Leukemia, a rapidly developing cancer of white blood cells, is commonly associated with exposure to high doses of ionizing radiation. Exposure also promotes other forms of cancer, anemia, heart problems, and cataracts (opaque spots on an eye lens).

Considerable controversy continues regarding whether very low doses of ionizing radiation, such as those from typical background sources, can cause cancer. Most of the data on cancer incidence have been based on human exposure to high doses of radiation; these data are extrapolated to much lower doses. Few studies have directly linked low radiation doses with cancer development. Most scientists agree that typical background levels of ionizing radiation are safe for most people. Some authorities argue that any increase above normal background levels increases the probability of developing cancer.

**B.4 Alpha, Beta, and Gamma Radiation**

**Introduction**

An early device used to detect radioactivity still used today is the Geiger-Mueller counter (Figure 6.25). As illustrated in Figure 6.26, ionizing radiation that strikes the detector produces electrical signals. In this investigation, a counter (or similar device) will detect the penetrating abilities of different types of ionizing radiation through cardboard, glass, and lead.

Ionizing radiation enters the counter’s detecting tube (or probe), producing an electrical signal. Most radiation counters register these signals as both audible clicks and meter readings. The intensity of the radiation is indicated by the number of electronic signals or counts per minute (cpm).

You must first take a reading of background radiation to establish a baseline before taking readings from a known radioactive source. You then subtract the background count from each radioactive-source reading to find the actual radiation level emitted by that source.

With proper handling, radioactive materials in this investigation pose no danger to you. Nuclear materials are strictly regulated by state and federal laws. The radioactive sources you will use emit only very small quantities of radiation; using them requires no special license.

**Path of ionizing radiation**

As ionizing radiation passes into a Geiger-Mueller detector tube, ions form in the gas inside. Positive ions are attracted to the tube’s negatively charged outer wall, while negative ions are attracted to the positively charged center. These electrically charged particle movements constitute a pulse of electrical current. Each pulse is detected and counted.

**Safety**

Students should always wear protective goggles, aprons, and gloves when handling radioactive materials throughout this investigation. (Note: The students shown in Figures 6.27 and 6.28 are not wearing gloves or goggles because they are not handling samples, but all students should be encouraged to wear protective equipment throughout the investigation.)

**Time**

50–90 min

**Materials**

*(For 12 student pairs)*

- 12 alpha, beta, gamma radiation source sets
- 12 meter sticks
- 12 lead plates (5 cm × 5 cm × 0.1 cm)
- 24 glass plates (5 cm × 5 cm × 0.3 cm)
- 12 pieces of cardboard (5 cm × 5 cm × 0.1 cm)
- Vernier calipers (optional) for measuring the exact thickness of plates
- 12 sheets of graph paper
- 12 forceps or crucible tongs (for handling isotopes)
- 24 pairs disposable safety gloves

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and check for radiation before disposal.

Check students’ hands with a radiation monitor before students leave the laboratory. If the monitor reading is high, students should carefully rewash their hands.

**Advance Preparation**
Check the background radiation level before students begin the investigation.
**Part 1 Answers**

1. Lead greatly reduces the levels of alpha, beta, and gamma radiation. Cardboard greatly reduces alpha radiation levels. Glass reduces the levels of alpha and beta radiation.

2. Gamma radiation is the most penetrating; alpha radiation is the least penetrating.

3. a. Lead is most effective. It reduced the levels of all three types of radiation.
   b. Cardboard is least effective. It can only reduce alpha (the least penetrating) radiation.

4. Density and thickness

**Part 2 Answers**

5. Intensity decreased by a factor of four.

6. No. Redoubled, it is approximately one-sixteenth the original.

7. The intensity varies inversely with the square of the distance \((I = \frac{k}{d^2})\).

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**Figure 6.29** Relationship between distance from the source (left) and radiation intensity. Intensity is expressed as counts per minute within a given area. Note how the same quantity of radiation spreads over a larger area (B vs. A) as distance from the source increases.

**Part 2: Effect of Distance on Intensity**

11. Read the following procedure and construct a data table suitable for recording all relevant data.

12. Using forceps, place a radioactive source designated by your teacher at a ruler distance (usually about 5 cm) that produces nearly a full-scale reading.

13. Observe the reading over 30 s. Determine the average number of counts per minute (cpm) and record that value. Then correct this reading by subtracting the background value. Record your corrected values.

14. Move the source so its distance from the detector is doubled.

15. Observe the reading over 30 s. Record the average value and the corrected value.

16. Move the source two more times, so the original distance is first tripled, then quadrupled, recording the initial and corrected readings after each move. (For example, if your first reading was at 2 cm, you would also take readings at 4, 6, and 8 cm.)

17. Graph your data, plotting corrected cpm values on the y-axis and distances from the source to the detector (in cm) on the x-axis.

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**Part 3: Shielding Effects**

18. Read the following procedure and construct a data table suitable for recording all relevant data.

19. Using forceps, place a radioactive source designated by your teacher on the ruler to give nearly a full-scale reading.

20. Take a typical reading over 30 s. Determine the number of counts per minute (cpm), correcting for background radiation. Record your actual and corrected values.
21. Place a glass sheet between the source and the detector. Do not change the distance between the detector and the source. Take an average reading over 30 s. Then determine and record the corrected number of counts per minute.

22. Place a second glass sheet between the source and the detector. Take an average reading over 30 s. Determine and record the corrected number of counts per minute.

23. Repeat Steps 21 and 22, using lead sheets rather than glass sheets.

24. Wash your hands thoroughly and check your hands with a radiation monitor before leaving the laboratory.

Questions for Part 1
1. Which shielding materials were effective in reducing the intensity of each type of radiation? Support your answers with data or observations.
2. How do the three types of radiation that you tested compare in terms of their penetrating ability?
3. Of the shielding materials tested, which do you conclude is the
   a. most effective in blocking radiation? Cite supporting evidence.
   b. least effective in blocking radiation? Cite supporting evidence.
4. Based on your observations, what properties of a material appear to affect its radiation-shielding ability?

Questions for Part 2
Analyze the graph that you prepared in Step 17:
5. By what factor did the intensity of radiation (measured in counts per minute) change when the initial distance was doubled?
6. Did this same factor apply when the distance was doubled again?
7. State the mathematical relationship between distance and intensity, using the factor identified in Question 5 and information in Figure 6.29.

Questions for Part 3
8. How effective was doubling the shield thickness in blocking the radiation intensity by
   a. glass?  
   b. lead?
9. A patient receiving an X-ray is covered by a protective shield (Figure 6.30).
   a. What material would be a good choice for this apron?
   b. Why?
10. a. Which type of ionizing radiation from a source outside the body is likely to be most dangerous to living organisms?
    b. Why? Give evidence to support your answer.

A factor is a number by which a value is multiplied to give a new value.

Figure 6.30  What type of body shielding is used as this dental X-ray is obtained?