Lesson #9: Cosmic Ray Detector

Teacher Section

This is a Bonus Lab, meaning that it's in addition to the experiments the kids get to do throughout the course. Feel free to skip this lab if the materials are out of your budget, or save it as a treat for the end of the year. You can alternatively make a single one of these and keep it in your classroom as a demo all year long.

Overview A cosmic ray is not like a ray of sunshine, but rather is a super-fast particle slinging through space. Think of throwing a grain of sand at a 100 mph - that's what a 'cosmic ray' is. Since these are tiny charged particles and not grains of sand, we built the electroscope back in Lesson #5 to detect electrons.

The Cosmic Ray Detector is a much better device at finding cosmic rays because it's going to catch negatively charged particles (electrons, also called 'beta particles') *and* positively charged particles (called 'alpha particles'). You'll actually get to see the thin, threadlike vapor trails appear and disappear, marking the path left by the particles. This type of detector was created by Charles Wilson in 1894, and later received a Nobel Prize (along with Arthur Compton) for their work on cloud chambers.

Suggested Time 30-45 minutes

Objectives Kids will build a special cloud chamber that will make these invisible particles visible. This cloud chamber works because it's filled with a super-saturated alcohol-water vapor mix. The alpha particles (ions) turn the vapor into microscopic clouds the kids can see.

Materials (per lab group)

- rubbing alcohol
- clean glass jar
- black felt
- hot glue gun
- magnet
- flashlight
- scissors
- dry ice
- goggles
- heavy gloves for handling the dry ice (adults only)

Lab Preparation

1. Since this is a tricky project, you'll want to build one yourself and get the kinks worked out *before* teaching this project to your class.
2. Print out copies of the student worksheets.
3. Watch the video for this experiment to prepare for teaching this class.
4. Read over the *Background Lesson Reading* before teaching this class.

Background Lesson Reading

Cosmic rays have a positive charge, as the particles are usually protons, though one in every 100 is an electron (which has a negative charge) or a muon (also a negative charge, but 200 times heavier than an electron). On a good day, your cosmic ray indicator will blip every 4-5 seconds. These galactic cosmic rays are one of the most important problems for interplanetary travel by crewed spacecraft.

Most cosmic rays zoom to us from extra-solar sources (*outside* our solar system but *inside* our galaxy) such as high-energy pulsars, grazing black holes, and exploding stars (supernovae). We're still figuring out whether some cosmic rays started from outside our own galaxy. If they are from outside our galaxy, it means that we're getting stuff from quasars and radio galaxies, too!

Cosmic rays are fast-moving, high-energy, charged particles. The particles can be electrons, protons, the nucleus of a helium atom, or something else. In our case, the cosmic rays we're detecting are 'alpha particles'. Alpha particles are actually high speed helium nuclei (helium nuclei are two protons and two neutrons stuck together). They were named 'alpha particles' long before we knew what they were made of, and the name just kind of stuck.

Did you know that your household smoke alarm emits alpha particles? Most smoke detectors contain a small bit (around 1/5,000th of a gram) of Americium-241, which emits an alpha particle onto a detector. As long as the detector sees the alpha particle, the smoke alarm stays quiet. However, since alpha particles are easy to block, when smoke gets in the way and blocks the alpha particles from reaching the detector, you hear the smoke alarm scream.

Alpha particles are pretty heavy and slow, and most get stopped by just about anything, like a sheet of paper or your skin. Because of this, alpha particles are not something people get very excited about, unless you actually eat the smoke detector and ingest the material (which is not recommended).

The electroscope we made in Lesson #5 can detect alpha and beta particles. Both brick buildings as well as people emit beta particles. Beta particles are actually high speed electrons or positrons (a positron is the antimatter counterpart to the electron), and they are quick, fast, and light. When an electron hit the foil ball, it traveled down and charged the foil leaves, which deflected a tiny bit inside the electroscope. A beta particle has a little more energy than an alpha particle, but you can still stop it in its tracks by holding up a thin sheet of plastic (like a cutting board) or tinfoil.

Important Project Considerations:

After creating your detector: You can bring your alpha particle detector near a smoke alarm, an old glow-in-the-dark watch dial or a Coleman lantern mantel. You can go on a hunt around your house to find where the particles are most concentrated. If you have trouble seeing the trails, try using a flashlight and shine it on the jar at an angle.

You will also be working with dry ice. The dry ice works with the alcohol to get the vapor inside the jar at just the right temperature so it will condense when hit with the particles. Note that you should **NEVER TOUCH DRY ICE WITH YOUR BARE HANDS.** Always use gloves and tongs and handle very carefully. **Keep out of reach of children** - the real danger is when kids think the ice is plain old water ice and pop it in their mouth.

If your dry ice comes in large blocks, the easiest way to break a large chunk of dry ice into smaller pieces is to insert your hands into heavy leather gloves, wrap the dry ice block in a few layers of towels, and hit with a hammer. Make sure you wrap the towels well enough so that when the dry ice shatters, it doesn't spew pieces all over. Use a metal pie plate to hold the chunks while you're working with them. Store unused dry ice in a paper bag in a cooler or the coldest part of the freezer. Dry ice freezes at -109 degrees Fahrenheit. Most freezers don't get that cold, so expect your dry ice to disappear soon.

Lesson

1. If you've previously completed Lesson #8: *The Alien Detector Lab*, you can follow up your space story by announcing to the kids that although you got rid of all the aliens from the last lab, now we're being invaded by invisible alien insects. But fear not! As a science teacher extraordinaire, you've figured out a way to detect these buggers and send them packing.
2. Hold up your detector and show it to the kids, explaining how it works. You will be making a special cloud chamber that holds alcohol gas inside. When you hold the jar in your hands, you warm it slightly and cause the air inside to get saturated with alcohol vapor. When the alpha particles (cosmic rays) zip through this portion of the jar, they quickly condense the alcohol and create spider-webby vapor trails. Kind of like when a jet flies through the air – you can't always see the jet, but the cloud vapor trails streaming out behind stay visible for a long time. In our case, the vapor trails are visible for only a couple of seconds.

Lab Time

1. Review the instructions on their worksheets and break the class into their groups and get started.
2. Walk the kids through the steps to building their detectors. Here are the main steps from the video:
3. Cut your felt to the size of the bottom of your jar. Glue the felt to the bottom of the jar.
4. Cut out another felt circle the size of the lid and glue it to the inside surface of the lid.
5. Cut a third felt piece, about 2 inches wide, and line the inside circumference of the jar, connecting it with the bottom felt. Glue it into place.
6. Very carefully pour a tablespoon or two of the highest concentration of rubbing alcohol onto the felt in the jar. You don't need much. Swirl it around to distribute it evenly. If the kids are doing this part, be sure to strap goggles on their eyes. Do the same for the lid. All the felt pieces should be thoroughly saturated. Cap the jar and leave it for ten minutes while you explain about dry ice (see safety precautions above under *Important Project Considerations*.
7. Put on your gloves, remove the lid and place a small piece of dry ice right on the lid. Invert the jar right over the lid. Leave the jar upside down.
8. **DO NOT SCREW ON THE CAP TIGHTLY!** Leave it loose to allow the pressure to escape.
9. Sit and wait and watch carefully for the tiny, thin, threadlike vapor trails.
10. If no vapor trails form in one of the jars, add more felt and alcohol. The jar might be too large for the amount of alcohol used. You need a thick cloud of air mixed with alcohol vapor for this experiment to work. You can also try a larger piece of dry ice, though usually the trouble is not enough alcohol molecules.
11. If you're still having trouble seeing the particles, remove the dry ice from the jar, screw on the lid to make an air-tight seal, and stick the entire jar right on a big block of dry ice, lid-side down for 15 minutes. Make sure you've got enough light to detect the trails. If things still aren't working right, use a different sized container.
12. Alpha particles are heavy and create straight, thick trails. Beta particles, which are light, will leave light, wispy, trails. You'll have way more alpha than beta trails in your cloud chamber. Bring a smoke detector close to the jar to test the experiment, as cosmic rays are often very tiny and spider-webby, and can be difficult to detect if you don't know what you are looking for.
13. You can use a magnet to deflect the cosmic rays if the magnet is strong enough and positioned just right.

Exercises

1. How does this detector work? (When the particle enters the chamber, it smacks into the alcohol vapor and makes free ions. The vapor in the chamber condenses around these ions, forming little droplets which form the cloud trail.)
2. Do all particles leave the same trail? (No. Different types of particles leave different trails. Alpha particles are heavy and create straight, thick trails. Beta particles, which are light, will leave light, wispy, trails. If you see any curly trails or straight paths that take a sharp turn, those are particles that have smacked into each other.)
3. What happens when the magnet is brought close to the jar? (You can use a magnet to deflect the cosmic rays if the magnet is strong enough and positioned just right.)

Closure Before moving on, ask your students if they have any recommendations or unanswered questions that they can work out on their own. Brainstorming extension ideas is a great way to add more science studies to your class time.

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Student Worksheet

Name____

Safety Alert! You'll be working with *hot* glue guns, toxic chemicals, glassware that can shatter, and finger-burning-cold dry ice. This is no time to mess around in the lab. Stay alert and work carefully to get your experiment to work.

Overview Your teacher has detected an alien invasion of cosmic insects. Your mission? Build a detector so you know where to aim your anti-alien bug spray.

What to Learn These 'alien insects' are cosmic rays which have a positive charge, as the particles are usually protons, though one in every 100 is an electron (which has a negative charge). These galactic cosmic rays are one of the most important problems for interplanetary travel by crewed spacecraft. Your job is to learn how to make the invisible *visible* so you can do something about it.

Materials

- rubbing alcohol
- clean glass jar
- black felt
- hot glue gun
- magnet
- flashlight
- scissors
- dry ice
- goggles
- heavy gloves for handling the dry ice (adults only)

Lab Time

1. Cut your felt to the size of the bottom of your jar. Glue the felt to the bottom of the jar.
2. Cut out another felt circle the size of the lid and glue it to the inside surface of the lid.
3. Cut a third felt piece, about 2 inches wide, and line the inside circumference of the jar, connecting it with the bottom felt. Glue it into place.
4. Strap goggles on your face. No exceptions.
5. Very carefully pour a tablespoon or two of the highest concentration of rubbing alcohol onto the felt in the jar. You don't need much. Swirl it around to distribute it evenly. Do the same for the lid. All the felt pieces should be thoroughly saturated. Cap the jar and leave it for ten minutes while you explain about dry ice (see safety precautions above under *Important Project Considerations*.
6. Your teacher is coming around with the dry ice. Remove the lid and your teacher will place a small piece of dry ice right on the lid. Invert the jar right over the lid. Leave the jar upside down.
7. **DO NOT SCREW ON THE CAP TIGHTLY!** Leave it loose to allow the pressure to escape.
8. Sit and wait and watch carefully for the tiny, thin, threadlike vapor trails.
9. What do you think the magnet is for? (Hint: keep it *outside* the jar.)

Draw a picture of your experiment and describe how it works and label each part:

Exercises

Answer the questions below:

1. How does this detector work?

2. Do all particles leave the same trail?

3. What happens when the magnet is brought close to the jar?