Is It Radioactive?

With the Measuring Laboratory, students gain a better understanding of radioactivity and radiation. Students are able to visualize what is meant by radiation and background radiation.

Grade Level

5-12

Disciplinary Core Ideas (DCI, NGSS)

5-PS1-1, 3-5ETS1-2, MS-PS1-1, MS-PS1-4, MS-PS3-2, MS-ETS1-1, MS-ETS1-3, HS-PS1-8, HS-PS3-2, HS-PS4-1, HS-PS4-4, HS-ESS1-2, HS-ESS2-3, HS-ESS3-6

Time for Teacher Preparation

30-60 minutes – Clear the room of any unnatural radioactive sources.

Create identifiable "locations" within the room – to correspond to the number of lab groups you will have. Code each of these locations in some way for easy reference.

Activity Time:

30-60 minutes (1 Class Period)

Materials

Use as many Geiger counters as you have available. *We will assume for this experiment that you are using Geiger counters which are **not** calibrated* (they may not provide the same readings under the same circumstances). So, you may want to label each Geiger counter with a code number or letter; then, each group can record the code of the Geiger counter being used and use it for future activities.

- Geiger counters

  NOTE: digital read-out Geiger Counters give easier readouts for classroom use and more accurate measurements

- An assortment of objects with varying radioactivity, including some in each of three categories:
  - Not detectably radioactive
  - Just barely radioactive ("Vaseline glass", thoriated welding rods, "depression green" glass, some fossils)
  - Unambiguously radioactive (orange/red Fiestaware, certain lantern mantles, some uranium ore and minerals)

Number each sample and record which category they fall into in a spreadsheet.

The students love testing the "hotter" items, but having the three categories of objects assures that everyone tests at least two each of clearly radioactive, marginally radioactive (would really need more counting time than available during lab to be sure), and essentially non-radioactive. The point is to have the students struggle with and face the uncertainty concerning whether or not items are radioactive.

Safety

- Students should use care when dealing with radioactive materials
- Students should wash their hands after this experiment

Science and Engineering Practices (NGSS)

- Ask questions and define problems
- Plan and Carry out investigation
- Analyze and interpret Data
- Use mathematics and computational thinking
- Construct Explanations
- Argue from Evidence
- Obtain, evaluate and communicate information

Cross Cutting Concepts (NGSS)

- Patterns
- Cause and Effect
- Scale, Proportion, and Quantity
- Energy and Matter: Flows, Cycles, and Conservation
- Structure and Function
- Stability and Change of Systems

Objectives

- Familiarize students with the concept of background radiation.
- Determine the amount of background radiation present at a specific location.
- To define the terms radiation
- To become familiar with the different types of radiation
- To become familiar with operating a Geiger-Mueller counter

The **key ideas** for students to understand upon completing this lab are:

- There is background radiation wherever they are.
- Levels of background radiation vary somewhat from one location to another and from one moment to the next.
- Background radiation must be taken into account when measuring the radiation from an object.
- Uncalibrated Geiger counters may give *slightly* different counts in identical situations; however, they are useful for:
  - determining that radiation is present.
  - comparing radiation levels for locations or objects.

Measuring and Units

Background

Introductory Information

We live in a radioactive world, as did our earliest ancestors. The radiation in our world comes from many sources – cosmic radiation (outer space), terrestrial sources (the earth), radon in the air, etc. In addition, we live and work in buildings made from materials (stone, adobe, brick, concrete) which contain elements that are naturally radioactive. The amount of naturally occurring background radiation we experience varies, depending upon location.

Background Radiation

Geiger counters will register the presence of some radiation even if you have not placed them near a known radiation source. This is a measure of the background radiation that is always present at a given location.

In order to make meaningful measurements of the radioactive nature of specific objects or materials, we will need to know how much radiation is naturally present in the environment. The difference between background radiation and the radiation measured near a specific object will give us the level of radiation due to the object.

Although background radiation is quite steady on average, you would never conclude that by listening to or watching a Geiger counter. The amount of radiation will appear to vary, depending upon the specific time at which you take a measurement.

The covert theme of this lab is dealing with ambiguity. Because there is background radiation always giving a background signal, and a non-constant signal at that, measuring a sample for a minute or two (with ordinary Geiger counters) just cannot determine with certainty if the sample is weakly radioactive or not.

Because of the randomness of radiation, if the true long-term average background count rate were 16 counts per minute, then by chance alone, a single one-minute measurement of background has about a 17% chance of being more than 20[1]. Similarly there is about a 1% chance of getting a one-minute count rate of 25 or higher[2].

Repeating the measurement and again getting 25 or higher increases the chance the object is really radioactive, as opposed to background just happening to be very high twice.

[1] $16 \pm \sqrt{16}$ = range of 12-20

[2] $16 \pm 2\sqrt{16}$ = range of 8-24

An Analogy

Suppose that someone sets up a water sprinkler and maintains a steady flow of water to the sprinkler. If one quantifies the rate at which the sprinkler puts water on the ground by how many drops of water fall on a sheet of notebook paper in a short time, one will not get the same result every time or in every location under the sprinkler. This is because the water falls onto the ground in discrete units (drops). Similarly, radiation (alpha and beta particles, gamma photons, etc.) strikes a given location in discrete units or amounts.

If the *average* number of water drops that fall on a piece of paper in one minute is 25 drops, you may **not** get exactly 25 drops in a one-minute measurement. Results ranging between 20 and 30 drops are likely, and counts as low as 15 and as high as 35 might occur, though that is less likely.

This same variation in measurements may occur with radiation.

Fundamental Particles Detection

Light has a wavelength of 10^{-7} m. Light microscopes enable us to view parts of a cell as small as 10^{-6} m. Electron microscopes enable us to see an image with a wavelength as small as 10^{-9} m. With the help of scanning electron microscopes, we can see fuzzy images of atoms. To detect a smaller image, such as a fundamental particle, we need to produce particles with greater energy, and thus, a shorter wavelength. The smallest fundamental particle is less than 10^{-18} m in diameter!

Although scientists have not yet been able to actually see fundamental particles, they can infer the presence of these particles by observing events and applying conservation laws of energy, momentum, electric charges, etc.

One way to do this is with a particle accelerator. Essentially, a particle accelerator works by shooting particles at high speed toward a target. When these bullet particles hit a target, a detector records the information about the resulting event.

Radiation Measurements

	Radioactivity	Absorbed	Dose Equivalent	Exposure
Common Units	curie (Ci)	rad	rem	roentgen (R)
SI Units	becquerel (Bq)	gray (Gy)	sievert (Sv)	coulomb/ kilogram (C/kg)

Teacher Lesson Plan:

Traditional

Before beginning, make sure students have some familiarity with the Geiger counter and how it will be used. Predetermine whether measurements are to be made with the "window" on the Geiger tube open or closed. Give students an overview of how and where to set the sensitivity level, etc.

1. Have the students measure background counts for one minute.
   a. This is done by counting the number of "clicks" from the Geiger counter. It is **not** practical to make this measurement by reading the counts/min scale on the Geiger counter.
2. Have each lab group enter the results of all the groups into the proper space on the table you provide.
   a. Ask students to examine the results. Do the results vary? If so, what is the lowest value and the highest value? What is the "range" of results? What are some possible reasons why the results might be different?
      i. Results **will** vary. Possible reasons include: inaccurate counting, inaccurate timing, slight variations in background radiation from location to location within the room, and/or differences between Geiger counters. There may be other suggestions from students -- which you must evaluate.
   b. Ask students how they could try to eliminate some sources of error. They may suggest repeating the measurements to rule out inaccurate timing and counting. They may suggest removing any jewelry, etc.
3. Have students run a second and third trial and *enter **only** the data **for their own group** into the table.*
   a. Ask the class: Do the results **for your lab group** vary from one trial to another? If so, why? What is the range for your own measurements?
      i. At this stage, students may have discovered that the results for their own group vary slightly in each trial. Discuss this variation. Consider the possibility that errors were made during every measurement and discuss whether this is likely.
      ii. Also, discuss the idea that the amount of background radiation present may actually be slightly different from one moment to the next -- even though it has an "average" value. Refer to the water sprinkler analogy mentioned in the introduction.
         1. Have each group enter the "range" for their own measurements in the bottom row of the table.
   b. Regarding the counts they took, ask "Were the clicks always evenly spaced? OR, did the clicks sometimes cluster together with pauses between them?"
      i. Clicks are usually NOT evenly spaced. There are usually some "clusters" of clicks and some pauses.
      ii. Discuss the possibility that this variation or "clustering" of clicks may have some impact on how long a time period we use for measuring radioactivity levels. For example, using a really short time period might make measurements more prone to error than a longer time, especially if you did the "short period" measurement during a "pause" or during a "cluster" of clicks.
         1. To illustrate, draw a clock face and let it represent a 60 second measurement. Then, make marks around the perimeter to represent when clicks are heard. This will give you clusters of marks and some empty spaces. If someone takes a measurement in a specific period of 5 seconds, it can easily affect the count they get.
4. Then, have the students enter the data for all of the groups into the table.
   a. Ask the students: Are there variations from group to group? If so, what are some possible reasons?
      i. Discuss possibilities: variations in Geiger counters, variations due to "location" in the room, etc.
   b. How could we determine if these differences are due to our Geiger counters being different or to differences within the room?
      i. You should realize when you begin this activity that these "uncalibrated" instruments are likely to give slightly different results under identical conditions and at the same time. However, it IS possible for there to be slight variations within the room. Proximity to a particular building material or exposure to some other radiation source, for example, may produce higher "background" readings in a specific location.
   c. There are several experimental approaches you and your students could use in resolving this issue.
      i. You could have each group make measurements at the same location and compare them. OR, each group could move to each of the identified locations and make readings for comparison purposes. Students may come up with other suggested solutions. Depending upon the time you want to allow and the sophistication level of your students, you can structure another set of measurements to provide an answer to the question above.

NOTE: If you are doing this activity in a one-period time slot, it is difficult to include measurement of background. Thus, most teachers use an average value for background, measured on a previous day. (Background varies little over time.) (Refer to Geiger Counter Resource for further instruction on attaching speakers or head phones to CPV700: www3.ans.org/pi/teachers/reactions/2001-04-02.html)

NOTE: If your Geiger counters have analog as opposed to digital (total counts) meters, fear not, you have many options. With earphones or an amplifier/speaker connected to the counter, your students can still count the number of clicks in a minute.

NOTE: A reasonably accurate count can also be obtained for low count rates by counting every time the needle jumps up a little (and counting as two if the needle jumps up significantly more than average). All of this will keep your class very busy and quiet.

NGSS Guided Inquiry

Have students design an experiment to discover about how much radiation can be found in different objects using Geiger-Mueller counters.

Student Procedure

1. Measure background counts for 1 minute. This is done by counting the number of "clicks" from the Geiger counter. Note that it is NOT practical to make this measurement by reading the counts/min scale on the Geiger counter.
2. Enter your results in the results table and share with the rest of the class.
3. Repeat the background measurement twice more and enter the results into the results table
4. Discuss with your group the results for your group and for the entire class

Data Collection

Attached Student Data Collection Sheets

Post Discussion/Effective Teaching Strategies

Questions provided on the Student Data Collection Sheets

Questions

1. What is background radiation? What are its sources?
2. Can you eliminate background radiation?
3. Why would we take a measurement of background radiation levels before starting a radiation experiment?

Assessment Ideas

- Have the students use their Geiger counters to identify which of three unknown sources are radioactive using the same methodology they used to find background.

Differentiated Learning/Enrichment

- Students could measure levels of background radiation in other areas of the school (indoors, outdoors, on a higher floor, in the basement, etc.). Each group could prepare a table to summarize its findings for use in comparing them to the results of other groups. They could compare to see if there are differences between clear, sunny days and cloudy days, etc.
- Use known radioactive sources so that students can experiment with different types of shielding (metal, paper, etc.)

Enrichment Questions

1. In measuring background radiation, would it be better to take a 5 second reading or a 1 minute reading? Why would this time period be a better choice?
2. When making measurements of radiation, would it be better to make one measurement or three measurements? Why?

Further Resources

Center for Nuclear Science and Technology Information
http://www.nuclearconnect.org/in-the-classroom/for-teachers/classroom-activities

Geiger Counter Resource for instructions on attaching speakers or head phones to CD-V 700:
http://www.nuclearconnect.org/in-the-classroom/connecting-a-speaker-to-your-geiger-counter

For more information on how to store and dispose of radioactive waste:

http://blink.ucsd.edu/safety/research-lab/hazardous-waste/radioactive.html

Citations for Reference

http://orise.orau.gov/reacts/guide/measure.htm

Measuring and Units

Is It Radioactive?

Student Data Collection ANSWER Sheet

Objectives

- Become familiar with the concept of background radiation
- Determine the amount of background radiation present at a specific location
- Define the term radiation
- Become familiar with the different types of radiation
- Become familiar with operating a Geiger-Mueller Counter

The **key ideas** for students to understand upon completing this lab are:

- There is background radiation wherever they are
- The level of background radiation varies somewhat from one location to another
- There are some small variations in the level of background radiation from one moment to the next
- When measuring the radiation from an object, we must take into account the contribution made by background radiation
- Although un-calibrated Geiger counters may give *slightly* different counts in identical situations; however, they are useful for
- We can compare radiation levels for locations or objects

** *Refer to Geiger Counter Resource for instructions on attaching speakers or head phones to CD-V 700: http://www.nuclearconnect.org/in-the-classroom/connecting-a-speaker-to-your-geiger-counter*

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2. Enter your results in the results table and share with the rest of the class.
3. Repeat the background measurement twice more and enter the results into the results table
4. Discuss with your group the results for your group and for the entire class

Results:

Measurement time (sec)	**Count Rate** (expressed in "counts per minute")					
	Lab Group or Student Name and "location" code					**Range** (Lowest Count to highest count ratio)
60 (1st trial)						
60 (2nd trial)						
60 (3rd trial)						
Range for group (Lowest count, Highest Count in a trial)						**Class Average** ↓
Mean (Average)						

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Is It Radioactive?

Student Data Collection ANSWER Sheet

Questions

1. What is background radiation? What are its sources?

Natural background radiation comes from the following three sources:

Cosmic Radiation
Terrestrial Radiation
Internal Radiation

Cosmic Radiation

The sun and stars send a constant stream of cosmic radiation to Earth, much like a steady drizzle of rain. Differences in elevation, atmospheric conditions, and the Earth's magnetic field can change the amount (or dose) of cosmic radiation that we receive.

Terrestrial Radiation

The Earth itself is a source of terrestrial radiation. Radioactive materials (including uranium, thorium, and radium) exist naturally in soil and rock. Essentially all air contains radon, which is responsible for most of the dose that Americans receive each year from natural background sources. In addition, water contains small amounts of dissolved uranium and thorium, and all organic matter (both plant and animal) contains radioactive carbon and potassium. Some of these materials are ingested with food and water, while others (such as radon) are inhaled. The dose from terrestrial sources varies in different parts of the world, but locations with higher soil concentrations of uranium and thorium generally have higher doses.

Internal Radiation

All people have internal radiation, mainly from radioactive potassium-40 and carbon-14 inside their bodies from birth and, therefore, are sources of exposure to others. The variation in dose from one person to another is not as great as that associated with cosmic and terrestrial sources.

(Information taken from the NRC Website: http://www.nrc.gov/about-nrc/radiation/around-us/sources/nat-bg-sources.html)

2. Can you eliminate background radiation?

No.

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Student Data Collection ANSWER Sheet

Questions

3. Why would we take a measurement of background radiation levels before starting a radiation experiment?

   The amount of background radiation is measured before starting a radiation experiment in order to get a more accurate reading that is not impacted by any radiation sources that could be present due to the experiment.

Enrichment Questions

1. In measuring background radiation, would it be better to take a 5 second reading or a 1 minute reading? Why would this time period be a better choice?

   It is better to take a 1 minute reading. It is often suggested to take 10 minute readings, but that is impractical in a 60 minute class period. Background radiation levels vary widely, so the longer you measure background, the more statistically accurate your background reading will be.

2. When making measurements of radiation, would it be better to make one measurement or three measurements? Why?

   Three measurements. Background radiation levels vary widely, so the longer you measure background, the more statistically accurate your background reading will be.

Measuring and Units

Is It Radioactive?

Student Data Collection Sheet

Name: ______________________________

Date: ______________________________

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Range for group (Lowest count, Highest Count in a trial)						**Class Average** ↓
Mean (Average)						

Measuring and Units –
Is It Radioactive?
Student Data Collection Sheet

Name: ______________________________

Date: ______________________________

Questions

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2. Can you eliminate background radiation?

Measuring and Units –
Is It Radioactive?
Student Data Collection Sheet

Name: ______________________________

Date: ______________________________

Questions

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Enrichment Questions

1. In measuring background radiation, would it be better to take a 5 second reading or a 1 minute reading? Why would this time period be a better choice?

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