25.4

1 FOCUS

Objectives

25.4.1 Identify three devices that are used to detect radiation.

25.4.2 Describe how radioisotopes are used in medicine.

Guide for Reading

Build Vocabulary L2

Graphic Organizers Have students prepare a table to compare and contrast the structures, uses, and other aspects of the different types of radiation detectors listed as vocabulary terms.

Reading Strategy L2

Reciprocal Teaching Encourage students to take a leadership role in reading this section. Teacher and students take turns in reading and in conducting discussions about what was read.

2 INSTRUCT

Connecting to Your World

Have students study the photograph and read the text that opens the section. Am-241 undergoes α decay. Ask, **What is the other product of the decay of an Am-241 nucleus?** *(Np-237)* **Why do you have to exert special care in disposing of these smoke detectors?** *(The detectors still contain radioactive materials.)*

Detecting Radiation

Use Visuals L1

Explain that a cloud chamber can be used to detect ionizing radiation. Ask, **What are some other devices used to detect radiation and how do they function?** *(Radiation can expose a photographic plate, cause the sealed gas in a Geiger counter to be ionized so that it conducts electricity, or produce a flash of light on the phosphor-coated surface of a scintillation counter.)*

25.4 Radiation in Your Life

Guide for Reading

Key Concepts

- What are three devices used to detect radiation?
- How are radioisotopes used in medicine?

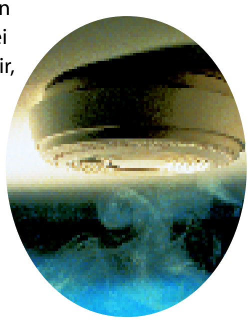
Vocabulary

ionizing radiation
Geiger counter
scintillation counter
film badge
neutron activation analysis

Reading Strategy

Summarizing When you summarize, you review and state, in the correct order, the main points you have read. As you read about using radiation, write a brief summary of the text following each use that is discussed. Your summary should include only the most important information.

Connecting to Your World A common household smoke detector uses the radiation from a radioisotope. The smoke detector contains a small amount of americium, $^{241}_{95}Am$, in the form AmO_2. Radiation from the $^{241}_{95}Am$ nuclei ionizes the nitrogen and oxygen in smoke-free air, allowing a current to flow. When smoke particles get in the way, they are ionized instead. The drop in current is detected by an electronic circuit, causing it to sound an alarm. In this section, you will learn about some of the other practical uses of radiation.



Detecting Radiation

Radiation emitted by radioisotopes is called ionizing radiation. **Ionizing radiation** is radiation with enough energy to knock electrons off some atoms of the bombarded substance to produce ions. Radiation cannot be seen, heard, felt, or smelled. Thus radiation detection instruments must be used to alert people to the presence of radiation and to monitor its level. **Devices such as Geiger counters, scintillation counters, and film badges are commonly used to detect radiation.** These devices operate because of the effects of the radiation when it strikes atoms or molecules. For example, the radiation can produce ions, which can then be detected, or it can expose a photographic plate and produce images such as the one shown in Figure 25.14. When the plate is developed, its darkened areas show where the plate has been exposed to radiation.

Checkpoint ***What is ionizing radiation?***

Figure 25.14 Radiation can expose a photographic plate.

Section Resources

Print

- **Laboratory Manual,** Lab 52
- **Probeware Laboratory Manual,** Section 25.4
- **Guided Reading and Study Workbook,** Section 25.4
- **Core Teaching Resources,** Section 25.4 Review
- **Transparency,** T294

Technology

- **Interactive Textbook with ChemASAP,** Assessment 25.4
- **Go Online,** Section 25.4

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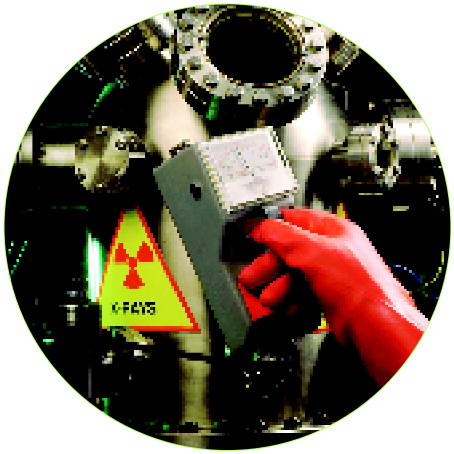
Geiger Counter A **Geiger counter** uses a gas-filled metal tube to detect radiation. The tube has a central wire electrode that is connected to a power supply. When ionizing radiation penetrates a thin window at one end of tube, the gas inside the tube becomes ionized. Because of the ions and free electrons produced, the gas becomes an electrical conductor. Each time a Geiger tube is exposed to radiation, current flows. The bursts of current drive electronic counters or cause audible clicks from a built-in speaker. Geiger counters can detect alpha, beta, and gamma radiation.



Geiger counter

Scintillation counter

Scintillation Counter A **scintillation counter** uses a phosphor-coated surface to detect radiation. Ionizing radiation striking the phosphor surface produces bright flashes of light, or scintillations. The number of flashes and their respective energies are detected electronically. The information is then converted into electronic pulses, which are measured and recorded. Scintillation counters have been designed to detect all types of ionizing radiation.

Film Badge A **film badge** consists of several layers of photographic film covered with black lightproof paper, all encased in a plastic or metal holder. The film badge is an important radiation detector for persons who work near any type of radiation source. The badge is worn the entire time the person is at work. At specific intervals, with the frequency depending on the type of work involved, the film is removed and developed. The strength and type of radiation exposure are determined from the darkening of the film. Records are kept of the results. Film badges do not protect a person from radiation exposure, but they do monitor the degree of exposure to radiation. Protection against radiation is achieved by keeping a safe distance from the source and by using adequate shielding.

Film badge

Discuss L2

Explain that the most commonly used radiation detector, the Geiger counter, is primarily used for the detection of beta radiation, because alpha particles cannot penetrate the tube and most gamma and X rays pass through the gas without causing many ionizations. Scintillation counters, though not generally portable, are designed to detect all types of radiation. They rely on a phosphor surface, which produces a bright flash when struck by ionizing radiation. The flashes and their energies can be detected electronically. The process is analogous to electrons striking the phosphor screen inside a television set. Explain that the third type of radiation detector, the film badge, is a modernday version of Becquerel's photographic plate.

TEACHER Demo

Background Radiation L2

Purpose Students observe background radiation.

Materials Geiger counter

Procedure Using a Geiger counter equipped with a rate meter and a loudspeaker, have students listen to the random clicking noise. Be sure that there are no radioactive sources nearby. Point out that the counter is recording background radiation, which is always present. Ask students about the possible sources of background radiation. *(cosmic, soil, and interior of Earth)* Explain that background radiation varies from location to location. To make an accurate measurement of radiation from a given source, you must take local background radiation into account. Next, place the Geiger counter near some objects containing radioactive elements, such as the luminous dial of a watch or a smoke detector.

Expected Outcome The Geiger counter indicates small amounts of background radiation and larger amounts near a source of radioactivity.

Answers to...

Checkpoint radiation with enough energy to knock electrons off some atoms of the bombarded substance to produce ions

Facts and Figures

Gold-Foil Experiment

Hans Geiger (1882–1945) was a student of Ernest Rutherford. It was Geiger, along with another student named Marsden, who carried out the gold-foil, alpha-scattering experiment at Rutherford's direction. Geiger gained experience with the problem of detecting radiation, which ultimately led to his invention of the Geiger counter. Ask students to review the gold-foil experiment and describe the detection method used to measure the scattering of alpha particles. This method was a precursor of the scintillation counter.

Using Radiation

Quick LAB

Studying Inverse-Square Relationships L2

Objective After completing this activity, students will be able to:
- demonstrate the relationship between radiation intensity and the distance from the radiation source.

Skills Focus observing, measuring, using graphs, calculating

Prep Time 20 minutes
Class Time 30 minutes

Expected Outcome As distance increases, intensity decreases and area increases.

Analyze and Conclude

1. Intensity is inversely related to the square of the distance.
2. When distance is doubled, area increases by a factor of four, and intensity is one-fourth as much. When distance is tripled, area increases by a factor of nine, and intensity is one-ninth as much.

For Enrichment L3

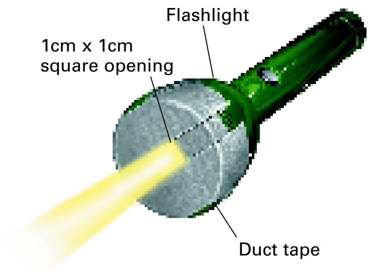
Have students repeat the Quick Lab two times, changing the size of the hole from what it is in the original lab. On one trial, the hole should be slightly larger. On the other trial, the hole should be slightly smaller. Ask, **Does the size of the hole affect the results?** *(No, the results are the same.)*

Go Online NSTA SCINKS

Download a worksheet on **Radio–active Tracers** for students to complete, and find additional teacher support from NSTA Sci Links.

Quick LAB

Studying Inverse-Square Relationships



Purpose
To demonstrate the relationship between radiation intensity and the distance from the radiation source.

Materials
- flashlight
- strips of duct tape
- scissors
- poster board, white (50 cm × 50 cm)
- meter ruler or tape measure
- flat surface, long enough to hold the meter ruler
- loose-leaf paper
- graph paper
- pen or pencil
- light sensor (optional)

Procedure

Probeware version available in the Probeware Lab Manual.

1. Measure and record the distance (*A*) from the bulb filament to the front surface of the flashlight.
2. Cover the end of a flashlight with tape. Leave a 1 cm × 1 cm square hole in the center.
3. Place the flashlight on its side on a flat, horizontal surface. Turn on the flashlight. Darken the room.
4. Mount a large piece of white poster board in front of the flashlight, perpendicular to the horizontal surface.
5. Move the flashlight away from the board in short increments. At each position, record the distance (*B*) from the flashlight to the board and the length (*L*) of one side of the square image on the board.
6. On a sheet of graph paper, plot *L* on the *y*-axis versus $A + B$ on the *x*-axis. On another sheet, plot L^2 on the *y*-axis versus $A + B$ on the *x*-axis.

Analyze and Conclude

1. As the flashlight is moved away from the board, what do you notice about the intensity of the light in the illuminated square? Use your graphs to describe the relationship between intensity and distance.
2. When the distance of the flashlight from the board is doubled and tripled, what happens to the areas and intensities of the illuminated squares?

Using Radiation

Although radiation can be harmful, it can be used safely and is important in many scientific procedures. **Neutron activation analysis** is a procedure used to detect trace amounts of elements in samples. A sample of the material to be studied is bombarded with neutrons from a radioactive source. Some atoms in the sample become radioactive. The half-life and type of radiation emitted by the radioisotopes are detected, and a computer processes this information. Because this information is characteristic for each element, scientists can determine what radioisotopes were produced and what elements were originally in the sample. Neutron activation analysis is used by museums to detect art forgeries, and by crime laboratories to analyze gunpowder residues.

Radioisotopes called tracers are used in agriculture to test the effects of herbicides, pesticides, and fertilizers. The tracer is introduced into the substance being tested to make the substance radioactive. Next, the plants are treated with the radioactively labeled substance. Then, the radioactivity of the plants is measured to find the locations of the substance. Often, the tracer is also monitored in animals that consume the plants, in water, and in soil.

Go Online NSTA SCINKS
For: Links on Radioactive Tracers
Visit: www.scilinks.org
Web Code: cdn-1254

Facts and Figures

Radioisotopes

Many of the radioactive isotopes used in medicine and agriculture are not naturally occurring. They are produced artificially by methods such as neutron bombardment. Radioisotopes are used by physicians to diagnose and treat some forms of cancer. Actively dividing cells are usually more sensitive to radiation than are normal cells.

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Radioisotopes can be used to diagnose medical problems and, in some cases, to treat diseases. Iodine-131, for example, is used to detect thyroid problems. The thyroid gland extracts iodide ions from the bloodstream and uses them to make the hormone thyroxine. To diagnose thyroid disease, the patient is given a drink containing a small amount of the radioisotope iodine-131. After about two hours, the amount of iodide uptake is measured by scanning the patient's throat with a radiation detector. Figure 25.15 shows the results of such a scan. In a similar way, the radioisotope technetium-99m is used to detect brain tumors and liver disorders. Phosphorus-32 is used to detect skin cancer.

Radiation has become a routine part of the treatment of some cancers. Cancer is a disease in which abnormal cells in the body are produced at a rate far beyond the rate for normal cells. The mass of cancerous tissue resulting from this runaway growth is called a tumor. Radiation therapy is often used to treat cancer because the fast-growing cancer cells are more susceptible to damage by high-energy radiation such as gamma rays than are the healthy cells. The cancerous area can be treated with radiation to kill the cancer cells. Some normal cells are also killed, however, and cancer cells at the center of the tumor may be resistant to the radiation. Therefore, the benefits of the treatment and the risks to the patient must be carefully evaluated before radiation treatment begins.

In a technique called teletherapy, a narrow beam of high-intensity gamma radiation is directed at cancerous tissue. Salts of radioisotopes can also be sealed in gold tubes and directly implanted in tumors. These seeds emit beta and gamma rays that kill the surrounding cancer cells. Because the radioisotope is in a sealed container, it is prevented from traveling throughout the body.

Pharmaceuticals containing radioisotopes of gold, iodine, or phosphorus are sometimes given in radiation therapy. For example, a dose of iodine-131 larger than that used simply to detect thyroid diseases can be given to treat the diseased thyroid. The radioactive iodine accumulates in the thyroid and emits beta and gamma rays to provide therapy.

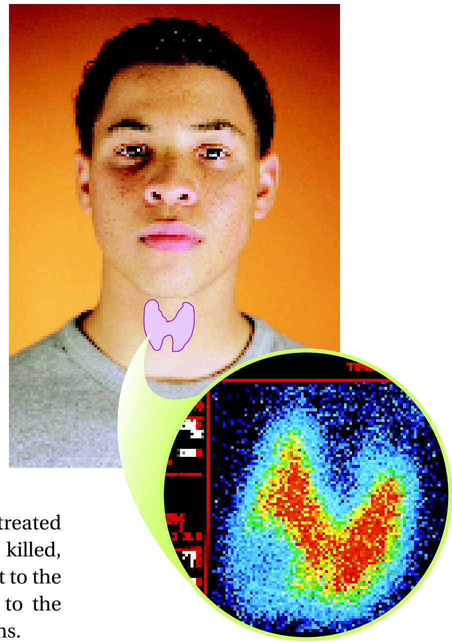

Figure 25.15 This scanned image of a thyroid gland shows where radioactive iodine-131 has been absorbed. Doctors use these images to identify thyroid disorders.

25.4 Section Assessment

21. **Key Concept** Describe three methods of detecting radiation.

22. **Key Concept** Describe two applications of radioisotopes in medicine.

23. If you work regularly near a radiation source, why might your employer want to monitor your exposure to radiation by having you use a film badge rather than a Geiger counter?

24. What is an advantage of using a radioactive seed, consisting of a radioisotope in a small gold tube, to treat a cancerous tumor?

Writing Activity

Write a Report Research and report how technetium-99m is produced, what the letter *m* at the end of its name means, and how the isotope is used in bone imaging and other methods of medical diagnosis.

Interactive Textbook

Assessment 25.4 Test yourself on the concepts in Section 25.4.

with ChemASAP

Section 25.4 Assessment

21. Geiger counter, scintillation counter, and film badge

22. medical diagnosis and treatment of disease

23. A film badge monitors the degree and type of exposure to all types of radiation for an individual.

24. The seeds emit beta particles and gamma rays to kill the surrounding cancer cells. The seed cannot move from its inserted location.

3 ASSESS

Evaluate Understanding L2

Have students compare and contrast detection of radiation by a film badge and detection of radiation by a scintillation counter. Ask, **What are two medical uses of radioactive isotopes?** *(as tracers in disease diagnosis and in the treatment of cancer)*

Reteach L1

Explain that the most common home smoke detector is based on the same principles as a radiation detector. The smoke detector contains a radioisotope that ionizes the air in a small chamber. The ionized air allows a current to flow in the chamber. When smoke particles enter the chamber, the ionization decreases, which decreases the current. The decreased current is detected by a secondary circuit, which triggers an alarm.

Writing Activity

Tc-99m is made from the decay of molybdenum-99, which also has a relatively short half-life. The *m* means "metastable," which indicates that the isotope might become more or less stable. Medical uses might include the following examples. To pinpoint a liver problem, doctors inject a mixture containing Tc-99m, which should be absorbed by the liver. If gamma radiation emitted by the Tc-99m atoms in the mixture is detected in the kidneys, there is likely a problem with the liver. If the mixture reaches the liver but does not reach the gallbladder, the duct connecting the organs is probably blocked. Tc-99m is also used to detect the presence of cancerous cells in bone marrow.

Interactive Textbook

If your class subscribes to the Interactive Textbook, use it to review key concepts in Section 25.4.

with ChemASAP