Construction of a Diffusion Cloud Chamber and Observation of Ionizing Radiation

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Abstract

We document the construction and operation of a diffusion-type cloud chamber built from standard materials as part of an extra-credit project for the Subatomic Physics course at the Florida Institute of Technology. The apparatus consisted of a sealed glass aquarium with an alcohol-saturated felt strip on the upper interior surface and a chilled metal plate, cooled by dry ice, forming the lower boundary. Across five build iterations we changed many variables, such as varying the chamber volume, alcohol concentration, dry-ice source, and thermal-contact strategy. In our third attempt, we observed transient regions of disturbed vapor consistent with ionizing events, indicating a successful observation. However, the particle tracks in our third attempt were not as clearly defined as we would have expected, leading to a fourth and fifth attempt.

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1 Introduction

The cloud chamber, first developed by C. T. R. Wilson in the early twentieth century [5], is a visually impressive and simple instrument in experimental particle physics. By producing a supersaturated vapor of alcohol above a sufficiently cold surface, the paths of individual charged particles become visible as trails of condensed droplets. This allows cosmic-ray muons, natural alpha emitters, and low-energy beta particles to be observed without specialized electronics.

This report documents our attempts to construct a working diffusion cloud chamber as an extra-credit project. We describe the apparatus, summarize the physical principles that govern its operation, detail each of our five built iterations of the device, and discuss the failure modes that we believe prevented us from observing well defined and reproducible tracks.

2 Background and Theory

The purpose of this experiment is to observe the passage of charged particles, primarily cosmic-ray muons in ambient air through a region of supersaturated alcohol vapor inside a sealed chamber.

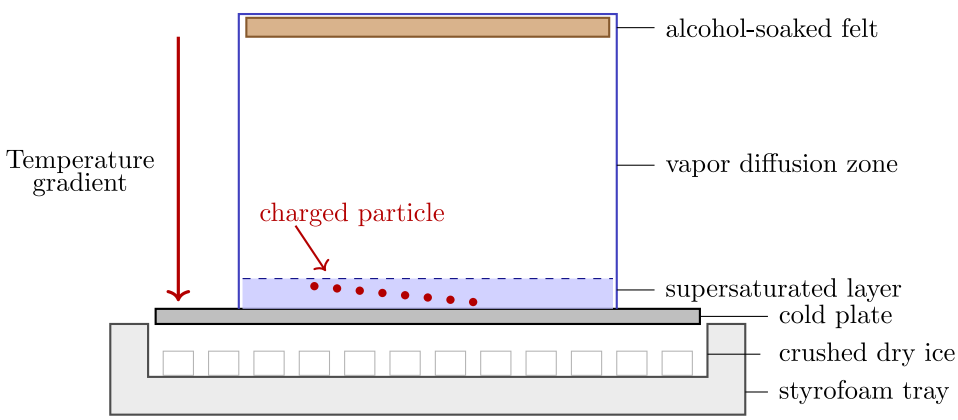

Figure 1: Schematic diagram of the diffusion cloud chamber. An inverted glass tank rests on a metal cold plate (cookie sheet) chilled by crushed dry ice within an insulating tray. Alcohol vapor evaporates from the felt strip glued to the inside of the now-upper face of the tank, diffuses downward through the resulting temperature gradient, and forms a thin supersaturated layer a few millimeters above the cold plate. Ionization left by a charged particle traversing this layer nucleates condensed droplets along the particle's trajectory.

2.1 Supersaturation

A diffusion cloud chamber relies on a steep vertical temperature gradient between a warm upper surface, where isopropyl alcohol evaporates, and a cold lower surface, typically chilled by dry ice. As alcohol vapor diffuses downward through the gradient, the local saturation vapor pressure decreases with temperature far faster than the partial pressure of the diffusing vapor, producing a thin horizontal layer in which the vapor is supersaturated when compared to its surroundings. In this layer, even a small disturbance such as the ionization left by a passing charged particle is enough to induce visible droplet formation.

For our setup, isopropyl alcohol was soaked into felt glued to the inside of the upper face of the chamber, and a thermally conductive metal pan in contact with crushed dry ice formed the cold floor. The supersaturated layer is expected to form as a thin sheet slightly above the cold plate.

2.2 Ionization and Track Formation

A charged particle passing through the chamber ionizes as it passes through, leaving a trail of ions and free electrons. These ions act as condensation nuclei for the supersaturated vapor, and droplets nucleate preferentially along the particle's trajectory. The resulting line of droplets, when illuminated from the side against a dark background, appears as a thin white track.

It is possible through more advanced techniques to identify which particular particles created the tracks seen within the cloud chamber by analyzing various properties such as track thickness, length, and curvature[3, 2]. Due to the nature of this project, such methods are outside of the scope of this project.

3 Apparatus

The chamber was assembled from inexpensive consumer materials, summarized in Table 1, and is shown in Figure 2. The principal components were a sealed glass aquarium serving as the chamber body, a strip of craft felt glued to the inside of the closed end of the aquarium and serving as the reservoir for the isopropyl alcohol, two stainless-steel cookie sheets pressed together with crushed dry ice between them, serving as the cold stage, and isopropyl alcohol at either 91% or 99% concentration. Side illumination was provided by a phone flashlight, and observations were made in a darkened room.

During the process of attempting this experiment, we used the following materials:

Table 1: Materials and approximate costs incurred over the project.

Item	**Source**	**Cost (USD)**
Isopropyl alcohol, 91%	Walmart	10
Isopropyl alcohol, 99% (1 gal)	ACE Hardware	40
Small fish tank	Amazon	20
20×10 in. fish tank	Borrowed (C. Harrison)	-
Full-size cookie sheets (×2)	Gordon Food Service	40
Dry ice, 8 bags	Publix	160
Dry ice, 10 lb	Rife Carbonic	20
Total		**300**

Figure 2: Attempt 1 Cloud Chamber Apparatus

4 Procedure and Iterations

Construction of the overall experiment followed this general structure:

1. Glue felt to the top of the tank, ensuring that there are sufficient layers so that it can be saturated by the Isopropyl Alcohol later on.

2. Crush Dry Ice within a bowl or other sturdy container with a hammer or other device. Place that dry ice into the first full sheet and flatten the ice so that a continuous layer is seen. Finer dry ice yields better results so ensuring granularity is important. Place the second sheet over and press down until it is steady.

3. Douse the felt with alcohol until it is sopping, then remove any excess from the tank and quickly flip the tank onto the pan with the dry ice contained. Make sure to seal any areas where a draft may be able to get inside.

4. Wait approximately 10-15 minutes and apply more alcohol if needed due to freezing. A foggy interior should now be visible that allows for some particle hits to be seen. To ensure this, create a dark environment and apply a light perpendicular to the tank.

A summary of the five iterations is given in Table 2; details follow in the subsections below.

4.1 First Attempt - March 2026

Our first attempt of the cloud chamber experiment involved us using the small fish tank and dry ice obtained by a local company called Rife Carbonic. Using two small metal sheets we

Table 2: Summary of build iterations.

#	Date	Tank	Alcohol	Dry-ice source	Tracks?
1	Mar. 2026	Small	91%	Rife Carbonic	No
2	Early-Apr. 2026	Small	91%	Publix	No
3	Late Apr. 2026	Small	99%	Publix	Observation
4	Late Apr. 2026	20×10 in.	99%	Publix	Faint disturbance
5	Early May 2026	20×10 in.	99%	Publix	None

attempted to make a gradient but were unable to get clouds to form within the chamber. This prompted us to try different dry ice as well as look for better ways to seal the chamber. Additionally, we realized that crushing the dry ice more finely would allow us to achieve better results.

4.2 Second Attempt - Early April 2026

Attempt number two focused on getting a visible cloud formation, which was marginally successful by using a heat source at the top of the tank and new dry ice from Publix at the bottom. With this setup, we were able to see some smoke and potentially some interactions, though not all members could verify this, leading to attempt number three.

4.3 Third Attempt - Late April 2026

This was our best and most conclusive attempt. During this attempt, we were able to finally see small puffs of smoke being displaced by the particle collisions. Though we did not get very well defined tracks, we were still able to see the impacts of the particles in the lower areas of the chamber.

We used the small fish tank alongside 99% Isopropyl Alcohol and dry ice from Publix for this specific attempt. Not seeing large tracks prompted us to do a redo with a larger tank, leading to attempt number four.

A video recording of this attempt is available online at https://youtube.com/shorts/szhR7-V3TjU?feature=share

4.4 Fourth Attempt - Late April 2026

This attempt focused around using both a larger tank and more pure 99% Isopropyl Alcohol. To compensate for the larger tank, two large pans were needed that were used to conduct the cold and contain the dry ice safely. During this attempt, smoke was visible but no tracks were clearly seen and no impacts were seen also.

4.5 Fifth Attempt - Early May 2026

The final attempt made to attempt to achieve better tracks was done with all of the prior knowledge and a few additional attempted tricks. In total we attempted 4 distinct methods, trying other ways of containing the isopropyl alcohol via felt, additional layers of felt, and sponges with a layer of felt on top.

Unfortunately, no new information was gained from this attempt as no well defined tracks were observed.

5 Discussion

Overall, the experiment was a minor success in that we were able to see some impacts of where the particles came through and disturbed the gas. Though no strong visible tracks were seen, the experiment still allowed to see disturbances that were indicative of particle tracks and allowed us to see the nuance behind how constructing and operating even a relatively simple experiment can have unexpected pitfalls and be of high cost. Cost prevented us from continuing experimentation, as dry ice and sufficient alcohol were pricey and required one to two bags of dry ice per iteration of the experiment.

A useful guide to identifying particle species from track morphology is provided by Symmetry Magazine [1]; we did not produce tracks of high enough quality for this classification to be applied. Our procedure followed closely the construction approach demonstrated in the cloud-chamber video [4].

6 Conclusion

We constructed a diffusion cloud chamber and operated it through five iterations, varying the chamber volume, alcohol concentration, dry-ice source, and alcohol-delivery method. We did not produce reproducible, well-defined particle tracks. We did repeatedly observe transient disturbances in the supersaturated layer that we interpret as marginal evidence of ionization events, most reliably reproduced in iteration three.

The most likely contributing failure modes, in our judgment, are insufficient thermal contact between the crushed dry ice and the cold-stage metal, and degradation of the supersaturated layer by ambient humidity. Future iterations would benefit from a thermoelectric cold plate instead of dry ice, finer dry-ice crushing combined with a thermally conductive surface, a better-sealed chamber, and operation in a dehumidified environment.

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