Lesson Plan

Title
Cosmic Ray Chamber

Primary Subject Area
Biology/ Physics

Grade Level
9th

Overview
This laboratory

Approximate Duration
90 minutes

MA Framework
Physics

4.1 Describe the measurable properties of waves (velocity, frequency, wavelength, amplitude, period) and explain the relationships among them. Recognize examples of simple harmonic motion.

4.2 Distinguish between mechanical and electromagnetic waves.

6.1 Recognize that electromagnetic waves are transverse waves and travel at the speed of light through a vacuum.

6.2 Describe the electromagnetic spectrum in terms of frequency and wavelength, and identify the locations of radio waves, microwaves, infrared radiation, visible light (red, orange, yellow, green, blue, indigo, and violet), ultraviolet rays, x-rays, and gamma rays on the spectrum.

Interdisciplinary Connections
Physics- Can work with Physics teacher to have physics students act as teachers for Biology students.

Lesson Objectives
At the end of this lab you will :

- be able to give a basic description of cosmic rays
- gain a better understanding of subatomic particles
- demonstrate an understanding of a cloud chamber

Lesson Materials and Resources
- Very Clear Jar with metal lid (available locally)
- Denatured alcohol (Hardware store)
- Black construction paper (Art Supply store)
- Sponge (Hardware Store)
- Pen or pencil for propping the sponge (Art Supply store)
- Flashlight (small with white LEDs) (Hardware Store)
- Dry Ice (crushed or sliced) (USE GLOVES, such as oven mitts, when handling dry ice!) (Most Walmart's have this now)
- OPTIONAL: small radioactive source that emits energetic helium nuclei (alpha particles). E.g. Lead-210 or Polonium-210 needle source http://www.imagesco.com/geiger/radioactive-sources.html

Technology Tools and Materials
Projector and Computer for introductory session

Background Information

Cosmic rays are not really rays; they are ***subatomic particles*** that are found in space that have high energies as a result of their rapid motion. Cosmic rays are streams of positively charged nuclei, mainly those of the hydrogen atom. Cosmic rays may also contain electrons, protons, gamma rays, positrons and neutrinos. Positively charged helium nuclei are referred to as **alpha rays** and streams of high-energy electrons are referred to as **beta rays**. These rays filter through the earth's atmosphere and can be studied using special detectors. Today we will be building a Cloud Chamber, which will help us to study these exotic particles from the far reaches of outer space.

In the past, cosmic rays were called "galactic cosmic rays" because we were unaware of their origin. Since these rays are atomic particles with an electric charge, they are deflected by the magnetic fields that occur throughout our galaxy, which means that we cannot tell where they came from. The space between stars is teeming with cosmic rays. It has been determined that the sun discharges a large number of lower energy cosmic rays, called "solar cosmic rays". Our sun, along with the explosion of dying stars, called supernovae, produces most of the cosmic rays that reach the Earth.

As mentioned earlier, cosmic rays are made up of subatomic particle, such as protons, electrons and atomic nuclei. About 87% of the cosmic ray nuclei are from hydrogen atoms that contain a single proton. Approximately 12% of the cosmic rays are from helium atoms that contain two protons and two neutrons and are referred to as **alpha rays**. The nuclei of heavier elements are also present in cosmic rays, but in much less numbers. When these rays travel through space at near the speed of light, electrons are stripped off of the rays. **Beta rays** are the name given to these high-speed electrons. As the cosmic rays travel through the earth's atmosphere, they smash into gas atoms that reside in the upper atmosphere. The fragments that are left over from the collision either evaporate or constantly shower down onto the surface of the Earth. These secondary rays are passing through your body as you read this sentence. When the cosmic rays collide with particles in the Earth's upper atmosphere, they disintegrate into smaller particles such as pions, muons and neutrinos. These particles are monitored and measured at the Earth's surface by devices called neutron monitors. The majority of the cosmic rays that we will be viewing in the cloud chamber today are muons. **Muons** are formed when the protons in the alpha rays are carried from outer space through the earth's atmosphere and undergo nuclear decay. The alpha rays break down first into pions and continue to decay into muons and neutrinos. Gamma rays, which are a type of cosmic ray composed of electromagnetic waves similar to light, are created from neutral pions that break down into additional electron and positron particles that can be seen in the cloud chamber.

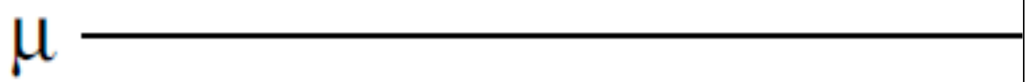
How a Cloud Chamber Works:

A cloud chamber is a device that makes visible the paths of particles emitted as a result of radioactive decay. With the chamber, we have created an enclosed environment filled with alcohol vapor. There is a temperature gradient between the top and the bottom of the box. This means that we can produce more alcohol vapor at the top of the box that becomes super-cooled by the time it gets to the bottom of the box where the temperature is too low for the vapor to exist. This allows the vapor to easily change into a liquid. When an electrically charged cosmic ray comes along, it collides with air or alcohol vapor molecules, ionizing the vapor by ripping away the electrons on some of the gas atoms along its path.

This leaves behind positively charged atoms. Nearby atoms are attracted to these ionized atoms, which initiate the condensation process. Eventually, enough atoms are attracted together to create visible liquid droplets which form "tracks". These tracks mark the path left by the particle moving through the chamber. Different types of particles will leave different trails based on their mass and charge.

What to Look For In the Chamber:

- A skinny track which goes straight
  - These are usually high energy muons barreling through the detector.



- A track which goes straight, then "kinks off to the left or right sharply.
  - This is a muon decay: μ → eνν
  - Since you can only see *charged* particles in the chamber and since neutrinos are neutral, you will not see the neutrinos.

- Three tracks that meet in a single point.
  - In these events, one track is an incoming cosmic ray. The particle hits

an atomic electron and knocks it out of the atom. The outgoing tracks are the electron and the muon (deflected).

- A track that zig-zags a lot.
    - This is “multiple scattering,” as a low energy cosmic ray bounces off one atom in the air to the next.

Lesson Procedures

Step 1: Lay the black construction paper on the inside of the lid (there’s no need to tape or glue it, although you can see the poster putty used to keep it in place in Figure 2 below).
Step 2: Thoroughly soak the sponge in the Isopropyl Alcohol, and squeeze out just a bit of the excess.
Step 3: Use the pen or pencil to jam (no looseness!) the sponge onto the bottom of the jar. This is important because you will be using the jar upside down.
Step 4: Place the lid on. Make sure it seals completely. (If you use a radioactive source, it should sit on the lid.)
Step 5: Turn the jar upside down. Make sure that the pen or pencil is firmly in place; it will keep the sponge from falling. Make sure the construction paper stays on the lid.
Step 6: Let the jar sit for between 5 and 10 minutes. This gives the alcohol vapor enough time to saturate the air inside the jar.
Step 7: Place the jar, still upside-down, on top of the dry ice (placing the dry ice in a disposable plastic bowl would do the job). See Figure 2b. This could take 15 minutes
Step 8: Darken the room.
Step 9: Shine the flashlight perpendicularly to your eyes and near the jar’s lid and watch carefully. You will probably see the fine mist of alcohol rain falling. As the air in the jar cools, the vaporized alcohol condenses and rains to the bottom. The dry ice cools the very lowest part of the jar (closest to the lid) so much that the air becomes supersaturated with alcohol. Supersaturation means that the air contains more alcohol vapor than possible under normal circumstances.

Assessment Procedures

Formative- Creation of Cloud Chambers with ability to see Cosmic Rays with detailed lab observations
Summative- Formal Laboratory Report

Accommodations/Modifications

Students with learning differences will be provided accommodations in compliance with IEP and 504 plans.

Reproducible Materials/Handouts

See attached Laboratories

Explorations and Extensions

Could be done as part of Space Unit

Lesson Development Resources

Cornell University, Laboratory for Elementary-Particle Physics:
http://www.lns.cornell.edu/Education/rsrc/LEPP/Education/Lessons/cloudchamber.pdf
Information about CRaTER and LRO

CRaTER's site: crater.unh.edu
A video in which the man responsible for CRaTER describes cosmic rays and the instrument:
www.nasa.gov/multimedia/nasatv/on_demand_video.html?param=http://anon.nasaglobal.edgesuite.net/anon.nasaglobal/ccvideos/GSFC_20090416_LRO_CRaTERvideo.asx&_id=190109&_title=LRO%3A%20New%20Window%20on%20the%20Universe&_tnimage=330170main_cratervid_100.jpg
(or you can search NASA's website, www.nasa.gov, for the video entitled "LRO: A New Window on the Universe")
LRO site: lunar.gsfc.nasa.gov
http://neutronm.bartol.udel.edu/catch/cr2.html

Reflections

Students will be divided into teams of 3 to build the cosmic ray chamber.
This laboratory is an excellent way to teach space science.

Contact Information

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