Lesson Plan: DIY Cloud Chamber

UW Science Expeditions
UW Medical Physics

Grade Level: All ages (adult supervision and aid required)
Length/Time: 30 minutes (overnight prep)
Location: At your home!

Safety:
Adult supervision and aid is required for this activity.

If using dry ice: Dry, insulated gloves or mittens to handle dry ice. Dry ice should not be handled directly as it can cause burns. Safety glasses (or other protective eye wear) and an apron.

Learning Objectives:

- Radiation is all around us all the time
- Radiation can be and is used effectively in medicine
- Medical Physicists help doctors diagnose and treat diseases through imaging and therapy that uses radiation
- We can measure/detect radiation

Prep work required:

- Prepare **frozen salt water solution**: combine about 2/3 c salt and 1 ¾ c hot water, stir until well combined. Transfer to freezer bag or plastic container to be placed in the freezer. Wrap in aluminum foil. Lay flat in freezer. **Freeze overnight** preferably.
- Prepare **radon balloon**: Inflate balloon. Rub it against your hair to make it staticky! Suspend in basement or crawl space for **~1 hour**.

Materials:

Item	**Quantity**
Salt	2/3 c
Isopropyl alcohol (>90%)	A few tsp
Aluminum foil	
Clear container with lid (wide opening is best!)	
Sponge/felt or other absorbent material	
Container to freeze salt water solution in	
Black paper or marker to cover the inside of the lid	
Strong glue/tape/adhesive	
Small bowl with hot water or handwarmers	
Flashlight (phone flashlight works)	
Dark room/space	
Balloon (optional)	
Alternate materials	
Dry ice (can be found at Hy-Vee)	
Ethanol (>90%)	A few tsp
Baking tray	

Procedure:

Construct chamber:

- Determine which side of your clear container will be the top and bottom of your cloud chamber.
- Either color the bottom of your chamber black with a marker or cut a piece of black paper to fit inside of your chamber.
- Take your sponge/felt attach it to the top of your chamber.
- Soak the sponge/felt in isopropyl alcohol.
- Close your cloud chamber.

Create the environment:

- Heat water or activate handwarmers.
- Determine your dark room/area for viewing.
- Take your frozen salt water solution out of the freezer and place on flat surface.
- Place your cloud chamber on top of the frozen salt water solution.
- Place the hot water or handwarmers on top of your cloud chamber.
- Use flashlight to illuminate area near the bottom of your cloud chamber.
- Allow some time for the cloud chamber environment to set.
- **Alcohol vapor should condense on tracks of cosmic ray muons as they pass through the cloud chamber making the tracks visible.**

Balloon (Optional):

- Retrieve inflated, statically-charged balloon from the basement.
- Carefully deflate ensuring the balloon doesn't pop.
- Set balloon next to or under the cloud chamber (directly in contact with it) to view tracks from alpha particles from radon decay.

Dry ice alternative:

- The cloud chamber we have in the lab for demonstrations uses dry ice to cool the bottom of the chamber and create the cloud effect. Dry ice is solid (frozen) carbon dioxide. It is much colder than ice and should be handled with care by an adult with protective gloves as it can cause burns.
- In the above procedure, replace the isopropyl alcohol with ethanol for improved results.
- Replace the frozen salt water solution with the dry ice.
- It may be helpful to place a baking tray between the dry ice and cloud chamber.
- The hot water/handwarmers may or may not be needed.

Science:

When we look into a cloud chamber we are peering through air with alcohol vapor. Special conditions in the cloud chamber cause the vapor to condense and form droplets near the chamber floor. This condensation occurs on electrically charged particles, or ions, created by cosmic rays or radioactivity. The droplets appear in threadlike tracks along the path of each ray. These droplet tracks fall to the floor of the chamber, and the process repeats as another cosmic ray passes through the chamber.

Supersaturation is the name we use to describe the special conditions which make this droplet condensation possible. The chamber air which is sensitive to cosmic rays is said to be supersaturated with alcohol vapor. This is another way of saying that the air is bursting with a lot of vapor, leading the vapor to easily condense and form a droplet. Charged ions left behind by a cosmic ray attract the vapor molecules, providing a site for these molecules to organize into a liquid state.

We create supersaturation in the cloud chamber by providing a vapor source at the ceiling, which is the sponge/felt soaked with liquid alcohol. This liquid evaporates easily at room temperature (and more dramatically when heated by the hot water or handwarmers). The air in the chamber contains almost as much alcohol vapor as possible. At lower temperatures, the air can hold less vapor. By cooling the chamber floor, with a frozen salt water solution or dry ice, we create a large temperature difference between the floor and ceiling. A thin layer forms near the cold chamber floor that contains more vapor than the air can hold at that temperature. We have created a supersaturated volume sensitive the cosmic rays. We place a bright light source at just the right angle to help see the tiny droplets.

Primary cosmic rays originate from outside our solar system, and frequently outside our galaxy. Upon colliding with gas molecules in our upper atmosphere, these high energy charged particles produce a cascade of secondary particles which may be observed with a cloud chamber. Occasionally, part of a single such cascade is seen as a group of parallel tracks.

The variations in track density and straightness help us distinguish different types of particles or radiation. Dense tracks contain more droplets along their length. This is because more ions are created, and more energy is lost per inch or centimeter of track length. Protons are heavy and tend to deposit more energy per length, and this effect increases as the particle slows down. Electrons are light and produce twisted tracks. Muons are common in cosmic rays, decay in two millionths of a second and are two hundred times heavier than an electron. Many of the straight tracks are cosmic ray muons.

Alpha particles are very heavy and create dense, straight tracks which are easy to see and distinguish from other types.

Radon is a radioactive gas which also emits alpha particles. Radon is created by radioactive decay within the rocks and minerals in and under our building materials, so it can build up in our enclosed spaces such as the basement. **In this activity, you will see a few tracks from cosmic rays, but there is also a way to produce those striking alpha tracks.** Most homes will contain some radon. If you charge a balloon by rubbing it on your hair, and then suspend it in your home for an hour (the basement is best), it will collect radioactive daughters of radon decay. These emit alpha particles. If you carefully deflate the balloon by cutting a small hole in the top or sticking a pin through a piece of tape, it will shrink without tearing. Place the deflated balloon on the bottom of your cloud chamber, and you should see tracks of alpha particles emitted from the balloon, against its black surface.

References and additional resources:

Yoshinaga, K., Kubota, M., & Kamata, M. (2015). Simple cloud chambers using a freezing mixture of ice and cooking salt. In *Physics Education*. https://doi.org/10.1088/0031-9120/50/1/23

PDF:
https://indico.cern.ch/event/335863/contributions/785342/attachments/1168798/1686802/cloudchamber_salt_ice_mix.pdf

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