Lesson 1: What is radon?

Lesson overview

This lesson introduces radon. It explains its characteristics, defines radiation, and describes the process of radon decay.

Lesson objectives

By the end of this lesson, the learners will be able to:
- Describe the characteristics of radon
- Define radiation
- Describe the process of radon decay

See slide 1-1.

In our first lesson, we’ll explain the basics of radon.

Some of you may already know quite a lot about radon, while others may be learning about it for the first time. To find out what you already know, I’m going to distribute a list of characteristics. Check off the ones that you think apply to radon.

See Handout 1-1.
See slide 1-2 and below for correct answers.

- Radon is a gas. In fact, radon is the densest gas known.
- Radon is colorless. You can’t see it.
- Radon has no smell.
- Radon has no taste.
- Radon occurs in nature.
  We’ll talk more about this topic later. For now, let’s just say that radon comes from the natural breakdown of uranium in soil, rock, and water. It is found all over the United States.
- Radon is inert, which means it does not readily react chemically.
- Radon has no static electrical charge.
- Radon is radioactive.
  We’ll discuss radioactivity in detail in a moment.
- Radon is harmful to human health.

See slide 1-3.

Is there radon in this room?
First, why would we care?

Suggested answers:
- Radon is harmful to human health.
- It is the leading cause of lung cancer among nonsmokers in the United States.

How would we know if there were radon in this room?

Suggested answers.

Radon may occur anywhere. It has no color, odor, or taste, which means that we cannot detect it using our senses.

For these reasons, we need ways of measuring radon levels. The methods for measuring radon are the topic of this training.

See slide 1-4.

We’ve said that radon is radioactive. To explain radioactivity, we need first to review what an atom is.

An atom is an elementary particle that consists of
- A nucleus in the center
- Electrons on the outside

The nucleus itself consists of protons, which have a positive electrical charge, and neutrons, which have no electrical charge. The electrons have a negative electrical charge. The number of electrons usually equals the number of protons, so the atom as a whole has no charge.

See slide 1-5.

Radon is a chemical element, a basic unit of matter. It cannot be broken down into simpler units by a chemical reaction.

The number of protons determines what the element is. It’s called the atomic number. Radon has an atomic number of 86. Note that the chemical symbol for radon is Rn.

The number of protons plus the number of neutrons is called the atomic mass or mass number. For radon, although the number of protons is always 86, the number of neutrons may vary, so the atomic mass may vary.

See slide 1-6.
The different forms of an element, with different atomic masses, are called isotopes. Three isotopes of radon occur naturally:

- Radon-219
- Radon-220
- Radon-222

Of these, radon-222 is the focus for this course because it contributes the most to human health problems.

See slide 1-7.

Isotopes can be stable or unstable. Unstable isotopes are radioactive—that is, they spontaneously decay (come apart) and change to another element (known as the decay product, progeny, or daughter), giving off radiation in the process. Radiation is energy emitted as invisible particles, waves, or rays.

See slide 1-8.

Slide 1-8 shows the decay products of radon.

When we talk about radon risk, we usually mean the risk of radon-222 and its decay products.

See slide 1-9.

The decay products differ from radon in several important characteristics:

- They are solids.
- They are chemically active.
- They have static electrical charges.
- They are the primary contributors to the cell damage that leads to lung cancer.

See slide 1-10.

In radioactive decay, three types of radiation are released:

- Alpha
- Beta
- Gamma

Slide 1-10 shows the differences among these types of radiation.

An alpha particle consists of two protons and two neutrons. The alpha particle is larger than the beta particle and moves more
slowly. An alpha particle may even fail to penetrate the dead cells covering the skin. It can be stopped easily by a piece of paper.

A beta particle is an electron. It is smaller and more penetrating than an alpha particle, but it can be stopped by thin sheets of metal or plastic.

Gamma radiation is pure energy. It is released whenever an alpha or beta particle is released. The fastest and most penetrating type of radiation, gamma radiation can penetrate concrete and many other materials.

However, in radon decay, **alpha** particles are the most damaging to human health. Although they are the least penetrating particles, they are harmful when they get **inside** the body. We’ll explain how they get inside a little later.

See slide 1-11.

This slide shows the radiation released in radon decay.

As you can see, two of the radon decay products—polonium-218 and polonium-214—also emit alpha particles. When this happens in the lung, the radiation can damage the cells lining the airways, leading eventually to lung cancer.

The decay of radon progeny also releases beta particles and gamma radiation, but these emissions are believed to have smaller effects on human health.

See slide 1-12.

The rate of radioactive decay is expressed as the *half-life*. The half-life is the amount of time required for half of the atoms to decay.

Imagine that a box contains atoms of a hypothetical element with a half-life of 1 day. After 1 day, 50% of the atoms would have decayed, and 50% would remain. After 2 days, half of the remaining atoms would have decayed, and the box would contain 25% of the original number of atoms. And so on.

See slide 1-13.

This is a graphic representation of the idea of half-life, showing the rate of decay of our hypothetical element.

See slide 1-14.
The half-life of radon is 3.8 days. That means that in 3.8 days, half of the radon atoms will decay.

In 3.8 days, radon gas can move from the soil, rock, and water into the air in a home, where people can breathe it in. And as the radon atoms decay, they release radiation. This radiation is the cause of radon’s damaging health effect.

Note that a real home is not like a closed box. Radon gas is continually entering the home and decaying.

See slide 1-15.

This slide shows the half-life of radon and its progeny.

You’ll notice that the first four progeny have half-lives much shorter than that of radon. You’ll learn about the significance of these progeny in a later lesson.

See slide 1-16.

Before we move on, let’s review what we’ve covered so far.

We’ve talked about the characteristics of radon, which is an element. Do you remember what they are?

Correct answers:
- Radon is a gas.
- Radon has no color.
- Radon has no smell.
- Radon has no taste.
- Radon occurs in nature.
- Radon is radioactive.
- Radon does not readily react chemically.
- Radon has no electrical charge.
- Radon is harmful to human health.

See slide 1-16.

We explained that in the process of radon decay, dangerous alpha particles are released.

See Handout 1-2, which summarizes the information about radon and its decay products.
See also the Environmental Protection Agency’s *Citizen’s Guide to Radon: The Guide to Protecting Yourself and Your Family from Radon* (EPA 402-K-02-006 [revised May 2004], available from [www.epa.gov/radon/pubs/citguide.html](http://www.epa.gov/radon/pubs/citguide.html)).

See slide 1-17.

Do you have any questions about radon?

See slide 1-17.
See Handout 1-3A. This comprehension check is not graded.

Now you’re going to see whether you remember the main points that we’ve discussed in this lesson. Please answer the questions on handout 1-3A. When you all finish, we’ll review the answers together.

Review the answers. See Handout 1-3B, the answer key.

In our next lesson, we’ll discuss why radon is a health problem.
Resources


[www.epa.gov/radon/pubs/citguide.html](http://www.epa.gov/radon/pubs/citguide.html)

U.S. Environmental Protection Agency. Understanding Radiation.

[http://www.epa.gov/radiation/understand/index.html](http://www.epa.gov/radiation/understand/index.html)
Handout 1-1: Characteristics of Radon

Check off all of the characteristics that you think apply to radon.

- Liquid
- Gas
- Solid

- Colorless
- Grayish-green
- Greenish-blue

- Smells like ozone
- Has no smell

- Has no taste
- Tastes metallic
- Tastes like chicken

- Occurs in nature
- Made by humans

- Reacts readily chemically
- Does not react readily (is inert)

- Has a static electrical charge
- Has no static electrical charge

- Radioactive
- Not radioactive

- Harmful to human health
- Harmless to human health
Measuring radon in residential properties

Handout 1-2: Radon and Radon Decay Series

Radon characteristics
- No color
- No smell
- No taste
- No electrical charge
- Gas
- Radioactive
- Naturally occurring
- Does not readily react chemically
- Harmful to human health

Radon decay series

<table>
<thead>
<tr>
<th>Element</th>
<th>Protons / neutrons</th>
<th>Radiation emitted on decay</th>
<th>Half-life</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radon-222</td>
<td>86 / 136</td>
<td>α + γ</td>
<td>3.8 days</td>
</tr>
<tr>
<td>Polonium-218</td>
<td>84 / 134</td>
<td>α + γ</td>
<td>3.1 minutes</td>
</tr>
<tr>
<td>Lead-214</td>
<td>82 / 134</td>
<td>β + γ</td>
<td>26.8 minutes</td>
</tr>
<tr>
<td>Bismuth-214</td>
<td>83 / 131</td>
<td>β + γ</td>
<td>19.7 minutes</td>
</tr>
<tr>
<td>Polonium-214</td>
<td>84 / 130</td>
<td>α + γ</td>
<td>160 microseconds</td>
</tr>
<tr>
<td>Lead-210</td>
<td>82 / 128</td>
<td>β + γ</td>
<td>22.6 years</td>
</tr>
</tbody>
</table>

Handout 1-3A: Check your understanding

List the characteristics of radon that we have discussed in this lesson:
1.
2.
3.
4.
5.
6.
7.
8.
9.

From the list below, select the best definition of radiation. Circle the correct answer.
1. Energy that is emitted as invisible particles, waves, or rays
2. Matter that is damaging to human health
3. Energy that is emitted as visible particles, waves, or rays
4. Matter that is produced mainly by human actions

In the paragraph below, fill in the blanks to describe the process of radon decay.

Radon is a radioactive element that has a half-life of _________ [period of time]. After this period of time, _______ percent of the radon atoms in a given space will have decayed. Radon decays, or changes, into elements that are called radon ________________, ________________, or ________________. During the process of radon decay, ________________, ________________, and ________________ [types of radiation] are released. In radon decay, the most damaging type of radiation for human health is ________________.
Handout 1-3B: Check your understanding

Answer key

The correct answers are shown in bold.

List the characteristics of radon that we have discussed in this lesson:

1. Colorless
2. Odorless
3. Tasteless
4. No electrical charge
5. Gas
6. Radioactive
7. Naturally occurring
8. Does not readily react chemically
9. Harmful to human health

From the list below, select the best definition of radiation. Circle the correct answer.

1. Energy that is emitted as invisible particles, waves, or rays
2. Matter that is damaging to human health
3. Energy that is emitted as visible particles, waves, or rays
4. Matter that is produced mainly by human actions

In the paragraph below, fill in the blanks to describe the process of radon decay.

Radon is a radioactive element that has a half-life of 3.8 days [period of time]. After this period of time, 50 percent of the radon atoms in a given space will have decayed. Radon decays, or changes, into elements that are called radon decay products, progeny, or daughters. During the process of radon decay, alpha particles, beta particles, and gamma radiation [types of radiation] are released. In radon decay, the most damaging type of radiation for human health is alpha radiation.