, the price of most minor home repairs.

For more information on radon mitigation options, please refer to the EPA's "Consumer's Guide to Radon Reduction" available at: http://1.usa.gov/acwKvN

Certified radon mitigation companies can be found at the National Environmental Health Association's website: http://bit.ly/1ebG9lC

Comprehension 1 – Guiding Questions

Read the selection *What is Radon?* and answer the following questions completely and concisely:

1. How often does radon emit ionizing radiation? What is another name for this?

2. Describe the primary avenue by which radon enters buildings.

3. Why does only 10% - 50% of the radon in the soil or rock escape into the environment?

4. Hypothesize as to why people using water from private wells are at a higher risk of radon exposure than people that use a municipal water supply.

5. What is the most common exposure pathway for radon and why?

6. Explain why residents of homes with basements are at a higher risk of radon exposure than residents of homes with other foundation types.

7. Determine the radon potential where you live. (Visit http://1.usa.gov/rejU5). You can select a larger map of your state by locating the "Find state-specific radon information" box. Select your state and then the "click here" button.). What does this classification mean in regard to radon?

Teacher Comments:

Radon Gas Detector Data Sheet

Student Name: _____

Start Date / Time: _____ / _____

Description of Sampling Location: _____

_____

_____

_____

Date (mm/dd/yy)	Time (00:00)	Reading (pCi/L)

End Date / Time: _____ / _____

Final Average (pCi/L): _____

Notes about sampling run (any information that may have influenced the results of your sample):

_____

_____

_____

_____

Updated 8/8/13 EW

 Name

'What is Radon?' Evaluation Questions

For questions 1-5, place the letter of the best answer in the space before the question.

_____1. An element can go directly from a gaseous state to a solid form of a different chemical substance without ever becoming a liquid.

A. true B. false

_____2. The process by which a substance permeates through a material by penetrating its pores or interstices is referred to as

A. sublimation B. dilution C. solvation D. infiltration

_____3. Consider a two-story house with a basement. Which of the following is the most likely radon concentration gradient, highest concentration → lowest concentration, for the three stories of the house?

A. 2nd floor, 1st floor, basement

B. basement, 1st floor, 2nd floor

C. 1st floor, 2nd floor, basement

D. 1st floor, basement, 2nd floor

_____4. If the radon level in the basement of a home is high, it is likely that radon level just outside of the home will also be high.

A. true B. false

_____5. Which of the following organs is most at risk when exposed to high levels of radon?

A. skin B. heart C. brain D. lungs

Answer the following questions completely and concisely using complete sentences.

6. Consider the data table below concerning the radon levels, measured in picocuries/liter – piC/L, in two houses. Each house has a basement and two upper floors.

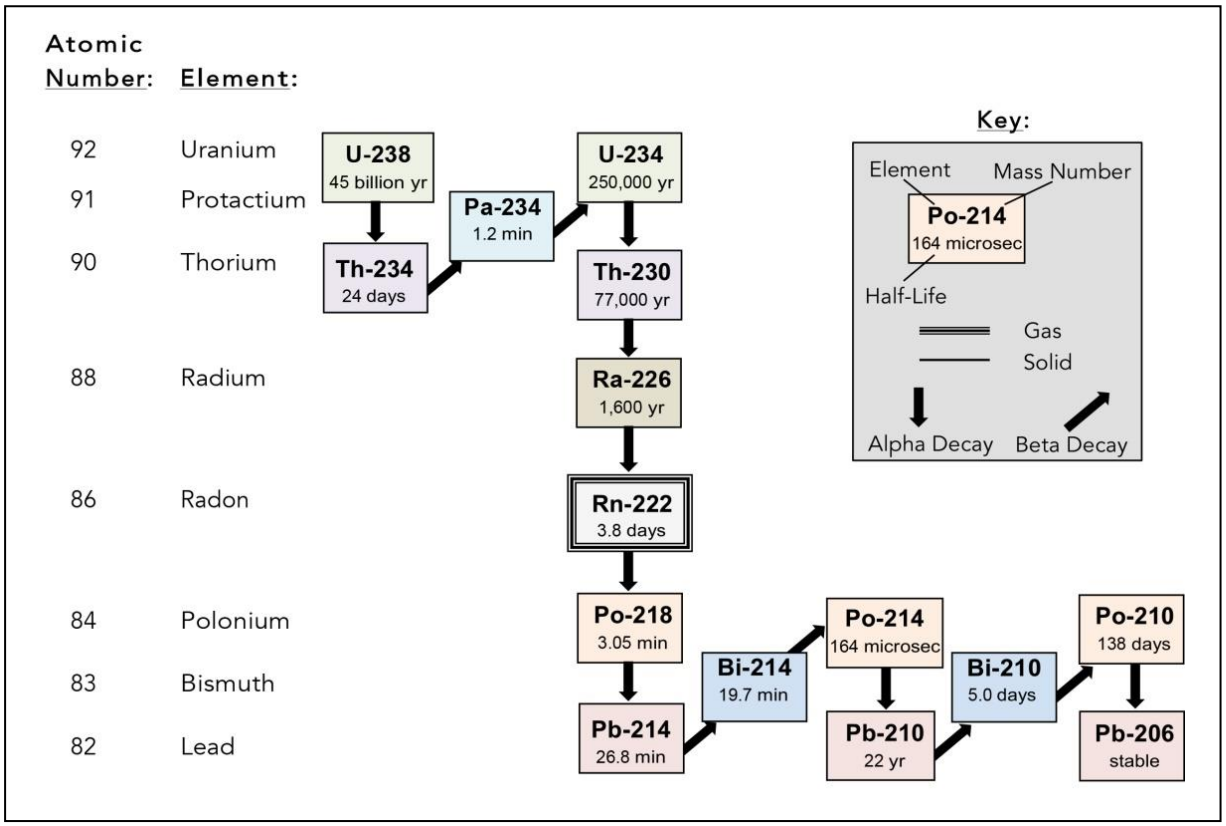
Table 1: Radon levels, piC/L, in two houses with basements and two upper floors.

House	Basement	1st Floor	2nd Floor
A	4.8	2.6	1.8
B	2.2	2.0	1.7

Develop a possible hypothesis or explanation for the apparent differences in this data.

7. Again, considering the data in Table 1 from question 6, what would you infer to be the most likely source of the radon gas found in homes A and B?

Use the Uranium Decay Series Chart below to answer questions 8 – 11.



8. You excitedly tell one of your friends about all of cool things you are learning about radon gas and the associated dangers of being exposed to high levels of radon gas. Your friend asks you, "where does radon come from?" Summarize an appropriate response to your friend's question.

9. Examine the actual radioactive decay that produces radon; radium-226 decays to produce radon-222. What type of radioactive decay is occurring during this process? Defend your response.

10. Explain why radon can enter a home more easily than the other radioactive decay products of uranium-238.

11. What is the half-life of radon-222? Would a shorter half-life make radon more or less dangerous as an environmental hazard? Explain.

12. Why do you need a technological instrument to detect radon gas?

13. A rock sample is tested with a Geiger counter and found to be slightly radioactive. You cover the sample with a sheet of aluminum foil and re-test with the Geiger counter. Would the Geiger counter measure more counts per minute, the same counts per minute, or less counts per minute when the sample is covered by the foil? Explain.

14. How does exposure to radon lead to possible health risks?

15. Explain why radon levels tend to be higher in basements than in other areas of a house.

16. A process called soil suction is commonly used to mitigate high radon levels in homes. Summarize how soil suction lowers radon levels in a home.

Teacher Comments: