## Lesson Questions

* What is natural background radiation? Where does it come from?
* How much natural background radiation do we experience?

## Lesson Big Ideas

* Radiation comes from things here on Earth (terrestrial) and things from outer space (cosmic).
* Radiation can come from both natural and man-made sources.
* Background radiation amounts depends on several factors, however they are measurable and typically constant in a specific location.

## Lesson Introduction

Regardless of the specific branch, the goal of science is to explore and explain the world (universe) around us. There is no better place to start, than exploring the building blocks of the universe - the things that make up you and me, the natural and built environment, the Earth and the space beyond it. So what are the building blocks of matter? For most, the answer is atoms - specifically the electrons, protons, and neutrons that make up the atom. When you tell a student that these are the most fundamental particles out there, they ask two important questions, “why” and “how do you know”. These types of questions as the same questions asked by scientists around the world. These types of questions caused scientists to dive deeper, keep exploring, and find answers. And what they found is that electrons are fundamental, but protons and neutrons are made up of other particles - quarks. Additionally, they found that there are other particles out there, some just subatomic, and others fundamental particles - particles that the rest of the universe is built on. This is where physics teachers may begin to talk about quantum or particle physics - the study of the extremely small (and fundamental). Other fields may continue to use electrons, protons, and neutrons as their building blocks, but they do need to have an appreciation for the other small stuff out there and what those fundamental particles mean for their field (e.g. biology or chemistry).

But how do you see these subatomic particles? How do you observe them and study them? It turns out that a relatively simple device allows us to observe these particles. Not directly, but from the tracks these particles make through clouds. Cloud chambers date back to the 1910s-1920s and allowed for the discovery of several incredibly small particles. Cloud chambers have evolved, to include diffusion chambers, bubble chambers, spark chambers and more. Iterations of cloud chambers are still used today, while some of the original cloud chamber designs are used for demonstrations worldwide. This lesson brings the diffusion cloud chamber to the classroom, in an inexpensive and hands-on way to step back in history and observe particles for the first time. Students will be able to observe alpha particles (the nucleus of a helium atom), protons, electrons, muons, and more. But where do these particles come from? Students will learn about three sources of natural radiation (cosmic, terrestrial, and internal) by reading an introductory article. Students will then get to witness this natural radiation by using a cloud chamber to observe particles whizzing through the system. Students will track the direction of these particles and count them in order to create rough estimates of the direction and amount of natural radiation. Observations will show that natural radiation comes from everywhere, as the particle tracks will come from all directions, including straight up/down - showing up as spots within the chamber. While numerical data will be rough, students will get an appreciation that natural radiation is not zero; and thus the word “radiation” should not be inherently scary.

This is a robust lesson in that it can be tailored to different branches of science. There are suggested activities to extend the lesson into the specific fields of biology, chemistry, earth science, or space science. For biology students, calculating their personal radiation dose brings awareness to radiation sources in their daily lives. Studying some of the known health effects of different doses furthers this awareness and builds to an interesting discussion about the difference between intensity of dose and duration of dose. For chemistry students, inserting a radioactive source in the cloud chamber allows them to witness radioactive decay. Students can learn by observing the different types of radiation, alpha, beta, and possibly even gamma. They will be able to compare different sources - both scientific sealed sources and common everyday consumer products. Earth science students will dive deeper into terrestrial radiation. They will first examine the effect of human activity on radiation by viewing a video on the most radioactive places on Earth. They will then explore radon, one of the largest contributors to natural airborne radiation, and create a project educating the general public on the importance of radon testing in their homes. Finally, space science students will explore the mysteries of cosmic radiation. By reading and discussing several technical articles, students will learn about supernovae, and the role they play in the production of cosmic rays.

This lesson can be repeated many times, as students will gain confidence with the cloud chambers and witness more and more particles and events with additional practice. Some events, such as a cosmic ray shower or muon decay, are rare enough that one day with the cloud chambers might not be enough. The cloud chambers can be used for additional lessons and data collection; they can be shared with science teachers across the department. The best part of the cloud chamber is that it can be easily built by students, relies on easy-to-obtain materials, works quickly and consistently for the length of the lesson, and costs under five dollars.

## Intended Learning Outcomes

*Students will be able to …*

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1. Identify the common sources of natural background radiation.
2. Use a cloud chamber to detect and observe particles.
3. Distinguish and describe particle tracks in order to identify different types of radiation.
4. Analyze data and interpret the results (i.e. radiation rates).
5. *Calculate personal radiation exposure.*
6. *Describe the effects of radiation on the human body.*
7. *Compare alpha and beta radiation.*
8. *Communicate information about radon to the general public.*
9. *Identify sources of cosmic radiation and describe difficulties in detecting these sources.*

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## Teaching Time: 2 Class Period (assuming 55 minute periods)

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## Materials, Resources, and Advanced Preparation Needed

* There are several options within the “Extend” instructional phase that allows the teacher to tailor the lesson to their specific course (i.e. biology, chemistry, earth science, or space science) and goals.
* This lesson’s main activity involves using a cloud chamber. There is a [supplementary resource](https://docs.google.com/document/d/14DMR0eFtU-ABk0p-wPXsEzEQ0hJ8VBWtnu5YkQb7BF4/edit) (as well as countless online websites, tutorials, and videos) that describes building and using this device. There are several materials needed and a couple steps that must be done prior to the start of the lesson.
* There is a [student guide](https://docs.google.com/document/d/1O5RpmlLhJ35BHnCOQZuFDuSPGahn-6IjsWeduviELIw/edit) that accompanies this lesson. There are also several articles and handouts that should be printed or posted in advance.

## NGSS Connections

### Performance Expectations may include:

*These performance expectations have been directly taken from the Next Generation Science Standards website at* [*https://www.nextgenscience.org/*](https://www.nextgenscience.org/)*.*

* [**HS-ESS1-1**](http://www.nextgenscience.org/pe/hs-ess1-1-earths-place-universe)**:** Develop a model based on evidence to illustrate the life span of the sun and the role of nuclear fusion in the sun’s core to release energy that eventually reaches Earth in the form of radiation.
	+ [Clarification Statement: Emphasis is on the energy transfer mechanisms that allow energy from nuclear fusion in the sun’s core to reach Earth. Examples of evidence for the model include observations of the masses and lifetimes of other stars, as well as the ways that the sun’s radiation varies due to sudden solar flares (“space weather”), the 11-year sunspot cycle, and non-cyclic variations over centuries.]
	+ [Assessment Boundary: Assessment does not include details of the atomic and sub-atomic processes involved with the sun’s nuclear fusion.]
* [**HS-ESS1-3**](http://www.nextgenscience.org/pe/hs-ess1-3-earths-place-universe)**:** Communicate scientific ideas about the way stars, over their life cycle, produce elements.
	+ [Clarification Statement: Emphasis is on the way nucleosynthesis, and therefore the different elements created, varies as a function of the mass of a star and the stage of its lifetime.]
	+ [Assessment Boundary: Details of the many different nucleosynthesis pathways for stars of differing masses are not assessed.]
* [**HS-LS3-2**](http://www.nextgenscience.org/pe/hs-ls3-2-heredity-inheritance-and-variation-traits)**:** Make and defend a claim based on evidence that inheritable genetic variations may result from (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors.
	+ [Clarification Statement: Emphasis is on using data to support arguments for the way variation occurs.]
	+ [Assessment Boundary: Assessment does not include the phases of meiosis or the biochemical mechanism of specific steps in the process.]
* [**HS-PS1-8**](http://www.nextgenscience.org/pe/hs-ps1-8-matter-and-its-interactions)**:** Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay.
	+ [Clarification Statement: Emphasis is on simple qualitative models, such as pictures or diagrams, and on the scale of energy released in nuclear processes relative to other kinds of transformations.]
	+ [Assessment Boundary: Assessment does not include quantitative calculation of energy released. Assessment is limited to alpha, beta, and gamma radioactive decays.]
* [**HS-PS4-4**](http://www.nextgenscience.org/pe/hs-ps4-4-waves-and-their-applications-technologies-information-transfer)**:** Evaluate the validity and reliability of claims in published materials of the effects that different frequencies of electromagnetic radiation have when absorbed by matter.
	+ [Clarification Statement: Emphasis is on the idea that photons associated with different frequencies of light have different energies, and the damage to living tissue from electromagnetic radiation depends on the energy of the radiation. Examples of published materials could include trade books, magazines, web resources, videos, and other passages that may reflect bias.]
	+ [Assessment Boundary: Assessment is limited to qualitative descriptions.]

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### Lesson Subcomponents may include

*The subcomponents listed below have been directly taken from the NGSS Appendices webpage at* [*https://www.nextgenscience.org/resources/ngss-appendices*](https://www.nextgenscience.org/resources/ngss-appendices)*.*

#### SEP: Science & Engineering Practices

* **Analyzing and Interpreting Data**
	+ Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible.
	+ Consider limitations of data analysis (e.g., measurement error, sample selection) when analyzing and interpreting data.
* **Constructing Explanations and Designing Solutions**
	+ Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students’ own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.
	+ Apply scientific reasoning, theory, and/or models to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion.
* **Engaging in Argument from Evidence**
	+ Construct, use, and/or present an oral and written argument or counter-arguments based on data and evidence.
* **Obtaining, Evaluating, and Communicating Information**
	+ Critically read scientific literature adapted for classroom use to determine the central ideas or conclusions and/or to obtain scientific and/or technical information to summarize complex evidence, concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.

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#### DCI: Disciplinary Core Ideas

* **ESS1.A: The universe and its stars**
	+ Light spectra from stars are used to determine their characteristics, processes, and lifecycles. Solar activity creates the elements through nuclear fusion. The development of technologies has provided the astronomical data that provide the empirical evidence for the Big Bang theory.
* **LS3.B: Variation of traits**
	+ The variation and distribution of traits in a population depend on genetic and environmental factors. Genetic variation can result from mutations caused by environmental factors or errors in DNA replication, or from chromosomes swapping sections during meiosis.
* **PS1.A: Structure of matter & PS1.C: Nuclear processes**
	+ The sub-atomic structural model and interactions between electric charges at the atomic scale can be used to explain the structure and interactions of matter, including chemical reactions and nuclear processes. Repeating patterns of the periodic table reflect patterns of outer electrons. A stable molecule has less energy than the same set of atoms separated; one must provide at least this energy to take the molecule apart
* **PS4.B: Electromagnetic radiation**
	+ Both an electromagnetic wave model and a photon model explain features of electromagnetic radiation broadly and describe common applications of electromagnetic radiation.

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#### CCC: Crosscutting Concepts

* **Patterns**
	+ Students observe patterns in systems at different scales and cite patterns as empirical evidence for causality in supporting their explanations of phenomena. They recognize classifications or explanations used at one scale may not be useful or need revision using a different scale; thus requiring improved investigations and experiments. They use mathematical representations to identify certain patterns and analyze patterns of performance in order to reengineer and improve a designed system.
* **Scale, Proportion, and Quantity**
	+ Students understand the significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs. They recognize patterns observable at one scale may not be observable or exist at other scales, and some systems can only be studied indirectly as they are too small, too large, too fast, or too slow to observe directly. Students use orders of magnitude to understand how a model at one scale relates to a model at another scale. They use algebraic thinking to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth).

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## Instructional Phases

### Engage: *(10 minutes)*

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| **Phase Summary:**Students read a short article from the United States Nuclear Regulatory Commission on natural background radiation and discuss with their classmates. Students then brainstorm initial answers to the lesson questions. |

**Student Steps:**

1. Students silently read “[Natural Background Sources](https://www.nrc.gov/about-nrc/radiation/around-us/sources/nat-bg-sources.html)” (United States Nuclear Regulatory Commission, 2017b). As they read, students should be encouraged to annotate the article by underlining ideas and jotting questions or notes down.
2. Students come together in small groups to share their thoughts and impressions about background radiation. The teacher should use this (brief) time to gauge students’ prior knowledge and possible misconceptions to address during the lesson.
3. Students are redirected to the lesson questions, which are displayed on the board. Students are given a chance to record their initial ideas and answers to the questions at the top of their [student guide](https://docs.google.com/document/d/1O5RpmlLhJ35BHnCOQZuFDuSPGahn-6IjsWeduviELIw/edit?usp=sharing). Students may use what they’ve learned from the article, and collaborate with classmates to create their initial explanations.
	* What is background radiation? Where does it come from?
	* How much background radiation do we experience?

### Explore: *(45 minutes)*

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| **Phase Summary:**Students build a diffusion cloud chamber to observe natural background radiation. Students use the cloud chambers to collect data on the direction and frequency of particles (radiation). |

**Student Steps:**

1. Students, together with their teacher, review the background information and safety concerns section of the “[Building a Cloud Chamber](https://docs.google.com/document/d/14DMR0eFtU-ABk0p-wPXsEzEQ0hJ8VBWtnu5YkQb7BF4/edit?usp=sharing)” resource.
2. Students work in groups of 3 - 4 to build a diffusion cloud chamber following the provided procedure.
	* **NOTE:** there are several steps that must be completed 24 hours before final construction and use of the cloud chamber. This advanced preparation can be done by students the day before or by the teacher.
	* **NOTE:** Step four (involving isopropyl alcohol) and step seven (involving dry ice) should be done under careful teacher supervision.
3. Students continue working with their group, with the classroom lights off and light sources minimized, to observe particle tracks in the cloud chamber. Students spend several minutes just observing and using the provided results section to practice identifying particles. The teacher should use this time to check student groups to ensure they have a working cloud chamber and are using the provided light source to see particle tracks. Sample videos showing several particles that students may be able to observe can be found [here](https://drive.google.com/open?id=1-xdhuXLOflyWhOEtHMUhM7dG6kOC1h-S) and [here](https://drive.google.com/open?id=1BLNLmu8rdY-xROsYXk-qztvj8OcrbUME).
	* **NOTE:** Students should easily be able to see alpha and muon particles. However, viewing the beta particles is harder to do and takes practice. One method of success to see the wispy thin, faint, and extremely fast beta particles is to use a non-direct gaze. Students are familiar with this gaze; tell them to look at the cloud chamber how they look at a lecturing teacher - seeing but unseeing. By not focusing on one spot, the eye can better detect beta particles throughout the mist of the chamber.
4. Students collect data, using the student guide to organize their work. Specifically, students conduct timed observations of the cloud chamber to sketch the observed particle tracks and count the number of particles observed.
	* **EXTENSION:** Students may also differentiate between particles using the provided results table as a guide. Students can then get rates for the different particles, instead of just one rate for all particles.
	* **EXTENSION:** If time allows, return to the cloud chambers a day or two later and have students repeat the data collection. Over time and with practice, students should be able to see more particles, which will increase their overall rates.

### Explain: *(30 minutes)*

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| **Phase Summary:**Students share their data with their classmates and create a class data set. Students make conclusions based on the combined data about natural background radiation. |

**Student Steps:**

1. Students work in their groups to convert their total number of particles per trial into the number of particles per minute. Students record these values on a piece of scrap paper and hand it to their teacher.
2. Students discuss in their small groups about what they predict the whole-class data set will look like (i.e. how their numbers might compare to their classmates). Students test their prediction by walking around the room to talk to classmates that were not in their group. Pairs of classmates share their findings - compare rates and examine observed tracks recorded on the [student guide](https://docs.google.com/document/d/1O5RpmlLhJ35BHnCOQZuFDuSPGahn-6IjsWeduviELIw/edit?usp=sharing). While students are sharing with their peers, the teacher is entering the data set into the prepared [Google Sheets file](https://docs.google.com/spreadsheets/d/1XTTGaR62HzG9NrX3x76vT7yGwYN55HyvZzp4bF_xH8Y/edit?usp=sharing),
	* **NOTE:** The Google Sheets file contains a second tab with sample data. This data was collected at an elevation of roughly 640 feet above sea level using a 240 cm2 circular cloud chamber constructed similarly to those used in the lesson.
	* **NOTE:** Depending on location and conditions, the natural background radiation rate should be somewhere between 25 cpm (counts per minute) and 75 cpm. [This website](http://radiationnetwork.com/) could be used as a *rough* indicator of expected results (Mineralab, LLC., 2018). The cloud chambers and associated procedure for observing/counting particles described in this lesson is not precise enough to get publishable results, but can provide a rough estimation of background rates for classroom discussion and use.
	* **Alternative:** If there is a natural day break between the explore and explain phases, the teacher may have student groups turn in their count rates as an exit ticket and predict what the whole-class data will look like as part of the exit ticket or as homework. The teacher could then prepare the histogram prior to the start of the next day of class. Students could share predictions briefly as a warm up before displaying the histogram.
3. Students return to their seats and view the displayed histogram of class data. Students compare the whole-class data with their own. Before discussing as a class, students are given a chance to individually reflect on the following questions:
	* How does your group’s data compare to the whole-class data?
	* What trends or patterns do you notice in the whole-class data?
	* From the whole-class data, what would you conclude is the natural background radiation rate?
	* **NOTE:** These questions are listed on the [student guide](https://docs.google.com/document/d/1O5RpmlLhJ35BHnCOQZuFDuSPGahn-6IjsWeduviELIw/edit?usp=sharing) so that students can write down their thoughts and be prepared for a whole-class discussion.
4. Students have a whole-class discussion about the cloud chamber activity, using the provided questions as guidance.

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| **Question** | **Expected Student Response** | **Teacher’s Note** |
| How does your group’s data compare to the whole-class data? | *Answer may vary. Students with outlier data should be able to explain possible errors within their investigation. Some students might state that they had trouble distinguishing between the beta tracks and the ripples formed in the mist of the cloud chamber* | Students who did not closely observe the cloud chamber during data collection may have lower rates than their peers. Students with especially good eyesight or lighting may have higher rates than their peers because they were able to see the small, faint, and fast beta particles better than others. |
| What trends or patterns do you notice in the whole-class data? | *The class generally got similar results - there is a definite peak to the histogram.* | Students conducting the same experiment in the same classroom should get similar results. For teacher reference, the data should follow a poisson distribution. Large fluctuations in data indicates issues with data collection and is not a good indicator of the natural background radiation rate. |
| From the whole-class data, what would you conclude is the natural background radiation rate? | *Some discussion about the measures of central tendency. Students may discuss “throwing out” any outliers to get a better answer. Students may also discuss the differences between mean, median, and mode.* | Students should have the mathematical background to discuss the measures of central tendency. To save time, these measures (mean, median, and mode) have been calculated on the Google Sheets file at the bottom of the graph. |

1. **EXTENSION:** Another method of measuring background radiation is through the use of a geiger counter. Ensure that the geiger counter is able to detect different types of radiation (alpha, beta, gamma) and measures in terms of counts. As a class demonstration, take a measurement to determine the current background radiation (counts per minute) and compare these results with the whole-class data collected from the cloud chambers. Discuss any differences and possible sources of error. In the discussion, include the different sampling volumes/sizes (i.e. the size of the cloud chamber versus the tube of the geiger counter) and the type/amount of particles that is able to be detected (recalling how the particle tracks were generally parallel to the bottom of the chamber versus any angle from the geiger counter).
2. Students continue their whole-class discussion about the cloud chamber activity, this time about the qualitative data, using the provided questions as guidance.

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| **Question** | **Expected Student Response** | **Teacher’s Note** |
| What do you notice about the particle tracks? What does the tracks’ directions mean about background radiation? | *The radiation comes from everywhere (ground, air, and space). The tracks cover the observation pad and come/go in all directions.* | Students should have seen particles from all directions throughout the cloud chamber. Some students may have noticed more particles directly where the dry ice was in contact with the metal (especially true of beta particles). Some students may comment that particles seemed to be coming side to side. Discuss how particles that entered the cloud chamber from the top/bottom would appear (i.e. a dot), and how this compares to other angles of entry. |
| What do you notice about the particle tracks? Were the tracks all the same, similar, or completely different from one another? | *Some particle tracks were really fat (alpha), and some were really straight (muon) and others were really thin/fast/short (beta). But, there were some that were similar - these particles were the same.* | Students may have difficulty differentiating between particles (especially alpha and muon), but should see some differences between tracks.  |

1. **EXTENSION:** A larger version of the cloud chamber could be made from an aquarium tank. This larger cloud chamber should provide similar (but potentially better quality) results. The teacher could also show students videos of working cloud chambers on YouTube. These videos should be used qualitatively only (i.e. not to determine natural background rates) as many videos do not indicate if a radioactive source is nearby, or if the video has been sped up or enhanced in any way.

### Extend: *(20 minutes)*

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| **Phase Summary:**Students work through a variety of activities, depending on the course and goal(s) of the teacher. Students may calculate their personal radiation dosage and explore health effects (biology), use the cloud chamber to study radioactive sources and half life (chemistry), or learn more about terrestrial (earth science) or cosmic (space science) radiation through a variety of sources. |

**Student Steps:**

#### Biology: Radiation and the Human Body

1. Students calculate their personal exposure to radiation using the provided [worksheet](https://www.nrc.gov/reading-rm/basic-ref/students/for-educators/average-dose-worksheet.pdf) (United States Nuclear Regulatory Commission, 2017a).
	* **NOTE:** For locations of nuclear power plants and coal-fired electrical utility plants in the United States, see this [website](https://www.eia.gov/state/maps.php) (United States Energy Information Administration,n. d.). [Also, a “video display terminal” is synonymous with a computer screen.]
2. Students view an [infographic](https://thumbnails-visually.netdna-ssl.com/radiation-doses-and-their-health-effects_50290b9a439e5_w1500.jpg) regarding radiation doses and health effects (Men’s Health, n. d.). Students compare their dose to the doses listed on the image, paying attention to the words “instant radiation” compared to “average”, “annual”, or “daily”.
	* **NOTE:** This image could be printed on the back of the radiation dose worksheet so that students can view it at their own pace.
3. Students have a whole-class discussion about radiation and the human bodies. As a part of the discussion, students should differentiate between the intensity of the radiation dose and the duration of the radiation dose.
	* **EXTENSION:** Introduce more sources that describe how radiation affects the human body (DNA). Include both positive (medical treatment) and negative (radiation poisoning) in the discussion. A common example of a medical treatment that uses radiation is gamma knife surgery (which is neither a knife or traditional surgery) or ion radiation therapy. A common example of radiation poisoning is that of the “Radium Girls”, which licked paint brushes covered in radium in order to paint luminous watch dials.

#### Chemistry: Radioactive Elements

1. Students work in small groups to repeat their cloud chamber investigation, but with an active radiation source. Since radioactive source should be placed near (beta) or in (alpha) the cloud chamber, it is suggested that different student groups set up their cloud chambers with different sources.
	* **NOTE:** The “[Building a Cloud Chamber](https://docs.google.com/document/d/14DMR0eFtU-ABk0p-wPXsEzEQ0hJ8VBWtnu5YkQb7BF4/edit?usp=sharing)” resource describes several sources for each type of radiation that a science teacher may be able to purchase or obtain. While a variety of sources is ideal, it is recommended to have at least one source that emits alpha particles and one that emits beta particles so that comparisons can be made.
	* **EXTENSION:** Include at least one gamma emitting source in the samples. Students should be able to observe that little/no particle tracks are created - suggesting (correctly) that gamma radiation is different than alpha and beta radiation.
2. Students observe the particle tracks created in the cloud chamber from their radioactive source, and confirm that the radiation rate is higher than natural background radiation. Students make observations regarding the frequency, duration (i.e. length), and pattern of the particle tracks.
3. Students compare their radiation source with other sources in the classroom by taking part in a gallery walk. In this activity, student groups travel to cloud chambers that contained different sources than their own to compare particle rates and tracks.
4. Students return to their seats and have a whole-class discussion about what they observed in the activity.

#### Earth Science: Terrestrial Radiation

1. Students watch a [video clip](https://www.youtube.com/watch?v=TRL7o2kPqw0) about the most radioactive places on Earth (Veritasium, 2014).
2. Students have a short discussion about how radioactivity depends on human activities on Earth, like those described in the video.
3. Students continue discussing terrestrial radiation by recalling sources of natural terrestrial radiation from the article read during the engage instructional phase. The teacher supplements this discussion by showing a [map of radon levels](https://www.epa.gov/radon/find-information-about-local-radon-zones-and-state-contact-information#radonmap) in the United States (United States Environmental Protection Agency, 2017).
	* **EXTENSION:** Obtain a radon test from a local health department and test the classroom/school for radon.
	* **EXTENSION:** Have students create a public service announcement (poster, presentation, etc.) to educate the local community about radon and the need to have homes tested.

#### Space Science: Cosmic Radiation

1. Students silently read and annotate one of three articles. The first article is “[Cosmic rays originate from supernova shockwaves](https://www.nature.com/news/cosmic-rays-originate-from-supernova-shockwaves-1.12436)”, while the second is “[What are Cosmic Rays](https://www.space.com/32644-cosmic-rays.html)?”, and the third is “[Cosmic Rays](https://imagine.gsfc.nasa.gov/science/toolbox/cosmic_rays1.html)” (McKee, 2013;Howell, 2018; NASA Imagine the Universe, 2017).
	* **NOTE:** These three articles target slightly different reading abilities. However, if none of the articles work for the students, the teacher may choose alternate articles about cosmic rays.
2. Students group with classmates that read different articles and discuss what they have read. Students should use this annotations (notes) to help guide their discussion.
3. Students briefly discuss as a whole class the answer to the question “where does cosmic radiation (rays) come from?” Students use their articles as evidence in their explanations. The teacher can also direct this discussion to talk about other current questions in science (showing students that not everything in the universe is figured out).

### Evaluate: *(5 minutes)*

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| **Phase Summary:**Students revisit the lesson questions and construct their explanation using the evidence gathered during the lesson. |

**Student Steps:**

1. Students are directed back to the lesson questions, which should still be displayed on the board. Students are given a chance to reflect on their initial ideas and answers to the questions at the top of their [student guide](https://docs.google.com/document/d/1O5RpmlLhJ35BHnCOQZuFDuSPGahn-6IjsWeduviELIw/edit?usp=sharing). Students use what they have learned and the evidence they have collected to construct new explanations at the end of their [student guide](https://docs.google.com/document/d/1O5RpmlLhJ35BHnCOQZuFDuSPGahn-6IjsWeduviELIw/edit?usp=sharing). Students should construct their explanations individually so that the teacher can use the responses as a formative assessment of the lesson.
	* What is background radiation? Where does it come from?
	* How much background radiation do we experience?

##

##

## Acknowledgements

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## Sources

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