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Nuclear Chemistry Lab: Creating a Cloud Chamger to Detect Background Radiation

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Nuclear Chemistry Lab: Creating a Cloud Chamber to Detect Background Radiation

Introduction

Radiation is emitted from a nuclear reaction. Instead of rearranging atoms through the breaking and forming of bonds, like in a chemical reaction, a nuclear reaction involves subatomic particles and high amounts of energy to form isotopes. One type of nuclear reaction is nuclear decay. Nuclear decay occurs when particles or electromagnetic radiation is emitted from an unstable nucleus (Burdge and Overby 875).

The particles that are emitted include alpha (α), beta/positron (β), and gamma (γ) particles. The particle emitted depends on the number of protons and neutrons in the nucleus, which also determine the properties of the particle. Alpha particles are emitted from any nucleus with an atomic number greater than eighty-three. Alpha particles are represented by a ${}^{4}_{2}\alpha$ or a ${}^{4}_{2}He$ symbol because the particle contains two protons and two neutrons. This nuclear decay is the biggest of the three particles emitted and travels 2-4 cm at a speed that's ninety percent the speed of light. Since alpha particles are larger and don't travel as far as other particles, they are easily blocked by paper and skin. Any atom where the number of protons exceeds the number of neutrons in its nucleus, a positron is emitted. In an opposite scenario, where the number of neutrons exceeds the number of protons in an atom's nucleus, a beta particle is emitted. Both particles are represented with the β symbol, but a positron gains a proton (${}^{0}_{+1}\beta$), while a beta particle loses a proton (${}^{0}_{-1}\beta$). Both emissions have similar properties; they are of an intermediate size and travel 100-400 centimeters at a speed that is ninety percent of the speed of light. Since beta particles travel further and are smaller in size, materials such as wood, metals, and clothing can be used to block these emissions. Gamma particles are considered “metastable” and are represented with a ${}^{0}_{0}\gamma$ or ${}^{\#\mathrm{m}}I$ symbol. They’re the smallest emission and travel 100-200 centimeters at about the speed of light. Since these particles travel a further distance and are the smallest in size, they are less easily blocked and require lead or a wall to be stopped (Rodriguez).

Natural radiation is emitted all around us as background ionization radiation. When absorbed, ionization radiation removes electrons from the matter it passes through and if a person were exposed to this radiation frequently enough, then it could cause permanent damage to cells and tissue. Knowing where this type of radiation is emitted is important to minimize unnecessary exposure. This radiation is let off naturally by various sources such as decaying natural elements, X-rays, and cosmic rays. Natural elements like uranium can be found in soil and rocks and account for ten percent of absorbed ionization radiation per year. This is because when uranium decays it forms radon, a radioactive gas, which we breathe in constantly. Another isomer, Carbon-14, comes from the upper atmosphere after nitrogen is bombarded with cosmic rays and is then integrated into everyday life such as our bodies and food that we eat. Other forms of radiation are man-made, such as medicinal techniques like X-rays, CAT scans, and PET scans. Even low energy versions of X-rays are emitted from TV screens and computer monitors (“Detecting Nuclear” 9).

The particles emitted in background radiation are subatomic particles that can’t be observed with the naked eye or microscope. However, a cloud chamber can be used to view background radiation. A cloud chamber is an enclosed apparatus filled with supersaturated alcohol vapor. Supersaturating vapor requires supercooling it, which can be done using dry ice (“Detecting Nuclear” 2). As the evaporated alcohol in the apparatus sinks towards the dry ice, it is cooled and is caught fluctuating between cooling and evaporating. At this point of supersaturation, the alcohol clings to the ionized particles in the chamber, therefore leaving a visible condensation trail of stripped electrons (Charley). The length of the condensation trails can be used to determine whether the radiation an alpha or a beta particle. The shorter trails will be from alpha particles and the longer trails will be from beta particles. Gamma radiation is also a form of background radiation but cannot be detected by a cloud chamber.

Methods

To create a cloud chamber, materials were used from Flinn Scientific Inc. and their "Detecting Nuclear Radiation: Cloud Chamber Classroom Set." The chamber was about two inches tall, cylindrically shaped, and made of plastic. It also came with a hole on one side and a lid. The procedure for performing this lab required setting up the cloud chamber, creating conditions to produce supersaturated alcohol vapor, and observing visible particles in the chamber. The first step was assembling the chamber (see figure 1b). A black, plastic circle was put in the bottom of the chamber. The dark plastic allowed for the white, wispy condensation trails to be seen better. Next, the black blotting paper was inserted and kept in place along the sides of the chamber by soaking it with 2-3 mL of 70% isopropyl alcohol using a disposable pipet. A thin layer of isopropyl alcohol remained on the bottom of the chamber after soaking the blotting paper. The isopropyl alcohol is what evaporated and condensed to show the condensation trails. The lid was then placed on the chamber and a Kimwipe was inserted into the hole on the side. Once the chamber was sealed, it was set on a chunk of dry ice that covered the bottom of the chamber. The conditions to create supersaturated alcohol vapor were created after the chamber sat on the dry ice for ten minutes and a misty vapor appeared at the bottom of the chamber. The Kimwipe was removed and the lantern provided by the kit was inserted into the hole with the cloth side in the chamber. The lantern mantel produced very low levels of radiation, which increased the number of particles to observe. The final step to completing the lab was turning out the lights and creating a light source on the opposite side of the chamber from the lantern to observe the background radiation in the form of condensation trails.

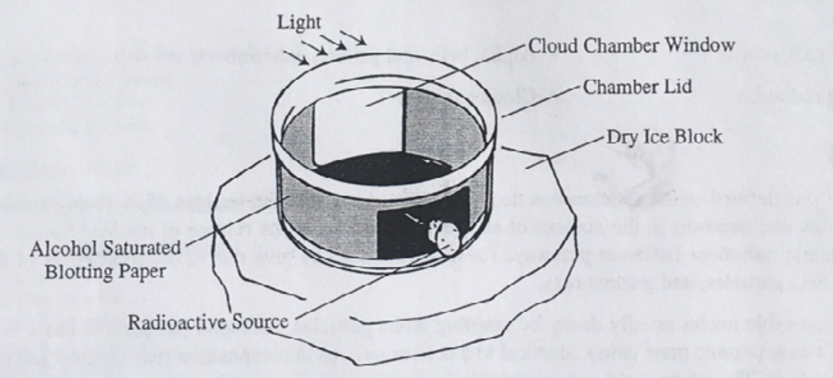
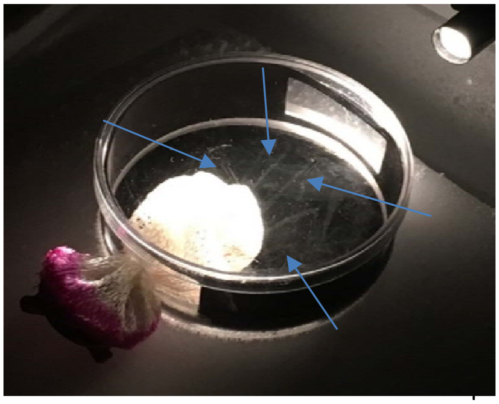


Figure 1. The Cloud Chamber.

Fig 1- Cloud Chamber Diagram ("Detecting Nuclear" 2)

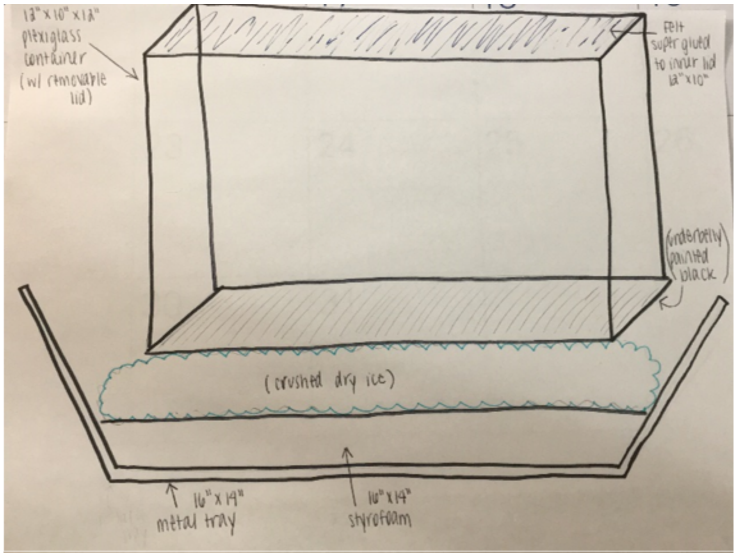
Results

Observations made while watching the cloud chamber include commentary on the width, length, and position of condensation. Some particles were short and were only a few centimeters in length. These particles remained close to the nuclear source, or lantern, throughout the experiment. It was concluded that these shorter condensation trails belonged to alpha particles. The longer, thinner trails spread the length of the chamber and even moved sideways. These longer trails were beta particles. The chamber and condensation trails were difficult to capture simultaneously on camera, but the trails can be seen in the image below. (They are the wispy tails coming off the lantern. The chamber may appear dirty, but those marks are the trails.)

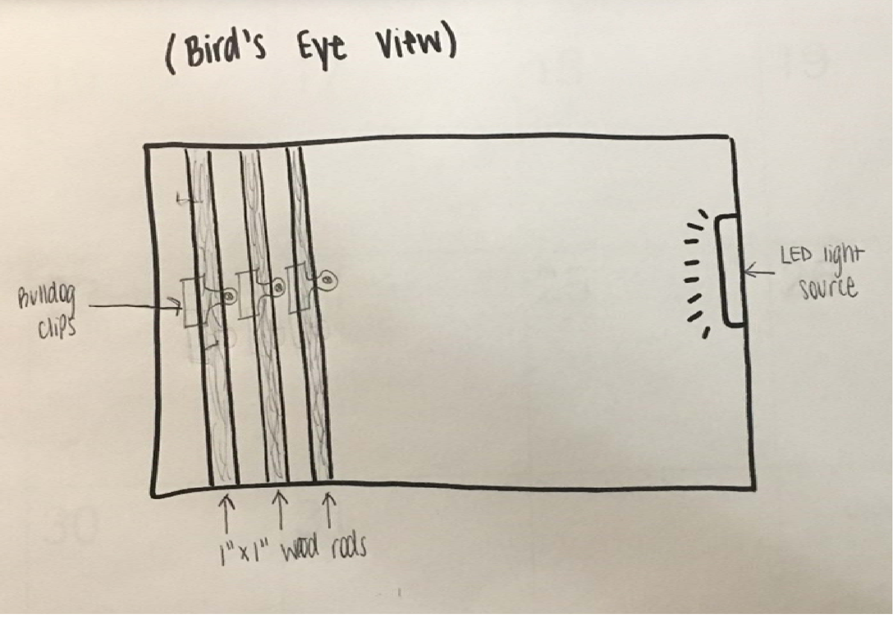


Proposal

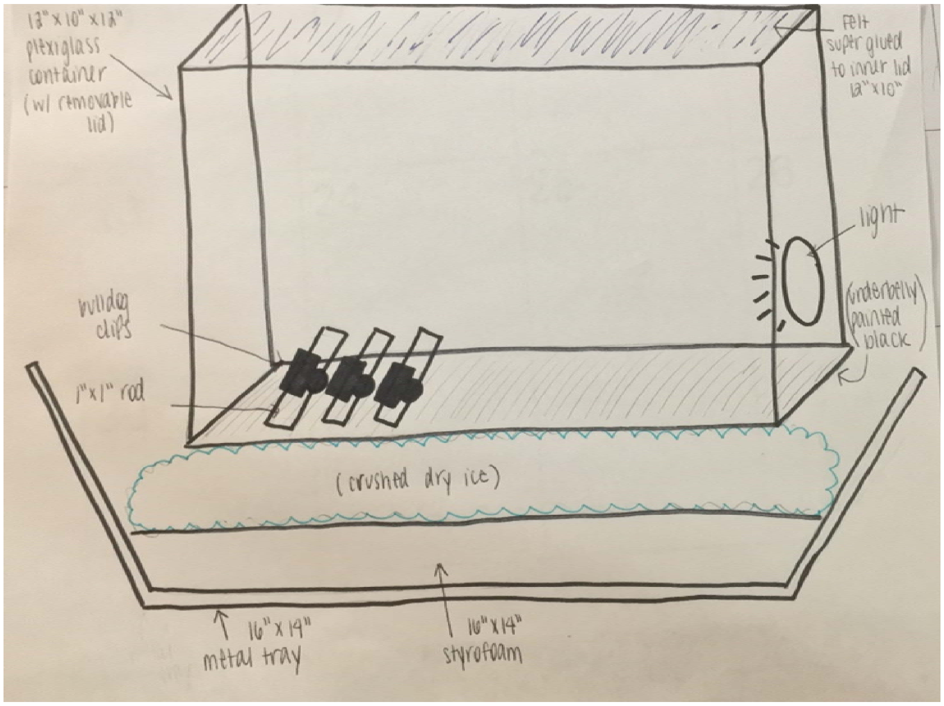
The methods used to make the cloud chamber and conduct the experiment were successful, but a larger chamber would allow for a more accurate representation of background radiation by seeing it in a larger space. A large chamber would also be better for demonstrations with a larger audience and allowing more people to view the apparatus at once. A similar, basic set up could be used, but the materials involved would be very different. The larger cloud chamber still would require a container sitting on dry ice, an insulated tray, an absorbent in the chamber, and a light source. My proposal for a larger chamber begins with the base. A 16” x 14” x 6” metal tray would hold the dry ice and chamber. Before the dry ice is placed on the tray, a layer of styrofoam, cut to fit the 16” x 14” tray, would be inserted on the bottom. Having an insulator between the tray and dry ice would keep the bottom from freezing as well as keep the dry ice cold. On top of the insulator is where the crushed dry ice would be placed and then the cloud chamber on top of the dry ice. The dry ice must be crushed because there may not be a block large enough to cover the entire bottom of the chamber. Buying multiple blocks and crushing them would better ensure that the base of the chamber was covered completely. The chamber itself would be a 12” x 10” x 12” plexiglass container. The plexiglass can be seen through easily and comes in larger dimensions like those necessary for the proposed chamber. The underbelly of the bottom panel of the chamber would be painted black to aid in seeing the white particles. The top of the container would be open and have a removable lid made of plexiglass as well. Having a lid would make inserting and removing radioactive substances easier than fitting them through a whole, like in the small cloud chamber experiment. Since an absorbent is required to absorb the isopropyl alcohol, a 12” x 10” piece of felt would be super glued to the inside of the lid. Below is a side view of the proposed apparatus.



The inside of the chamber would require inserts for a radioactive substance and blocking materials. This would be implemented into my chamber by placing three 1” x 1” square, wooden rods near the bottom of the chamber, but without touching the bottom. Sawing holes into the plexiglass for the wooden rods to connect to would help stabilize the rods. Connected to each of these rods would be a screwed-on bulldog clip with the clip pointed to the lid. This would allow for the radioactive material to be clipped in the chamber as well as up to two blocking materials. Since clips are used, the sizes and thicknesses of materials can differ and still be held by the clip. Finally, a light source would be needed, which I’d use a remote controlled, LED base light and super glue it to the opposite wall of the radioactive material. The final product would reflect a similar set up as the miniature cloud chamber but would then be able to test what types of materials block certain particles with the flexibility of the clips to test different thicknesses of materials also.



Proposed Chamber



Works Cited

Burdge, Julia, and Jason Overby. *Chemistry: Atoms First*. McGraw-Hill Education, 2018.

Charley, Sarah. “How to Build Your Own Particle Detector.” Symmetry. Fermilab/SLAC, 20 Jan. 2015, www.symmetrymagazine.org/article/january-2015/how-to-build-your-own-particle-detector.

“Detecting Nuclear Radiation.” *Flinn Scientific Inc*, vol. 18, 2005, pp. 1-10.

Rodriguez, Manuel. “Nuclear Chemistry Lecture.” Champaign, Parkland College.