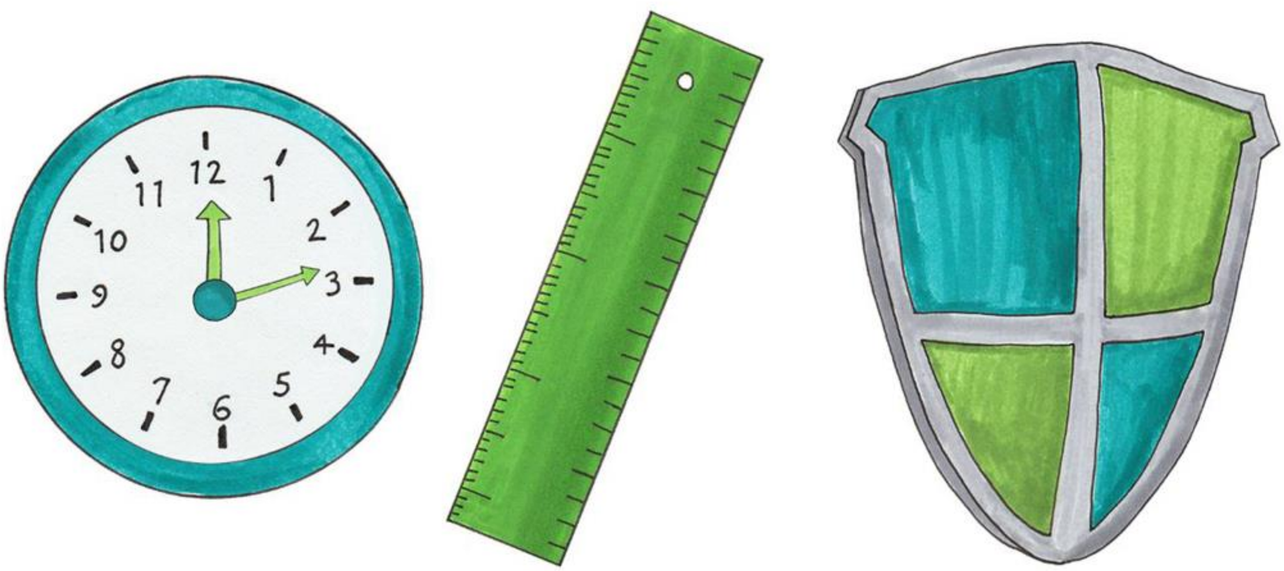
U.S. EPA Radiation Education Activities:

Radiation Protection



United States Environmental Protection Agency

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

Ionizing radiation is all around us and we cannot avoid exposure to naturally occurring (background) forms of ionizing radiation. Controlled radiation sources, like those used in the irradiation process, tritium exit signs or ionizing smoke detectors, can even protect us. We also benefit from radiation that is used in medicine, nuclear power generation, construction and other industrial processes.

People who work with radiation sources must follow radiation protection practices. The public should also be aware of radiation protection practices and apply them in situations where it can limit exposure to radiation or in the event of a radiological disaster. The three basic radiation protection concepts are time, distance and shielding. Technology can also be used to monitor and limit people's exposure to radiation.

Target Audience and Activity Topics

The Radiation Protection activities introduce middle and high school students to the history of radiation protection, the concepts and devices used in radiation protection, careers and laws related to radiation protection, and radiological emergency planning and response. Students will learn about events that led to the development of radiation protection practices. They will gain an understanding of the radiation protection concepts of time, distance and shielding and an understanding of the devices people can use to detect radiation and the warning signs that may alert us and others to the presence of radiation. Students will also be introduced to several radiation protection careers and have the opportunity to "perform" their jobs.

NOTE: The term "radiation" used in the activities generally 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:

- PS4. Waves and Electromagnetic Radiation
- ESS3. Human Impact

Common Core State Standards (CCSS)

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

- Writing: CCSS.ELA-LITERACY.L.6-12.6
- 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
- Comprehension and Collaboration: CCSS.ELA-LITERACY.SL.6-12.1 and CCSS.ELA-LITERACY.SL.6-8.2
- Integration of Knowledge and Ideas: CCSS.ELA-LITERACY.RST.6-12.7
- Text Types and Purposes: CCSS.ELA-LITERACY.WHST.6-12.2
- Research to Build and Present Knowledge: CCSS.ELA-LITERACY.WHST.6-12.7, CCSS.ELA-LITERACY.WHST.6-12.8 and CCSS.ELA-LITERACY.WHST.6-12.9
- Production and Distribution of Writing: CCSS.ELA-LITERACY.WHST.6-12.4 and CCSS.ELA-LITERACY.WHST.6-8.6

Mathematics Standards:

- CCSS.MATH.PRACTICE.MP1, CCSS.MATH.PRACTICE.MP2, CCSS.MATH.PRACTICE.MP4 and CCSS.MATH.PRACTICE.MP5
- CCSS.MATH.CONTENT.6.NS.C.7, CCSS.MATH.CONTENT.6.SP.B.4, CCSS.MATH.CONTENT.6.SP.B.5, CCSS.MATH.CONTENT.6.SP.B.5.B, CCSS.MATH.CONTENT.6.RP.A.3, CCSS.MATH.CONTENT.7.SP.A.1, CCSS.MATH.CONTENT.7.EE.B.4, CCSS.MATH.CONTENT.HSN.Q.A.1 and CCSS.MATH.CONTENT.HSS.ID.A.1.

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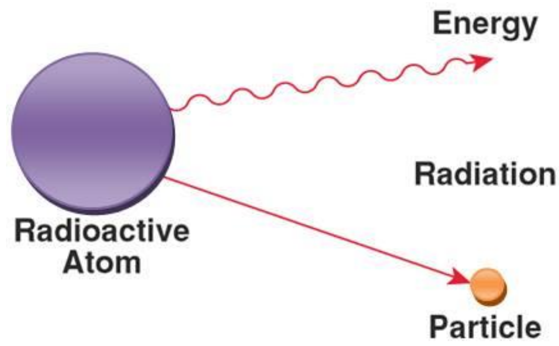
Radiation Protection: Teacher Background Information

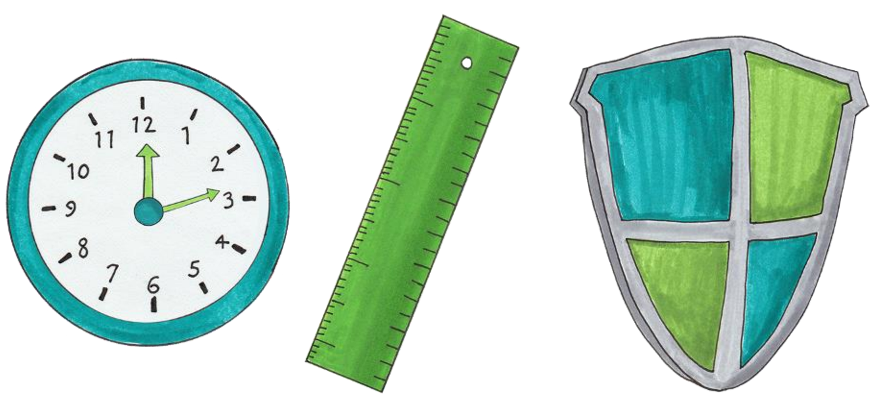
When radioactive atoms decay, they give off energy in the form of ionizing radiation (gamma rays, alpha particles or beta particles). The energy is called ionizing radiation because as this radiation moves through matter it has enough energy to knock tightly bound electrons from atoms. This causes the atom to become a charged ion. Radioactive atoms continue to decay (some for seconds or days, others for thousands of years) until they give off enough energy to become stable atoms and no longer emit ionizing radiation.



If ionizing radiation is absorbed by the body, the effects can potentially damage living cells and the DNA of these cells. Our bodies can handle some degree of exposure to ionizing radiation and still repair damaged cells. This is because humans have evolved in the presence of radiation. The effects of ionizing radiation may vary from person to person based on the total amount of energy absorbed, the time period and dose rate of the exposure, and the particular organs exposed. Dose refers to the quantity of energy absorbed by a person exposed to radiation and in the United States it is measured in millirem (mrem) or rem (Roentgen Equivalent Man). A person's risk generally increases with the amount of exposure.

Time, Distance and Shielding

People may be exposed to an increased radiation dose in certain situations (for example, when receiving a medical radiation treatment or during a radiological emergency). The concepts of time, distance and shielding are used to help limit radiation exposure. These radiation protection concepts can be applied separately or in combination. For example, people who work with radioactive materials may have time limits on how long they can be near a source which are set according to the exposure risk and shielding requirements such as wearing protective clothing or working behind a barrier.

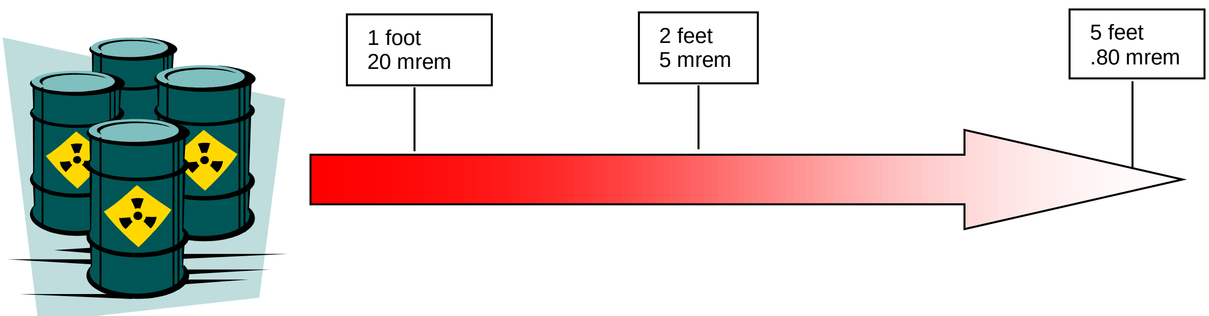


Time

The dose of radiation you receive depends on how long you are near a radiation source. Setting time limits helps keep the time spent near a source of radiation as short as possible. For example, a worker may only be allowed to work around radioactive materials for 4 to 6 hours of an 8-hour shift.

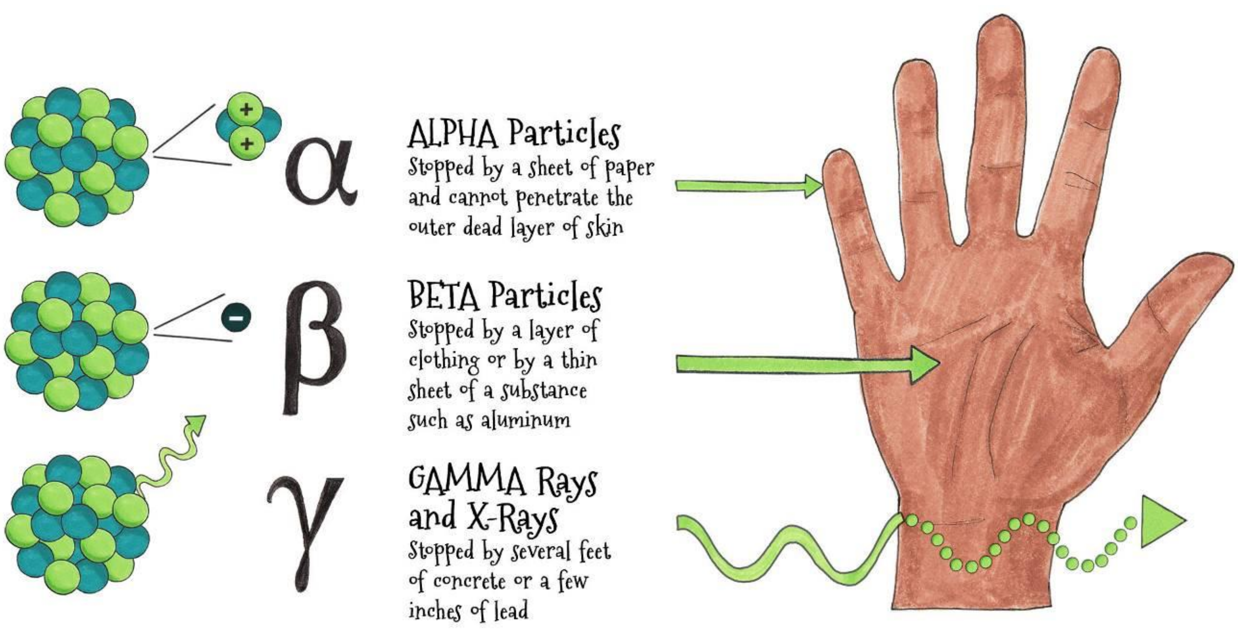
Distance

The radiation dose you receive strongly depends on how close you are to a radioactive source. For example, barrels of radioactive waste might emit or give off a dose of 20 millirem (mrem) per hour at a distance of 1 foot from the surface. At 5 feet away, the dose rate would be less than 1 mrem per hour. As you distance yourself from the radiation source, you increase the likelihood that some radiation will lose its energy. As a rule, as you double the distance from the radiation source, you reduce the exposure by a factor of four. Conversely, decreasing the distance by half increases the exposure by a factor of four.



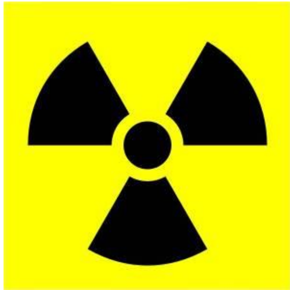
Shielding

Placing some material or a barrier, called shielding, between a person and a radiation source is another way to minimize the amount of radiation exposure. The image below shows the penetrating power of ionizing radiation (far right) and potential methods of shielding against alpha particles, beta particles, gamma rays and x-rays (center).



Radiation Warning Symbols

The international symbol of radiation, called a “tri-foil,” or “trefoil,” is used to identify areas restricted because of the presence of radiation. This symbol is displayed where radioactive materials are handled or where radiation-producing equipment is used. The tri-foil symbol is often displayed with a message about the nature of the radiation hazard so authorized people can take the appropriate radiation protection precautions before entering the restricted area.


International tri-foil, or trefoil, symbol of radiation

Believing the symbol was not intuitive, the United Nations introduced a new international radiation symbol in 2007. Both symbols are meant to identify an ionizing radiation source and alert people of the potential dangers so they can take action to protect against radiation exposure. The new international symbol indicates to the public the importance of moving away from the source.


United Nations symbol of radiation

The hazardous materials, or HAZMAT, placard for radioactive materials must be displayed on packages, cargo units and transport vehicles when radioactive materials are transported by road, air, rail or water. Carriers are responsible for handling and storing these materials properly to prevent the release of radioactive materials. If an accident should occur during transport, the radioactive placard identifies the radiation source. First responders can use this information to assess and respond to the situation appropriately.

Hazardous materials, HAZMAT, placard

The fallout shelter sign is displayed on the outside of some buildings (e.g., schools or other public buildings) so the public can locate them in the event of an emergency. The symbol may also be displayed inside buildings to mark access routes to the shelter area.

Individuals and communities began thinking about fallout shelters in the late 1940s and early 1950s. In the early 1960s fallout shelters became part of a comprehensive Defense Civil Preparedness Agency (DCPA) program created to prepare U.S. citizens in the event of a nuclear attack.


Fallout shelter sign

In 1979, the Federal Emergency Management Agency (FEMA) took over the DCPA responsibilities. FEMA is still involved in disaster and emergency response along with state and local governments and other federal agencies, including the Environmental Protection Agency (EPA).

Additional Resources

- RadTown USA: www3.epa.gov/radtown
- Radiation Basics: http://www2.epa.gov/radiation/radiation-basics
- Radiation: Facts, Risks and Realities: http://www2.epa.gov/sites/production/files/2015-05/documents/402-k-10-008.pdf

Radiation Protection 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 and Standards for Literacy in History/Social Studies, Science, & Technical Subjects:

- CCSS.ELA-LITERACY.L.6-12.6
- 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: History of Radiation Protection	• Ionizing radiation • Radiation • Radiation exposure • Radiation protection	• Radioactive decay • Radium • X-rays
Activity 2: Time, Distance and Shielding	• Geiger counter • Ionizing radiation • Radiation	• Radiation exposure • Radiation protection
Activity 3: Radiation Warning and Protection Equipment	• Dosimeter • Geiger counter • Ionizing radiation • Radiation	• Radiation exposure • Radiation protection • Radon
Activity 4: Buildings as Shielding	• Dose • Ionizing radiation • Radiation	• Radiation exposure • Radiation protection
Activity 5: A Career in Radiation Protection	• Ionizing radiation • Radiation	• Radiation protection
Activity 6: Impact of Radiological Emergencies	• Ionizing radiation • Radiation	• Radiation protection
Activity 7: Benefits of Radiation	• Alpha particles • Beta particles • Gamma rays • Ionizing radiation	• Radiation • Radioactive atom • Radioactive materials

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 (being careful to avoid 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 at the front of the classroom.
  - 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 words and images at the front of the classroom.
  - 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 confirm the accurate definition.

Activity 1: History of Radiation Protection

Objectives

Students will:

- Learn about and create a timeline of the history of radiation protection.
- Research and discover how radiation protection practices were developed.

Next Generation Science Standards

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

- PS4. Waves and Electromagnetic Radiation.

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:

- Comprehension and Collaboration: CCSS.ELA-LITERACY.SL.6-12.1
- Integration of Knowledge and Ideas: CCSS.ELA-LITERACY.RST.6-12.7
- Research to Build and Present Knowledge: CCSS.ELA-LITERACY.WHST.6-12.9

The concepts in this activity align with the following CCSS Mathematics Standards:

- CCSS.MATH.PRACTICE.MP4 Model with mathematics.
- CCSS.MATH.CONTENT.6.NS.C.7. Understand ordering and absolute value of rational numbers.
- CCSS.MATH.CONTENT.6.SP.B.4. Display numerical data in plots on a number line, including dot plots, histograms, and box plots.
- CCSS.MATH.CONTENT.HSS.ID.A.1. Represent data with plots on the real number line (dot plots, histograms, and box plots).

Materials and Resources

- *Radiation Protection: Teacher Background Information*.
- *Vocabulary Materials.*
- Materials to create a timeline:
  - *History of Radiation Protection Timeline Cards* (Option A).
  - Paper or poster board and colored pencils, pens, markers or other art supplies (Option B).
  - Student computers and a printer (Option B).
- *Significant Discoveries and the History of Radiation Protection Handout* (one per student, pair or group).
  - *History of Radiation Protection Worksheet* (one per student, pair or group) and the *History of Radiation Protection Teacher Answer Key*.

Time

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

Vocabulary

- Ionizing radiation
- Radiation
- Radiation exposure
- Radiation protection
- Radioactive decay
- Radium
- X-rays

Directions

1. Start with a vocabulary activity if students are not familiar with radiation and the terms used in this activity, or provide students with the terms and definitions.

2. Ask students to provide examples of how people might prevent or reduce their exposure to radiation if, for example, they live in a home with high radon levels, work in a lab or industry that requires them to handle or work around radioactive materials, or when receiving an x-ray. Radiation protection involves three main concepts:
   - Time: limiting the time spent near a radiation source.
   - Distance: increasing the distance from a radiation source.
   - Shielding: using a barrier to prevent or reduce the risk of exposure. Examples include lead aprons or other protective equipment and thick walls or shields.
   - Devices and systems are also available to detect, monitor and reduce people's exposure to radiation.

3. Have students hypothesize how scientists discovered the risks of radiation exposure and ways to protect people from exposure to radiation.

4. Select and complete one of the timeline activities using the *Significant Discoveries and the History of Radiation Protection Handout*.
   - **Option A: Class Timeline Activity**
     Ask for 12 volunteers. Provide each volunteer with a card from the *History of Radiation Protection Timeline Card*s. Ask the volunteers to organize themselves, or let the class direct and organize the volunteers, in chronological order. They can do this first or while one or more students take turns reading the *Significant Discoveries and the History of Radiation Protection Handout*. Post the timeline cards on a wall in chronological order so students can complete the *History of Radiation Protection Worksheet*.
   - **Option B: Individual or Small Group Timeline Activity**
     Have students read the *Significant Discoveries and the History of Radiation Protection Handout* and create a paper- or computer-based timeline. A Sample Timeline is provided on Page 12.

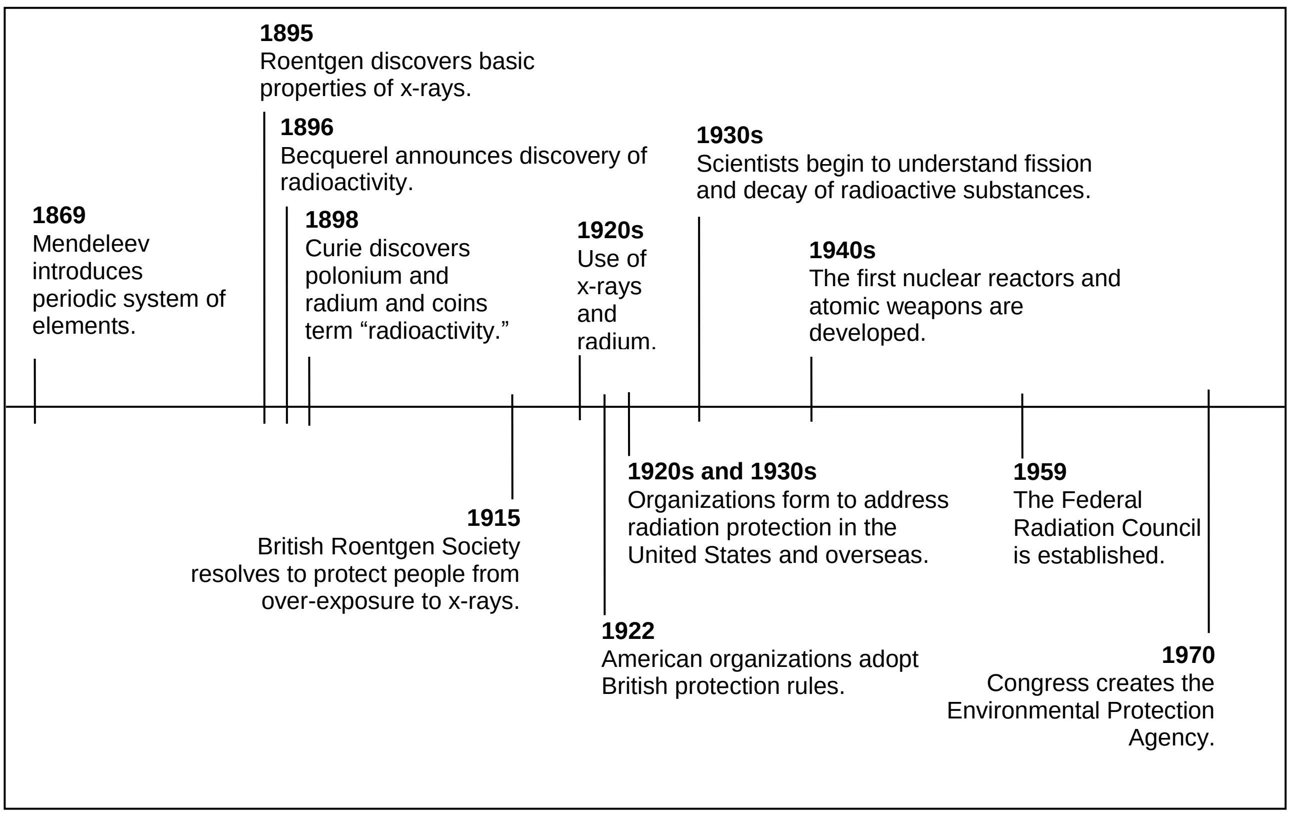
5. Distribute the *History of Radiation Protection Worksheet.* Have students answer the questions in pairs or small groups.

6. Discuss their responses using the *History of Radiation Protection Teacher Answer Key*.

7. Conclude by having students share one or two things they learned about the history and personal benefits of radiation protection with a classmate.

8. Optional activities or extensions: Have students investigate related topics and summarize their findings in a report, science journal entry, skit or presentation, or an educational blog or wiki. Topics could include:
   - Illnesses and deaths of early scientists, physicians, patients and industrial workers (e.g., the radium dial workers or uranium miners) related to their radiation exposure and any early protection measures established as a result of their deaths.
   - Early radiation protection standards (e.g., dose/exposure limits and methods of reducing exposure time and frequency) compared to today's standards.
   - Early research on the biological effects of radiation and how the information compares to our understanding of the effects today.
   - Events that led to the development of the health physicist career in 1942 and the duties, educational requirements and career options for a health physicist today.

Sample Timeline



Significant Discoveries and the History of Radiation Protection Handout

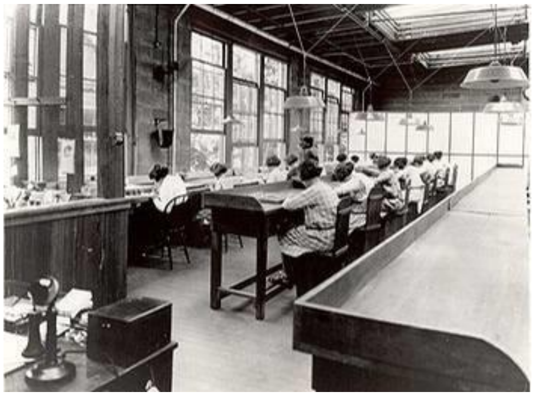
Philosophers and scientists have been interested in the basic building blocks of our physical universe since ancient times. In fact, the ancient Greeks were the first to believe that all matter in the universe must be made of tiny building blocks — or atoms. Beginning with the earliest scholars of science throughout history and into this century, scientists have been driven to learn more about the atom and how to control it.

Significant Discoveries

Scientists truly began to make advances in the study of atomic structure and radiation during the late part of the 19th century. Dmitri Mendeleev introduced the periodic system of elements in 1869. In December 1895, Wilhelm Roentgen accidentally discovered the basic properties of x-rays when he captured an x-ray image of his wife's hand. This led to further discoveries in the properties of ionizing radiation and the possibility of using radiation in medicine. In 1896, Henri Becquerel announced the discovery of radioactivity to the Academy of Sciences in Paris after he discovered the radioactive properties of uranium. Marie and Pierre Curie studied the radioactivity of uranium for several years, and discovered the elements polonium and radium after chemically extracting uranium from the ore. Marie Curie reported their discovery and coined the term "radioactivity" in 1898. By the early 1900s the study of radiation was a widely accepted scientific endeavor.

New Dangers Come with Discoveries

These discoveries did not come without a price. Scientists learned that radiation was not only a source of energy and medicine; it could also be a potential threat to human health if not handled properly. In fact, early pioneers in radiation research died from radiation-induced illnesses from too much exposure.



For instance, Thomas Edison's assistant died from a radiation-induced tumor as a result of too much x-ray exposure. As new uses for radioactive elements were discovered, potentially fatal incidents of overexposure increased.

During World War I, radium paint (a mixture of radium and phosphor) was used on military aircraft instruments to make them glow in the dark so they would be more visible to pilots flying at night. After the war was over, the industry that supported this technology changed its focus to paint glow-in-the-dark clocks and watch faces. The young women who painted these items would form a fine point on their paint brushes by pulling the freshly-dipped brushes between their lips before applying the paint onto the watch faces. Unknowingly, they were swallowing small amounts of radium and damaging their bodies. Several of the women died of unexplained anemia and disease complications with their mouth, teeth and jaw. The dentist who treated one of the women connected the issues with the radium dial painting.

Meeting the Need for Radiation Protection

By 1915, the British Roentgen Society had adopted a resolution to protect people from overexposure to x-rays. This was one of the first organized efforts in radiation protection.

American organizations had adopted the British protection rules by 1922. Awareness and education continued to grow. Throughout the 1920s and 1930s more guidelines were developed, scientists were studying the effects of radiation on living organisms, and various organizations were formed to address radiation protection in the United States and overseas.

By the 1930s, physicists were beginning to understand fission and radioactive decay, which led to the research and development of the first nuclear reactors and atomic weapons in the 1940s. Until that time, radiation protection was primarily a non-governmental function. After World War II, the development of the atomic bomb and nuclear reactors caused the federal government to establish policies dealing with human exposure to radiation. In 1959, the Federal Radiation Council was established to:

- Advise the President of the United States on radiological issues that affected public health.
- Provide guidance to all federal agencies in setting radiation protection standards.
- Work with the states on radiation issues.

In 1970, Congress created the U.S. Environmental Protection Agency (EPA) to serve as the primary federal agency to protect people and the environment from harmful and avoidable exposure to radiation. EPA's Radiation Protection Division carries out this responsibility by:

- Setting standards that protect people and the environment.
- Managing federal radiation protection programs.
- Providing radiation protection guidance and emergency response training to other federal agencies.
- Working closely with other national and international radiation protection organizations to further our scientific understanding of radiation risk.

History of Radiation Protection Worksheet

Name: ___________________________________ Date: ___________________

Research and answer the following questions.

1. How many years ago was radioactivity discovered? ___________________________

2. Approximately how many years elapsed between the discovery of radioactivity and the first efforts to implement radiation protection rules?

   In Britain: ____________________ In the United States: ______________________

3. How were radiation protection guidelines established in the early 1900s?

   ____
   ____
   ____
   ____

4. In what ways do you benefit from the discovery of ionizing radiation and radioactivity?

   ____
   ____
   ____
   ____

5. Do you think the benefits of radiation outweigh the exposure risks with the existence of radiation protection standards?

   ____
   ____
   ____
   ____

6. Name at least three types of jobs (or industries) that use radiation or radioactive materials and practice radiation protection.

   ____
   ____
   ____
   ____

7. When might you, or the general public, need to be aware of and practice radiation protection?

   ____
   ____
   ____
   ____

History of Radiation Protection Teacher Answer Key

1. How many years ago was radioactivity discovered? **Current year - 1896 = XXX years.**

2. Approximately how many years elapsed between the discovery of radioactivity and the first efforts to implement radiation protection rules?
   In Britain: 1915 - 1896 = 19 years
   In the United States: 1922 - 1896 = 26 years

3. How were radiation protection guidelines established in the early 1900s?
   While scientists and medical professionals saw the benefits of radiation, they were becoming more aware of the illnesses and deaths caused by radiation if it was not handled properly.

4. In what ways do you benefit from the discovery of ionizing radiation and radioactivity?
   We benefit from many uses of radiation, including medical and dental treatments and diagnostic tools, nuclear power generation, smoke and security detectors, and safe roads that are built and tested with moisture and density nuclear gauges.

5. Do you think the benefits of radiation outweigh the exposure risks with the existence of radiation protection standards?
   Answers will vary.

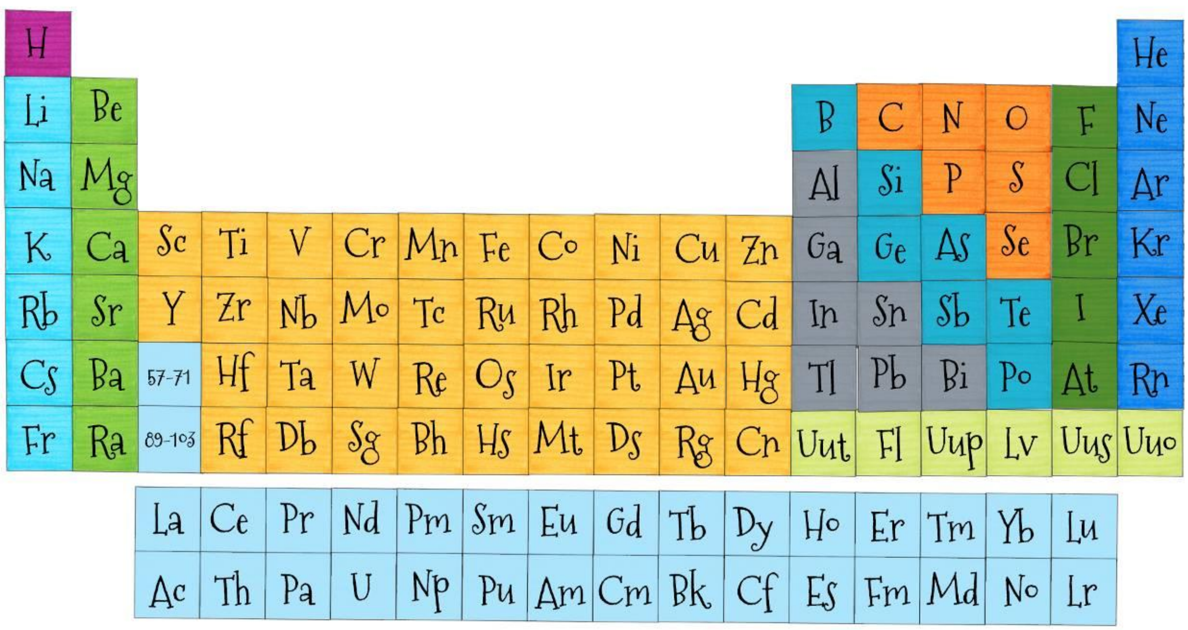
6. Name at least three types of jobs (or industries) that use radiation or radioactive materials and practice radiation protection.
   Answers will vary and may include nuclear power, medical, research, construction, transportation and industrial industries in addition to the military.

7. When might you, or the general public, need to be aware of and practice radiation protection?
   Potential answers may include: when receiving medical treatments (e.g., x-rays), when radon levels become too high in a home, in certain work settings, or when an accident occurs and radioactive materials are released into the environment.

History of Radiation

Protection Timeline Cards

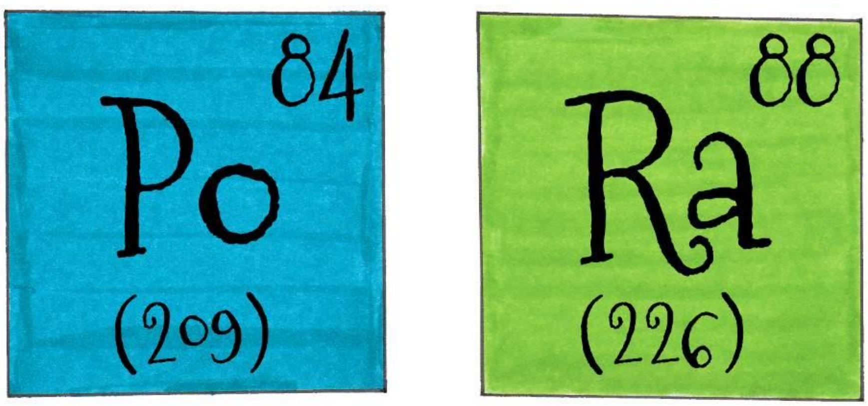
Mendeleev introduces the periodic system of elements



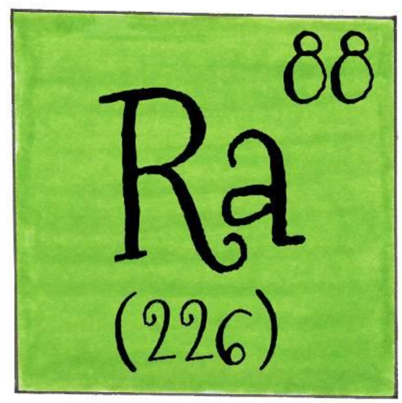
Roentgen discovers basic properties of x-rays

Becquerel announces discovery of radioactivity

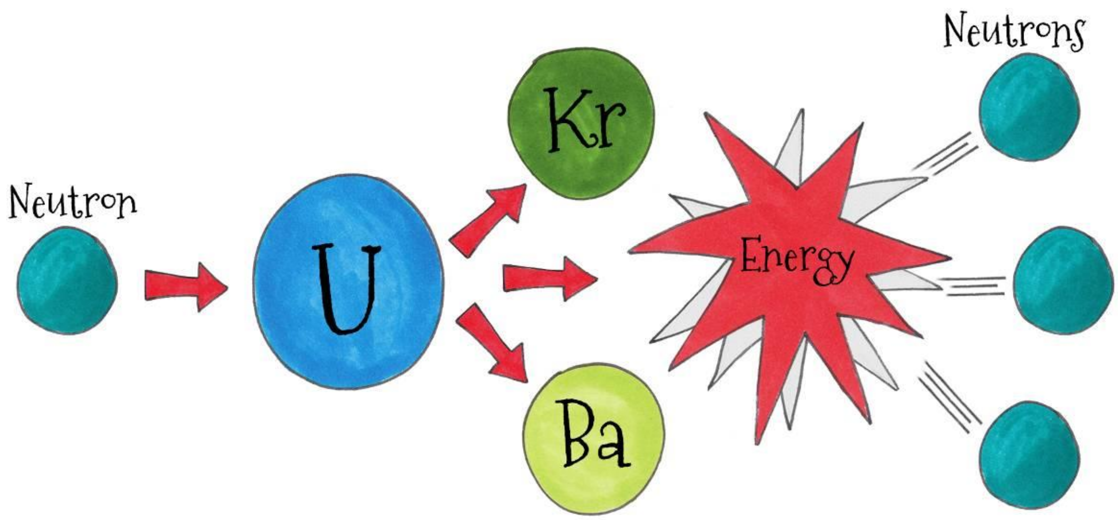
Curie discovers polonium and radium and coins the term radioactivity



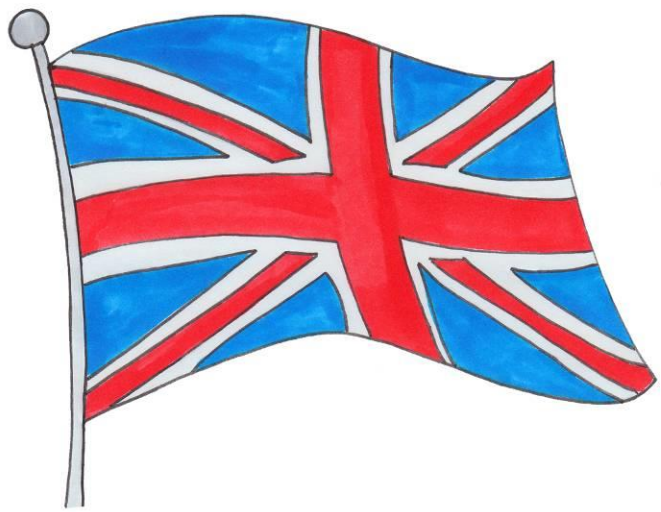
X-rays and radium are widely used



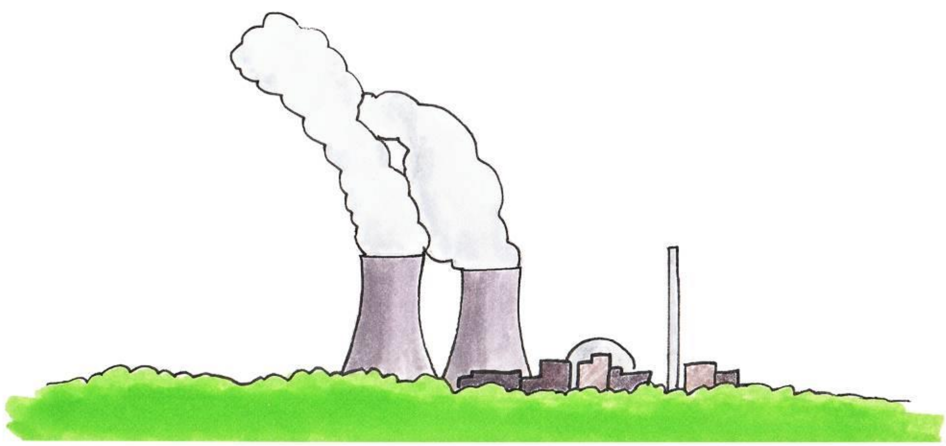
Scientists begin to understand fission and the decay of radioactive substances



American organizations adopt British protection rules



The first nuclear reactors and atomic weapons are developed



The British Roentgen Society resolves to protect people from overexposure to x-rays

Organizations form to address radiation protection in the United States and overseas

The Federal Radiation Council is established

Congress creates the Environmental Protection Agency

EPA

Activity 2: Time, Distance and Shielding

Objectives

Students will investigate how time, distance and shielding can reduce exposure risks.

Next Generation Science Standards

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

- PS4. Waves and Electromagnetic Radiation.

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:

- Comprehension and Collaboration: CCSS.ELA-LITERACY.SL.6-12.1
- Text Types and Purposes: CCSS.ELA-LITERACY.WHST.6-12.2
- Research to Build and Present Knowledge: CCSS.ELA-LITERACY.WHST.6-12.7

The concepts in this activity align with the following CCSS Mathematics Standards:

- CCSS.MATH.PRACTICE.MP1 Make sense of problems and persevere in solving them.
- CCSS.MATH.PRACTICE.MP2 Reason abstractly and quantitatively.
- CCSS.MATH.PRACTICE.MP5 Use appropriate tools strategically.
- CCSS.MATH.CONTENT.6.SP.B.5. Summarize numerical data sets in relation to their context, such as by:
  - CCSS.MATH.CONTENT.6.SP.B.5.B. Describing the nature of the attribute under investigation, including how it was measured and its units of measurement.
- CCSS.MATH.CONTENT.7.EE.B.4. Use variables to represent quantities in a real-world or mathematical problem, and construct simple equations and inequalities to solve problems by reasoning about the quantities.
- CCSS.MATH.CONTENT.HSN.Q.A.1. Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.

Materials and Resources

- *Radiation Protection: Teacher Background Information*.
- *Vocabulary Materials.*
- *Radiation Protection Worksheet* (one per student, pair or group).
- *Applying Time, Distance and Shielding Worksheet* (one per student, pair or group).
- Option A (per group or class based on supplies available):
  - Geiger counter and radioactive source (e.g., commercially purchased source, Fiesta dinnerware, luminescent clock or watch face, or gas camping lantern with a thorium mantel).
  - Alternative to Geiger counter: Heat source (e.g., hot plate or heat lamp).
  - Measuring device (ruler, measuring stick or tape measure).
  - Clock with a second hand or a stopwatch.
  - A thermometer (if using a heat source).
  - Shielding sources (e.g., piece of glass, clothing or aluminum foil; or sheet of paper or metal).

- Option C:
  - Student computers with Internet access or printed resources for students with information about protection measures taken in nuclear reactor incident(s).

Time

45-60 minutes depending on the activity option chosen. Students may also complete the activity outside of class and discuss their findings in the next class period.

Vocabulary

- Geiger counter
- Ionizing radiation
- Radiation
- Radiation exposure
- Radiation protection

Directions

1. Start with a vocabulary activity if students are not familiar with radiation and the terms used in this activity, or provide students with the terms and definitions.

2. Explain that there are situations in which we may or may not have control over our exposure to ionizing radiation. Ask students:
   - When do we not have control over our exposure to radiation? We do not have control over our exposure to some naturally occurring (background) radiation, and we may not have control over our exposure to undetected sources of radiation.
   - When do we have control over our exposure to radiation? Examples may include when evaluating whether to have an x-ray or medical procedure (using radiation), when testing for and fixing radon levels in your home, or when following warnings or emergency response directives and staying away from radioactive areas.
   - Why might we want to limit our exposure to radiation when possible? Radiation can deposit energy in body tissue and can damage or kill cells.

3. Select and prepare an activity option:
   - **Option A:** Have students use a Geiger counter and a radioactive source or heat source and thermometer to conduct an experiment and test possible radiation protection methods. Provide time, distance and shielding materials that are listed in Materials and Resources.
   - **Option B:** Have students predict what steps they can or might take to reduce their exposure to radiation (e.g., if living near a radioactive area like an abandoned uranium mine, if finding an orphan radioactive source, or in the event of a nuclear explosion or accident).
   - **Option C:** Have students research what radiation protection concepts are, and have been, used in radiological emergencies (e.g., Japan's Fukushima nuclear power plant incident or other historical nuclear power plant incidents).
   - **Option D:** Have students interview a person who practices radiation protection at work to determine what radiation practices are followed according to the source(s) of radiation used. Interviewees may include medical, dental or veterinary staff; x-ray equipment or environmental inspectors; people who test and resolve radon issues; Department of Health staff who deal with radiation issues; truck drivers who haul radioactive materials; emergency responders; researchers; power plant workers; radon mitigation workers; and construction workers who use moisture and density nuclear gauges.

4. Explain to students that their task is to hypothesize and test (or research) ways people can limit their exposure to ionizing radiation.

5. Introduce the three main concepts of radiation protection. Determine how much information you want to provide about these concepts before students complete the activity and investigate the concepts. For instance if using Option A, you may want students to identify these concepts through the activity and review the concepts afterwards. Information on the concepts (time, distance and shielding) can be found in the *Radiation Protection: Teacher Background Information*.

6. Distribute the *Radiation Protection Worksheet* (if using Option A) or the *Time, Distance and Shielding Worksheet* (if using Options B through D). Have students work in pairs or small groups to conduct the activity and complete the worksheet. Students should determine that one can limit their exposure by:
   - Limiting their time spent near a radiation source.
   - Increasing the distance from a radiation source.
   - Using shielding to provide a barrier between themselves and a radiation source.

7. Have students share the radiation protection concepts they identified in their experiment or research and how they help reduce or eliminate a person's exposure to radiation. Prompt students to consider how using two or more forms of protection might affect a person's exposure level. NOTE: You may want to extend Activity Option A and have students hypothesize and test how using two or more forms of protection might affect a person's exposure level if they did not already do so.

Radiation Protection Worksheet

Name: ___________________________________ Date: ____________________

Conduct an experiment to test the ways in which you and others can limit your radiation exposure when you have control over the situation.

1. State the problem or question.

   ____
   ____
   ____

2. Conduct research and state your hypothesis.

   ____
   ____
   ____

3. List any materials or resources used to test your hypothesis.

   ____
   ____
   ____
   ____
   ____

4. Describe the procedure(s) to test your hypothesis.

   ____
   ____
   ____
   ____
   ____
   ____
   ____

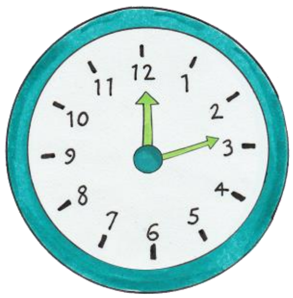
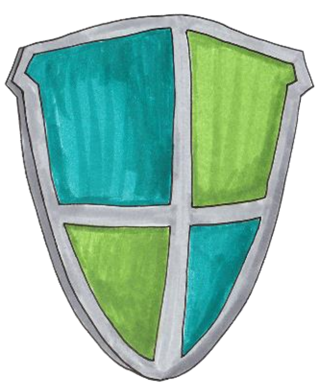
5. Collect the data on the back of this sheet or a separate sheet of paper and present the results in tables or graphs, if applicable.

6. State your conclusions.

   ____
   ____
   ____
   ____
   ____
   ____

Applying Time, Distance and Shielding Worksheet

Describe how you and others can use time, distance and shielding to limit your radiation exposure when you have control over the situation.

 **Time**	
 **Distance**	
 **Shielding**	

Activity 3: Radiation Warning and Protection Equipment

Objectives

Students will:

- Interpret the meaning of several radiation warning signs.
- Investigate how radiation protection technology and equipment are used to protect workers, the public and our environment.

Next Generation Science Standards

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

- PS4. Waves and Electromagnetic Radiation.

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:

- Comprehension and Collaboration: CCSS.ELA-LITERACY.SL.6-12.1
- Comprehension and Collaboration: CCSS.ELA-LITERACY.SL.6-8.2

Materials and Resources

- *Radiation Protection: Teacher Background Information*.
- *Vocabulary Materials.*
- Computer and/or projector to display information/images and capture student comments.
- *Radiation Detection Equipment* images.
- *Radiation Symbols Worksheet* (one per student, pair or group) and teacher answer key.
- Student computers with Internet access and printers (if conducting research in class).

Time

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

Vocabulary

- Dosimeter
- Geiger counter
- Ionizing radiation
- Radiation
- Radiation exposure
- Radiation protection
- Radon

Directions

1. Start with a vocabulary activity if students are not familiar with radiation and the terms used in this activity, or provide students with the terms and definitions.

2. Explain that radiation is energy that travels in the form of waves or high speed particles. Ask students how people might be able to detect whether radiation is present since it is not detectable with our senses.

3. Display the *Radiation Detection Equipment* images. Explain that these show a few devices that people can use to detect and monitor radiation levels. Ask students to hypothesize the purpose or uses of each piece of equipment.
   - **Ground and gamma scanners (top, left) monitor the clean up at contaminated sites such as radioactive waste sites or emergency response sites.**
   - **Radon test kits (center, left) measure radon levels in the home. At-home test kits include canisters, detectors, or devices that you can purchase in stores, by mail, phone or online. You leave them in your home for a recommended period and then send them to a laboratory for analysis. Professionals can also come to your home and measure the radon levels.**
   - **Dosimeters (bottom, left) are worn by people who work near radioactive sources or handle radioactive materials. People wear dosimeters to measure exposure to radiation so they stay within the legal exposure limits of their job. People who might wear these include astronauts, scientists, radiation protection workers, medical workers, x-ray technicians and nuclear power plant workers.**
   - **Air monitoring equipment (top, right) detects and monitors outdoor radiation levels. EPA's RadNet system monitors the nation's air, drinking water, precipitation, and pasteurized milk to determine levels of radiation in the environment.**
   - **Geiger counters (bottom, right) are hand-held devices that detect the presence of radiation. They are often used in the health physics, nuclear and geology fields.**

4. Ask students: How is the public warned about the presence of radiation? **Warning signs and radiation protection measures can alert and protect workers and the general public. Radiation warning signs may be found in workplaces, on packaging or transport vehicles, and on the sides of buildings. They often alert us to radiation sources and may direct us on how to limit or avoid exposure to radiation. We also depend on technology and protective equipment to help detect, monitor and limit our exposure to radiation.**

5. Provide students with a copy of the *Radiation Symbols Worksheet.* Direct them to answer the questions regarding the three symbols to the best of their knowledge – some students may be seeing these images for the first time.

6. Review students' responses using the *Radiation Symbols Teacher Answer Key*. You may also share the Radiation Warning Symbols information in the *Radiation Protection: Teacher Background Information* and have students confirm their responses or complete the worksheet. Students may want to share where they have seen these warning signs.

7. Ask students:
   - Based on the warning symbols or what you know about ionizing radiation, what are the three basic concepts of radiation protection? **Time, distance and shielding.**
   - How do these signs relate to the concepts of radiation protection?
     - **The international symbols of radiation prompt people to remain a safe distance from a radiation source and workers to follow the appropriate radiation protection standards (time, distance and shielding).**
     - **Hazardous materials (HAZMAT) symbols provide carriers with the necessary information they need to store radioactive materials safe distances away from people, animals and other materials and handle the materials in a safe manner. In the event of an accident, this symbol helps first responders quickly identify the materials so they can respond appropriately.**
     - **A fallout shelter indicates a location that offers shielding during a radiation emergency.**

6. Conclude by having students reflect and share one or more things they learned about radiation detection and protection.

7. Optional activities or extensions: Have students:
   - Research a radiation protection device and investigate its purpose, where and how it is used and any impacts it has on personal health and environmental protection.
   - Investigate the units of measurements calculated by the device (e.g., picocuries per liter (pCi/L) for measuring radon levels or counts per second (CPS) or counts per minute (CPM) for Geiger counter readings) and collect and graph data samples.
   - Summarize and share their findings in a verbal or online presentation (potentially including a demonstration, model or video of the device) similar to science shows and sites that describe how things work or how they are made.

Radiation Detection Equipment

Ground and Gamma Scanners

Air Monitoring Equipment

Radon Test Kits

Source: National Institute of Environmental Health Sciences (top), Michigan Department of Environmental Quality (bottom)

Geiger Counters

Source: Oak Ridge Institute for Science and Education

Dosimeters

Source: Virginia Department of Health

Radiation Symbols Worksheet

Name: ________________________________ Date: __________________

Answer the questions for each symbol.

1. 

These two symbols represent the same message.

What do the symbols mean?

Where might you see either of them?

What actions might you or others need to take if you see either of these symbols?

2. 

What does the symbol mean?

Where might you see it?

What actions might you or others need to take if you see this symbol?

3. 

What does the symbol mean?

Where might you see it?

What actions might you or others need to take if you see this symbol?

Radiation Symbols Teacher Answer Key

Name: ______________________________ Date: ________________

Answer the questions for each symbol.

1. 

What do the symbols mean? **Both symbols are meant to identify an ionizing radiation source and alert people of the potential dangers so they can take action to protect against radiation exposure. The first (yellow) is an international symbol of radiation. The United Nations introduced the new international radiation symbol (red) in 2007.**

Where might you see either of them? **Potentially around radioactive areas such as active or abandoned uranium mines and mills, nuclear test and radioactive waste sites, nuclear power plants, labs and medical sites.**

What actions might you or others need to take if you see either of these symbols? **Distance yourself from the area or take the appropriate precautions when entering the area such as wearing protective clothing, using shielding or limiting your time in the area.**

2. 

What does the symbol mean? **There are radioactive materials present.**

Where might you see it? **On trucks or trains carrying radioactive materials or on packages containing radioactive materials.**

What actions might you or others need to take if you see this symbol? **Take precautions to package, transport and handle the materials with care.**

3. 

What does the symbol mean? **It indicates the location of a fallout shelter.**

Where might you see it? **On a public building.**

What actions might you or others need to take if you see this symbol? **Going to that location in the event of a nuclear attack or large radiological disaster.**

Activity 4: Buildings as Shielding

Objectives

Students will:

- Tour a fallout shelter or research information about fallout shelters.
- Examine the concepts of buildings as shielding and shelter in place.

Next Generation Science Standards

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

- PS4. Waves and Electromagnetic Radiation.

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:

- Comprehension and Collaboration: CCSS.ELA-LITERACY.SL.6-12.1
- Comprehension and Collaboration: CCSS.ELA-LITERACY.SL.6-8.2
- Craft and Structure: CCSS.ELA-LITERACY.RST.6-12.4
- Research to Build and Present Knowledge: CCSS.ELA-LITERACY.WHST.6-12.9

The concepts in this activity align with the following CCSS Mathematics Standards:

- CCSS.MATH.PRACTICE.MP2 Reason abstractly and quantitatively.
- CCSS.MATH.CONTENT.6.RP.A.3. Use ratio and rate reasoning to solve real-world and mathematical problems, e.g., by reasoning about tables of equivalent ratios, tape diagrams, double number line diagrams, or equations.
- CCSS.MATH.CONTENT.7.SP.A.1. Understand that statistics can be used to gain information about a population by examining a sample of the population; generalizations about a population from a sample are valid only if the sample is representative of that population. Understand that random sampling tends to produce representative samples and support valid inferences.
- CCSS.MATH.CONTENT.HSN.Q.A.1. Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.

Materials and Resources

- *Radiation Protection: Teacher Background Information*.
- *Vocabulary Materials.*
- *Emergency Planning and Preparedness Quiz* (one per student, pair or group) and teacher answer key.
- Fallout shelter; determine if there is a fallout shelter location in your school or community.
- *Fallout Shelters Worksheet* (one per student, pair or group) and *Fallout Shelters Teacher Answer Key.*
- *Buildings as Shielding* image (one per student, pair or group).
- Student computers with Internet access to: (optional)
  - www.ready.gov
  - http://www2.epa.gov/radiation/protecting-yourself-radiation

- A copy of your school's emergency response plan (optional).

Time

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

Vocabulary

- Dose
- Ionizing radiation
- Radiation
- Radiation exposure
- Radiation protection

Directions

1. Start with a vocabulary activity if students are not familiar with radiation and the terms used in this activity, or provide students with the terms and definitions.

2. Ask students to hypothesize what they might do in the event of an airborne radiation incident. **Explain that these events are rare, but might occur, for example, in the event of a traffic accident if a tractor trailer is carrying materials that may pose a risk, a natural disaster (such as Japan's Fukushima nuclear power plant incident or other historical nuclear power plant incidents), or a terrorist attack. Student answers will vary, but may include going to a basement or other shelter for protection.**

3. Distribute the *Emergency Planning and Preparedness Quiz* if using it as a pre-test. Have students complete the quiz. NOTE: the quiz can be used as a pre- and/or post-test based on your preference. Review the correct answers after students have completed the post-test. If using the quiz as a learning tool only, let students know the quiz is meant to be a fun way to determine what students know and learn and will not be graded.

4. Explain that the United States and Soviet Union were in a race to develop atomic weapons between 1947 and 1991. This period was known as the Cold War. Many people were fearful of a nuclear attack and many fallout shelters were built during this time. These shelters were designed to protect people from the nuclear fallout should a nuclear explosion occur.

5. Ask students:
    - What is nuclear fallout**? Particles of radioactive debris that fall from the atmosphere following a nuclear explosion. Exposure to gamma radiation is a primary concern because gamma radiation can pass through many kinds of materials, including our bodies.**
    - How does a fallout shelter serve as a form of radiation protection? **It serves as shielding.**

6. Tour or research a fallout shelter. Students may visit a designated fallout shelter location within your school or community or research and tour the Greenbrier Bunker online (also known as Project Greek Island) on the Public Broadcasting Service (PBS)' website: www.pbs.org/wgbh/amex/bomb/sfeature/bunker.html.

7. Provide students with a copy of the *Fallout Shelters Worksheet*. Have them answer questions 1–5 while touring or researching a fallout shelter. Review their responses as a class. Internet resources may include the PBS Greenbrier Bunker and the National Archives

and Records Administration (NARA) websites: www.archives.gov/education/lessons/fallout-docs/

8. Provide students with a copy of the *Buildings as Shielding* image. Have students examine the radiation dose reduction factors within the two images, answer questions 6 and 7 on the *Fallout Shelters Worksheet*, and discuss and compare their responses.

9. Asks students:
   - Why do the third floors of the 5-story building and office/apartment building offer more protection than the first and second floors? **Because when the radiation falls and settles on the ground, the first and second floors are closer to the radiation source. Therefore, the third floor offers more shielding.**
   - Why are we not able to completely avoid exposure to radiation? **Gamma radiation can pass through many kinds of materials. Additionally, it is very difficult to completely seal off a building to avoid exposure. Radiation may enter through doors, windows, ventilation systems and other cracks or openings.**

10. Distribute the *Emergency Planning and Preparedness Quiz* if using it as a post-test. Have students complete the quiz and review the correct answers.

11. Optional extension: Direct students to:
    - Develop a plan with their family in the event of an airborne radiation incident when advised to remain indoors. Resources may include:
      - Ready.gov: www.ready.gov
      - Protecting Yourself from Radiation*:* http://www2.epa.gov/radiation/protecting-yourself-radiation
    - Review your school's emergency response plan to determine where students should go in the event of a radiation emergency.

Emergency Planning and Preparedness Quiz

Name: ___________________________________ Date: ___________________

The following questions are based on a situation in which an airborne radiation incident occurs. Circle or mark the correct answer. There may be more than one correct response for some questions.

1. If you are not near adequate shelter or if you are directed to evacuate, which direction should you travel? There may be more than one correct response.
    a. Move in a direction that is downwind or in the airflow of the radiation source
    b. Move in a direction that is upwind or away from the airflow of the radiation source
    c. Move away from the radiation source
    d. Move toward the radiation source

2. If you are inside a home or building, which area(s) offers the best protection? There may be more than one correct response.
    a. The basement or underground area
    b. The top floor
    c. An interior room that is farthest from exterior walls and the roof and has no windows
    d. The ground floor by a window

3. Which of the following should you have in an emergency kit should this situation occur?
    a. A battery-powered radio
    b. Plastic sheeting, duct tape and scissors
    c. Water, nonperishable food and any up-to-date medications
    d. A change of clothing
    e. All of the above

4. If safely possible, before seeking shelter, you should turn off ventilation and heating systems and close any doors, windows, vents, dampers and exhaust fans.
    a. True
    b. False

5. If you are in a car and unable to seek shelter in a building, what should you do?
    a. Close the windows
    b. Turn on the air conditioner or heater
    c. Use re-circulating air
    d. All of the above

6. How might this symbol be helpful in the event of a radiation emergency?
    a. It would signal that radiation is present in the place where it is posted.
    b. It would signal that hazardous materials (HAZMAT) are in a package or transport vehicle.
    c. It would direct me to a safe place to wait in a radiation emergency.

Emergency Planning and Preparedness Quiz
Teacher Answer Key

Correct responses are bolded.

1. If you are not near adequate shelter or if you are directed to evacuate, which direction should you travel? There may be more than one correct response.
    a. Move in a direction that is downwind or in the airflow of the radiation source
    b. Move in a direction that is upwind or away from the airflow of the radiation source
    c. Move away from the radiation source
    d. Move toward the radiation source

2. If you are inside a home or building, which area(s) offers the best protection? There may be more than one correct response.
    a. The basement or underground area
    b. The top floor
    c. An interior room that is farthest from exterior walls and the roof and has no windows
    d. The ground floor by a window

3. Which of the following should you have in an emergency kit should this situation occur?
    a. A battery-powered radio
    b. Plastic sheeting, duct tape and scissors
    c. Water, nonperishable food and any up-to-date medications
    d. A change of clothing
    e. All of the above

4. If safely possible, before seeking shelter, you should turn off ventilation and heating systems and close any doors, windows, vents, dampers and exhaust fans.
    a. True
    b. False

5. If you are in a car and unable to seek shelter in a building, what should you do?
    a. Close the windows
    b. Turn on the air conditioner or heater
    c. Use re-circulating air
    d. All of the above

    It is best if you close the windows, turn off the air conditioner or heater, and close the vents. However, if you need air or ventilation use air that is re-circulated from within the car.

6. How might this symbol be helpful in the event of a radiation emergency?
    a. It would signal that radiation is present in the place where it is posted.
    b. It would signal that hazardous materials (HAZMAT) are in a package or transport vehicle.
    c. It would direct me to a safe place to wait in a radiation emergency.

Fallout Shelters Worksheet

Name: ________________________________ Date: __________________

Fallout shelters serve as a means of shielding people from nuclear fallout or airborne biological, chemical or radioactive hazards. Answer the following questions.

1. Around what time period or historical events did the federal government recommend fallout shelters in the United States and why?
   ____
   ____
   ____

2. Where are fallout shelters generally located? How does the location help shield, or protect against radiation exposure?
   ____
   ____
   ____
   ____

Photo from U.S. National Archives and Records Administration

3. What structural characteristics should fallout shelters have to help shield, or protect people against radiation exposure?
   ____
   ____
   ____

4. Are fallout shelters necessary today? Why or why not?
   ____
   ____
   ____

5. If needing to seek shelter in your home, which part of your home would offer the best shielding protection and why?
   ____
   ____

Use the *Buildings and Shielding* image to answer the following questions.

6. What is the estimated radiation dose reduction factor of the area (indicated in #5)?
   ____

7. Based on your findings, does the location (indicated in #5) offer the best shielding? If not, which location in your home offers better protection and why?
   ____
   ____
   ____

Fallout Shelters Teacher Answer Key

1. Around what time period or historical events did the federal government recommend fallout shelters in the United States and why?
   Following World War II, political and military tensions and economic competition between the United States and the Soviet Union increased. These tensions, along with the Soviet Union developing and testing nuclear weapons, led to a nuclear arms race between the two countries during a period called the Cold War (1947–1991). With the possibility of a nuclear attack, fallout shelters were developed and "duck and cover" drills became commonplace in the 1950s.

2. Where are fallout shelters generally located? How does the location help shield, or protect against radiation exposure?
   Fallout shelters are typically located in the lowermost level or centermost portion of a structure to provide shielding from gamma rays. This might include basements, or other in-ground or below-ground structures, and windowless areas in the center of a home or high-rise building structure.

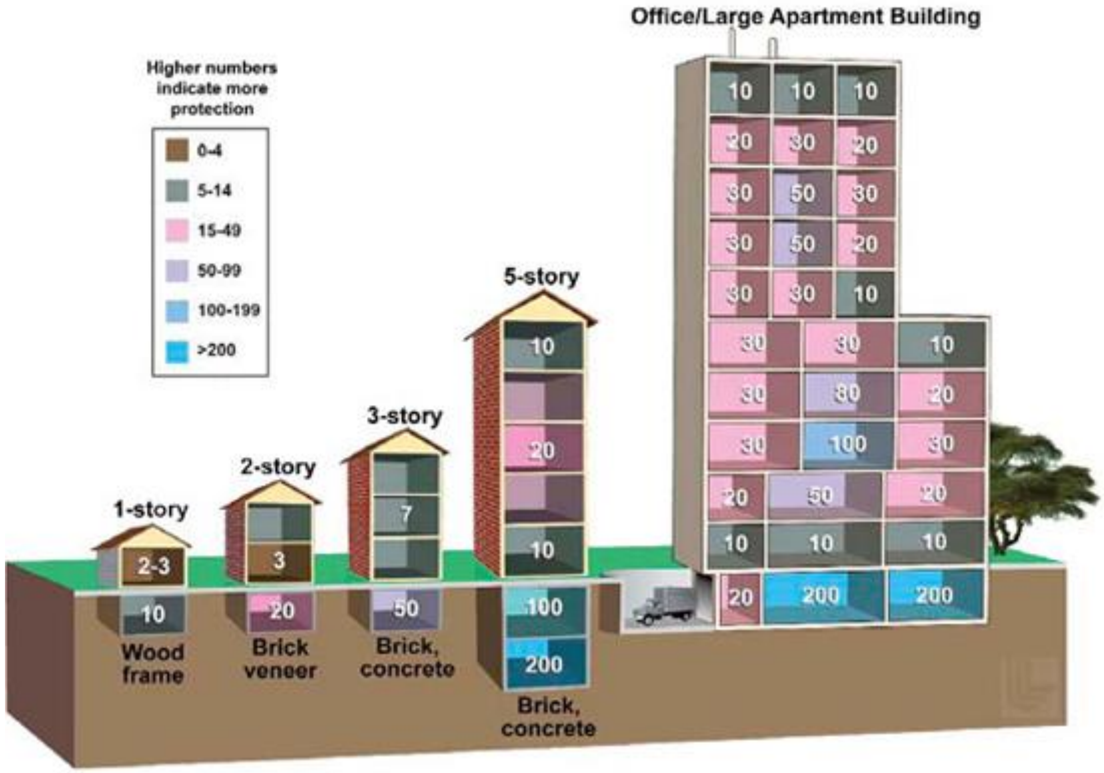
3. What structural characteristics should fallout shelters have to help shield, or protect people against radiation exposure?
   The walls and roof should be thick and dense enough to absorb the radiation given off by fallout particles. The structure should be windowless because windows do not shield against gamma radiation. Windows also produce an additional risk if they break (e.g., during a blast). Some fallout shelters may have their own ventilation system.

4. Are fallout shelters necessary today? Why or why not?
   Fallout shelters serve as a means of shielding oneself from nuclear fallout or airborne biological, chemical or radioactive hazards. Answers will vary based on students' perceived threats of these situations occuring.

Answers for questions 5–7 will be student specific.

Buildings as Shielding

The numbers in the diagram represent a radiation dose reduction factor. For example, the number 50 indicates that a person in that area would receive 1/50th of the dose of a person standing outside of the building. Higher numbers indicate more protection from ionizing radiation.



Building as Shielding image source: www.ready.gov

Activity 5: A Career in Radiation Protection

Objectives

Students will research and compare career opportunities in the field of radiation protection.

Next Generation Science Standards

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

- PS4. Waves and Electromagnetic Radiation.

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:

- Comprehension and Collaboration: CCSS.ELA-LITERACY.SL.6-12.1
- Key Ideas and Details: CCSS.ELA-LITERACY.RST.6-12.2
- Research to Build and Present Knowledge: CCSS.ELA-LITERACY.WHST.6-12.7
- Research to Build and Present Knowledge: CCSS.ELA-LITERACY.WHST.6-12.8
- Research to Build and Present Knowledge: CCSS.ELA-LITERACY.WHST.6-12.9
- Production and Distribution of Writing: CCSS.ELA-LITERACY.WHST.6-12.4
- Production and Distribution of Writing: CCSS.ELA-LITERACY.WHST.6-8.6

Materials and Resources

- *Radiation Protection: Teacher Background Information*.
- *Vocabulary Materials.*
- Computer and/or projector for displaying images.
- *What Do They Do?* Images (display or share a print version).
- Student computers with Internet access and a printer (if conducting all research in class).
- Paper and/or poster board and colored pencils, pens or markers (optional).

Time

You may choose to have students complete the entire activity within one or two (45-60 minutes) class periods. If time or computer access is limited, the activity can be introduced, completed outside of the class and concluded in another class period.

Vocabulary

- Ionizing radiation
- Radiation
- Radiation protection

Directions

1. Start with a vocabulary activity if students are not familiar with radiation and the terms used in this activity, or provide students with the terms and definitions.

2. Explain that when we think about ionizing radiation we often think about medical workers, nuclear power plant workers and others who use radiation in their jobs. Rarely do we think about the people working to keep us and our environment safe.

3. Display or provide students with the *What Do They Do?* images. Ask students to explain or hypothesize what each person is doing and what they have in common.
   - An inspector tests an x-ray machine (top, left).
   - A scientist examines the effects of radiation on human cells (top, right).
   - An Environmental Protection Agency (EPA) employee uses an air monitor to monitor and measure radiation in the air (bottom, left).
   - An EPA emergency responder monitors ground radiation levels (bottom, right).
   - They all have jobs focusing on radiation protection.

4. Direct students to identify and research radiation protection careers. They may interview a person in the field or conduct online research. Career options might include any of the following:
   - Health physics provides the practical means for protecting workers, the general public and the environment from harmful radiation exposures.
   - Radiobiology is a specialized branch of biology that studies the effects of ionizing radiation on cells and organisms.
   - Radiochemistry is the branch of chemistry that uses analytical techniques along with sophisticated radiation measurement techniques to determine the presence of, or in many cases to quantify the activity of, individual radioactive elements at extremely low levels.
   - Radioecology determines how radioactive material is transported through the physical environment (ground, water and air) and through ecosystems (e.g., through bioaccumulation).

5. Have students report on:
   - The education, knowledge and skills required for the profession.
   - The main job functions.
   - The industries in which they may work (and potentially the job setting – e.g., in a laboratory, outdoors or at a desk).

6. Establish formats for delivering the final product. Examples may include:
   - A job description or a brochure promoting the career.
   - A role play of a job interview (e.g., the “employer” may describe some of the job tasks and ask the “candidate” about his education, skills and experience).
   - A career fair in which students display their products (e.g., job description, brochures, and posters) at a “booth” or provide a brief presentation and answer questions about the profession.

7. Conclude by asking students what they have learned about careers in radiation protection. Students can submit their conclusions in writing if preferred.

What Do They Do?

Inspector

Photo courtesy of the
Hawaii Department of Health

Scientist

Photo courtesy of the National Aeronautics and Space Administration

EPA Radiation Protection Specialist

EPA Emergency Responder

Activity 6: Impact of Radiological Emergencies

Objectives

Students will:

- Examine a radiation emergency.
- Explain the impacts it had on public health and the environment.
- Identify the parties who respond to radiation emergencies.

Next Generation Science Standards

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

- PS4. Waves and Electromagnetic Radiation.
- ESS3. Human Impact.

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:

- Comprehension and Collaboration: CCSS.ELA-LITERACY.SL.6-12.1
- Key Ideas and Details: CCSS.ELA-LITERACY.RST.6-12.2
- Integration of Knowledge and Ideas: CCSS.ELA-LITERACY.RST.6-12.7
- Research to Build and Present Knowledge: CCSS.ELA-LITERACY.WHST.6-12.7
- Research to Build and Present Knowledge: CCSS.ELA-LITERACY.WHST.6-12.8
- Research to Build and Present Knowledge: CCSS.ELA-LITERACY.WHST.6-12.9
- Production and Distribution of Writing: CCSS.ELA-LITERACY.WHST.6-12.4
- Production and Distribution of Writing: CCSS.ELA-LITERACY.WHST.6-12.6

Materials and Resources

- *Radiation Protection: Teacher Background Information*.
- *Vocabulary Materials.*
- Paper and/or poster board and colored pencils, pens or markers (optional).
- Student computers with Internet access to the following and a printer: (optional)
  - Protecting Yourself from Radiation: http://www2.epa.gov/radiation/protecting-yourself-radiation
  - Radiation: www.epa.gov/radiation/
  - Three Mile Island: http://www2.epa.gov/aboutepa/three-mile-island
  - Historical Radiological Event Monitoring: http://www2.epa.gov/radnet/historical-radiological-event-monitoring
  - Radiological Emergency Response: Planning and Past Responses: http://www2.epa.gov/radiation/radiological-emergency-response-planning-and-past-responses

Time

You may choose to have students complete the entire activity within one or two (45-60 minutes) class periods. If time or computer access is limited, the activity can be introduced, completed outside of the class and concluded in another class period.

Vocabulary

- Ionizing radiation
- Radiation
- Radiation protection

Directions

1. Start with a vocabulary activity if students are not familiar with radiation and the terms used in this activity, or provide students with the terms and definitions.

2. Ask students to provide an example of a radiological emergency, who responded to the emergency, and how it impacted public health and/or the environment. Examples may include the Fukushima Daiichi nuclear disaster, the Three Mile Island incident or a local accident or emergency that may have occurred.

3. Direct students to select and investigate a past radiological emergency. In addition to nuclear power plant incidents, others radiological emergencies may include the release of radioactive materials due to:
   - A transportation (highway, air, rail or water) accident.
   - Terrorist act (e.g., explosion of a radiation dispersion device (RDD) or "dirty bomb").
   - An accident during the launch and re-entry of satellites with radioactive power sources.
   - Improper handling and disposal of sealed radioactive sources or radiation devices (e.g., moisture and density nuclear gauges, tritium-lit exit signs and ionization smoke detectors).
   - A research facility incident.
   - Contaminated materials at steel mills or scrap metal recycling facilities.

   See the links provided under Materials and Resources or use additional resources.

4. Direct students to summarize the factors that led to the event, the nature of the incident, who responded (e.g., first responders, environmental agency representatives and cleanup crews), the type of radioactive materials released and the effects or impacts the incident had on public health and the environment.

   Student products may include:
   - Timelines of the events, response efforts and effects observed.
   - Webs or chains depicting how people and the environment were affected by the radioactive materials released during the emergency and how various agencies worked together to respond to and clean up the emergency site.
   - Other visual presentations (paper- or computer-based) of the event, health and environmental effects, and response efforts.

5. Have students share their findings. Have the class evaluate whether they think the situations were handled effectively and how public health and environmental impacts could be minimized in the future based on lessons learned.

6. Optional activities or extensions: Have students:
   - Research and debate the effectiveness of laws that address and limit radioactive contaminants in our environment. See Radiation Regulations and Laws: http://www2.epa.gov/radiation/radiation-regulations-and-laws
   - Analyze the average radon levels in their area (see online resources or contact the local health or environmental department), compare the levels with Environmental Protection

Agency's (EPA) recommended exposure limits and determine how to test for and resolve any issues. Students can also research, graph and compare radon levels in their area/region with levels in other regions or states.

- Research the radiation protection practices that are in place to protect their community if living near a uranium mine, a nuclear power plant, or other facilities that produce, utilize or store radioactive materials.

Activity 7: Benefits of Radiation

Objectives

Students will examine how radiation is often used in devices and processes that help protect us and ensure our safety.

Next Generation Science Standards

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

- PS4. Waves and Electromagnetic Radiation.
- ESS3. Human Impact.

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:

- Comprehension and Collaboration: CCSS.ELA-LITERACY.SL.6-12.1
- Research to Build and Present Knowledge: CCSS.ELA-LITERACY.WHST.6-12.7
- Research to Build and Present Knowledge: CCSS.ELA-LITERACY.WHST.6-12.8
- Research to Build and Present Knowledge: CCSS.ELA-LITERACY.WHST.6-12.9
- Key Ideas and Details: CCSS.ELA-LITERACY.RST.6-12.2
- Integration of Knowledge and Ideas: CCSS.ELA-LITERACY.RST.6-12.7

Materials and Resources

- *Radiation Protection: Teacher Background Information*.
- *Vocabulary Materials.*
- *Benefits and Unintended Impacts Worksheet* (one per student, pair or group).
- Paper and/or poster board and colored pencils, pens or markers (optional).
- Student computers with Internet access to the following and a printer: (optional)
    - RadTown USA: www3.epa.gov/radtown/

Time

You may choose to have students complete the entire activity within one or two (45-60 minutes) class periods. If time or computer access is limited, the activity can be introduced, completed outside of the class and concluded in another class period.

Vocabulary

- Alpha particles
- Beta particles
- Gamma rays
- Ionizing radiation
- Radiation
- Radioactive atom
- Radioactive material

Directions

1. Start with a vocabulary activity if students are not familiar with radiation and the terms used in this activity, or provide students with the terms and definitions.

2. Explain that we use radioactive elements in many devices, processes and treatments that are beneficial and life-saving. These elements may emit ionizing radiation in the form of alpha or beta particles, x-rays and/or gamma rays.

3. Have students brainstorm sources of ionizing radiation and their useful purpose. You may want to list student responses on the board. Examples include irradiation (used to kill bacteria in food and on medical tools and devices), diagnostic nuclear medicine, nuclear energy, moisture and density nuclear gauges (used to construct stable and safe road and highways), navigation beacons and buoys, security screening devices, radiation testing and protection devices, ionizing smoke detectors and devices used to test for leaks or cracks in pipeline and aircraft parts.

4. Distribute the *Benefits and Impacts Worksheet*.

5. Direct students to:
   - Select a device, a process or a treatment that uses radiation. Students may refer to RadTown USA (www3.epa.gov/radtown) or the links provided (Materials and Resources).
   - Identify the type of radiation used (alpha or beta particles, x-rays and/or gamma rays).
   - Research and list the benefits of the selected device, process or treatment including supporting data.
   - Research and list the impacts that may result from developing or using this radiation source, include supporting data, and consider social, economic and environmental impacts. For example, a potential social impact of nuclear medicine is that people may live longer by surviving illnesses like cancer; economically there are costs associated with the proper storage and disposal of radiation sources; and environmentally, radiation sources that are not disposed of properly may lead to radiation contamination.
   - Determine whether they think benefits outweigh the impacts.
   - *Optional:* Find or create a visual diagram that describes the technology and use of the radiation source.

6. Have students share their findings and thoughts on whether the benefits outweigh the impacts. Some uses of radiation may be more controversial than others. Allow students to comment on or debate the issues.

7. Explain that agencies like the U.S. Environmental Protection Agency (EPA) help monitor and manage potential impacts and protect us and our environment from radiation exposure or contamination.

8. Students should determine that:
   - Radiation is a part of our daily lives.
   - There are many benefits and uses of radiation.
   - Ionizing radiation may present health and environmental risks if not handled or disposed of properly.

Benefits and Unintended Impacts Worksheet

Name: ___________________________________ Date: ____________________

Identify a device, a process or a treatment that uses radiation:

____

What types of radiation (alpha particles, beta particles, x-rays or gamma rays) are used or given off by the device, process or treatment?

____

List the benefits and impacts of the source in the appropriate columns. Consider the social, economic and environmental impacts. List any supporting data.

Benefits	Impacts

If possible, create or provide a visual diagram that shows the technology or way the device, process or treatment is used.

Do the benefits outweigh the impacts? Explain your answer.