A DIY CLOUD CHAMBER FOR DETECTION OF SUBATOMIC PARTICLES! LESSON PLAN.

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Time: ~1½ hours
Grade Level: Grade 5 to 7+.
Staff: 1 physicist

Equipment: foil, glass container, plasticine, isopropanol, sponges, dry ice, LED light, and access to a room with no windows.

This SCLS[1] lesson plan provides instruction for making a DIY cloud chamber suitable for the detection of sub atomic particles. Note that it is a great activity to bring up ideas around "what is science?" since we are, in effect, looking for "invisible" things. Note that the experiment itself is a bit finicky – depending on the supplies used, we find about a 50% to 75% success rate of particle detection, and students should be forewarned that patience is required even in the good chambers. Please also highlight some of the hazards of using isopropanol and dry ice.

1. Set-up and supplies.

Below is the list of reagents and equipment necessary for the DIY cloud chamber activity.

Per 2 to 3 students:
- A see through container (plastic cup or fat wine glass seems to work well).
- Sponge that will wedge inside your see-through container.
- Plasticine
- A foil pie plate or foil sheets (dependant on the type of dry ice you have)
- LED light
- Lab gloves are also handy, primarily to prevent student's hands from getting greasy whilst working with the plasticine.

In the classroom to be dispensed at specific times by the instructor:

[1] See http://www.bioteach.ubc.ca/portfolio/science-creative-literacy-symposia/ (accessed April 22nd, 2015)

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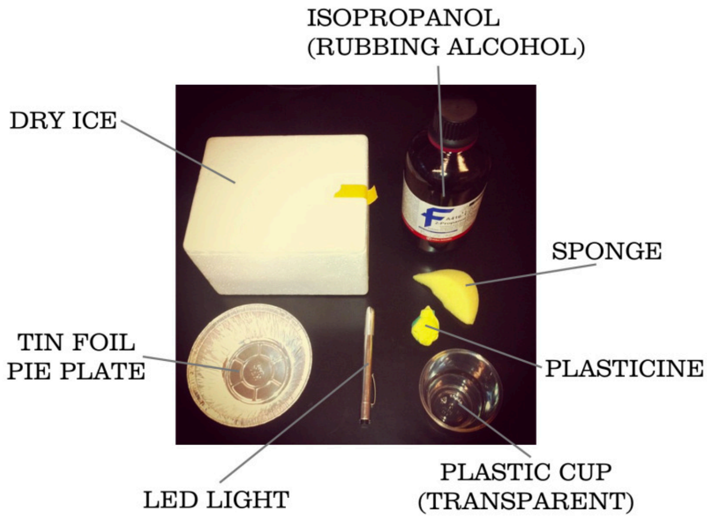
- Dry ice – either chips or blocks work. For chips, you will need to use the pie plates, for dry ice blocks, you can use a sheet of foil. Note that the block option tends to work better but you will need a lot more dry ice if you plan on making multiple set ups.
- Isopropanol (research grade), or high concentration rubbing alcohol from the pharmacy.



And here is what you can put out on the bench from the very get go.

There's a couple key things that we can point out here. You will need isopropanol, which is actually quite easy to get (look for the 99% rubbing alcohol in your local pharmacy, although make sure it is isopropanol or isoamyl alocohol). Note that you do need to be careful around isopropanol. Dry ice on the other hand is sometimes tricky to get (in Canada for instance, there are official rules for its transportation). Also note that dry ice, if not handled properly can cause mild frost burn, so definitely warn the class to try avoid touching the dry ice.

The tin foil pie plate is essentially the base that will be made cold (with the dry ice), so as to create a temperature gradient, which in turn is responsible for producing an isopropanol cloud. As such, there's a few important things it needs:

1. The base needs to be of a colour that allows you to see an isopropanol droplet cloud easily. Most videos seem to suggest something with a black surface, but this isn't always

easy to find, and possibly expensive if you need 12 of them. We've tried pie plates that were silver/grey (usually the most common) and red in colour (red was really difficult to observe), but the tin foil variety actually worked really well. This seems partly because it's able to reflect the incoming flashlight, so that you can control the angle of light (just so) and in a way to best see this cloud.

2. The base needs to be deep enough to encase a sufficient enough amount of dry ice, so as to more effectively maintain that cold temperature gradient. Here, we tested plates that were about 1/2 inch deep versus 1 inch deep, and the 1 inch variety worked much better. Presumably, it would also work if you just sat a thin sheet of metal right on top of a dry ice block (we were using pellets). Note that the flat dry ice block works really well, but tends to result in needing a lot more amounts of dry ice - you can try to break the block into smaller pieces that happen to fit within the pie plate (foil or otherwise).

3. The base needs to be of a material that best transfers the coldness of the dry ice to the rest of the chamber. This is why metal is often suggested, but the tin foil was just about perfect here. It's metal, but it's also very thin. I noted that the chamber got cold very quickly and reliably.

Another piece of equipment that needs mentioning, is the plastic cup. You can use glass, but the plastic cup works just as beautifully. Don't forget that it has to be small enough to create a supersaturation situation, and it's true (as the video suggested), that the smaller it is, the quicker you can see results. If possible, try to get cups without ridges so that there's no obstructions to the observations.

2. Introduction: What is Science? What is in the Jar? (<30 minutes)

Begin the session by asking the kids to think about **what science is**. It's usually best to do this as a group activity, so that kids can discuss with their immediate neighbours. It might even be good to do this exercise where they have to write out their answers.

In this context, you'll probably get a bunch of different answers that will range from a who's who of disciplines/subjects (i.e. it's about chemicals, it's about animals, it's about medicine...), or sometimes about science culture (it's about being in a lab, wearing a lab coat, doing experiments, making technology...), and occasionally, you might even get answers that essentially delve into the epistemology of science (it's about asking questions, it's about understanding the world). All are technically correct, and make sure you emphasize that point, but for the purposes of our session, we really want the kids to focus on this important outcome of what science is all about.

That:

SCIENCE IS REALLY A WAY OF THINKING, AND ONE THAT HELPS YOU FIGURE OUT WHAT IS REAL.

This statement can actually be a little tricky to grasp, so it's useful to guide the kids through an exercise that makes them think about what might be real or not real. For instance, what has worked well in the past, is to ask whether they think you (the instructor) are real (i.e. you would simply say, "How do you know that I am real?") The most common responses tend to revolve around vague statements like , "Because you're right there!" and if so, do your best to bring up alternative answers that would refute that general response. Examples might include statements like, "How do you know that *I am actually there*? What if I am a ghost? What if I am a robot? What if I am a hologram? Could I be a ghost? Could I be a robot? Could I be a hologram? How would you would be able to tell a real me, from a ghost or a hologram?"

The hologram example seems to work well, especially since the lab space clearly has a projector shining a light in the general vicinity of where you might be standing (i.e. you could ask, what would a hologram need - a projector? Well then, how could you test for whether I am a hologram, etc). All to say, that hopefully, this goofy discussion will get the kids to think that sometimes figuring out what is real or not isn't always so simple. As well, introduce the idea of "evidence" here, or perhaps use the word "proof" which seems to be a word they have better grasp of.

With that in mind, then you introduce the next discussion, which simply presents an empty jar, with the statement in big bold letter: **WHAT IS IN THIS JAR?** *(you can use a slide, but for full effect, you can even show them a real empty jar).*

Again, get the kids to discuss with their neighbours for a few minutes, and then query them on what answers they have come up with. Write this ideas on the white board. You'll find that there are some common answers (such as "nothing" or "air"), and that some classes will also come up with fancier answers like "molecules/gas/oxygen" or even "germs." Occasionally, you'll get a joker who will refer to "something invisible" - this is actually a great response. In fact, if it doesn't come up, suggest it anyway - maybe even in a funny way (we've used invisible miniature unicorns for example!) Essentially, highlight the fact that it is a perfectly good suggestion, but that one shouldn't forget that eventually, you'll need to come up evidence or proof around the idea.

Then, see if you can coerce them to explore some more subtle answers. There are two great non-obvious possibilities. One would be to imagine the jar wrapped in a blanket and to imagine being inside that jar - what is missing that is obviously there without the blanket (that's right - light!). As well, ask them what would happen if you let go of a coin at the top of the (open) jar - that's right, it would fall! What would be responsible for that? And if they say "gravity," then ask them does that mean that "gravity is in the jar?" Overall, you want a list of possible things in the jar, which again, will hopefully reinforce the idea that figuring out a real answer often takes a bit of effort, and that this is what scientists are trained to do - they basically look at the world in very careful ways, and they also ponder the question of how would you know whether any of these options are real.

Now that we've established a few obvious and not so obvious options, we can then move to the "scientific process" proper. Which is to say that we want to established how "science" might go about figuring out whether something is real is or not. As well, this is a good time for the instructor to announce that the experiment we're going to do today will explore what might be in the jar. In fact, the instructor might even say to them that the jar contains special particles that are actually traveling super fast, and possibly come from very far away. However, they are so small that they are, to all intents and purposes, invisible. Basically, as an instructor, you've just announced a "claim."

And here is how we want the kids to treat that claim, or any of the claims that happen to be on the whiteboard:

1. QUESTION IT!

2. THINK ABOUT WHY IT COULD BE TRUE.

3. THINK ABOUT HOW YOU WOULD FIND EVIDENCE FOR THIS.

4. GET THE EVIDENCE. IF YOU CAN'T FIND ANY, GO BACK TO 1.

5. SHOW OFF THE EVIDENCE TO SMART PEOPLE.

6. IF THEY DON'T LIKE IT, GO BACK TO 1.

7. IF THEY LIKE IT – GREAT! NOW FIND MORE EVIDENCE THAT MAKES YOU STILL THINK IT'S TRUE (REPEAT STARTING AT 2).

You can walk the kids through this (but don't take too long - at this point, they'll be starting to get a little restless). If anything, two elements that were emphasized were to (1) really get the kids to appreciate the "QUESTION IT" point (i.e. what does it mean to be skeptical. How a scientist tends to always respond to any idea with a simple "really?" - get the kids to go "*Really?*" in unison); and (2) that when you get "OTHERS" to look at your evidence, the identity of the OTHER is very very important.

Anyway, at this point, the kids are usually ready to do something with their hands. And so on to the next part.

3. Starting the DIY Cloud Chamber (15 minutes)

Start off by saying that we're going to make a cloud chamber, and the reason being that if we can create a "cloud" in the jar, we can maybe see how different things affect it. In other words, even though the things are invisible, we can indirectly see their effect by seeing how the cloud behaves.

Overall, in this section, the primary goals are to guide the kids through the initial stages of the cloud chamber construction, but also to introduce the notion of what types of things we are hoping to detect (sub-atomic particles like muons, electrons, cosmic rays), as well as show a video that nicely encapsulates some of the crazy scientific facts around atomic structure. Finally, we want to give them a heads up on what they're hoping to see.

Anyway, for the construction part, basically we want the kids to get to a point where they make something that looks like this:

What we have here, is a lining of the top of the plastic cup with a ring of plasticine. The kids can do this using gloves (so their hands don't get oily), and also on matts provided on the bench tops (so the benches don't get oily). Then, ask the kids to insert their piece of sponge into the cup in such a way, that they feel pretty confident that the sponge is nicely wedged in. In general, this step takes longer than you would expect (~15 minutes), but at in the end, you want all groups to have done this and whereby someone has done a visual check of the finished product.

4. Finishing the DIY Cloud Chambers and a bit about subatomic particles (20 minutes)

To break things up a bit, we next go into a short bit about things at the sub atomic scale. Usually at the grade 5, 6, or 7 level, some mention of atoms has been done in the curricula. However, it’s fairly basic, and definitely doesn’t delve into the really interesting (re: bizarre stuff).

In this light, this section is really just about giving the kids a taste of this, and highlighting two key points.

1. At the subatomic scale (and even at the atomic scale), you can't rely on sight. Indeed, to all intents and purposes, things are "invisible."
2. At the subatomic level, obvious scientific laws go out the door. For this, we show a TED Education video, which nicely encapsulates a lot of weirdness. (see http://www.youtube.com/watch?v=yQP4UJhNn0I). One weird fact coming out of this is the realization that things (including people) are mostly "empty space."

At this point we finish making the cloud chambers. This essentially involves getting the foil plate/tin foil ready, and systematically aliquoting the isopropanol to each chamber. This is where some coordination has to occur as isopropanol is a hazardous material.

Best to do the following:

1. Get kids to put their gloves on.
2. One chamber at a time, get them to bring their cup+sponge+plasticine ring over.
3. Add isopropanol (~12mls, although this can vary depending on the size of the container you use – do experiment – you want as much alcohol as possible without excessive dripping.).
4. Get them to immediately take it back to their bench. This is where it's handy that the other instructor makes sure they don't dilly dally here.
5. Seal the plasticine to the foil, making sure there are no leaks (this is absolutely crucial for the thing to work).
6. Get them to wait. They can keep the cup upright, so that the sponge is still at the bottom, whilst they wait.

Once this is done for the entire class, it's often a good idea to go over what the students will hopefully see, as the next step involves using the dry ice, going to the windowless room, and then looking for the particles in the dark.

Here, we can talk more about contrails. In other words, we're going to see "invisible" particles, via the creation of a cloud within our glass, which is affected by the passing through of such particles. More importantly, what are these contrails going to look like, and what do they mean exactly? It's up to you whether you want to get specific as to the types of particles observed, and whether you want to go in depth into the alcohol ionization aspects. We've found it best not to go too in depth with the ionization angle, but sometimes naming the types of particles is handy (especially since the trails seen are distinct and identifiable).

We have a video of the cloud contrails in our slide show as well (a re-edited and looped clip from http://www.youtube.com/watch?v=mI1FPT0U8Qo). This video is best seen in the dark, and also gives an idea of what the kids are hoping to see.

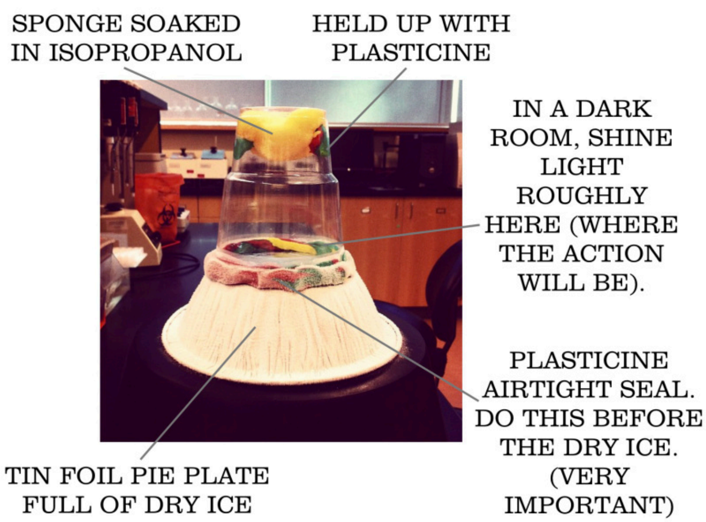
One way to explain it, is to stress that the angle of how you shine the LED light into the container, and where you stand to look for things is important. What you want to see is something that looks a little like a mini snow storm at the place where the base of the foil. A sub atomic particle will be a super fast occurrence where it looks like something has streaked across that cloud leaving a trail. These are events are not super common, and they also happen VERY quickly. Patience is key!

5. Equilibriation of cloud chambers on dry ice, and the hunt! (20 minutes)

Now, we move into the windowless room (we have a lecture hall that works well for us). This is also when the dry ice step is being used.

Take the cloud chambers, and place them on the dry ice (or fill pie plates with dry ice). Again, highlight the safety issues around working with dry ice. It can cause mild frost burn if handled too long with bare hands. Definitely no ingestion, and make sure no-one takes some for playing with later (for instance, you definitely want to avoid keeping dry ice in a sealed container, as it will rupture once the CO2 sublimates!)

Anyway, when all is set up, it should look something like this:



Then it's away we go with the particle hunting. Lights out, LEDs on, and usually, kids can easily spend 10 minutes just looking for stuff. Re-emphasize the importance of patience, as well as light placement (and looking out for the mini snow storm).

Students may see a variety of different contrails. In general, they identify the following particles:

Thick, straight tracks: Alpha particles (these probably look the most impressive).
Thin tracks, often in a zig zag pathway: Electrons.
Thin, straight tracks: Muons (which is kind of like a heavy electron).

If a cloud chamber isn't working so well, students will also find the following alternative activity pretty neat. Here, you would break the seal between the foil and container, and if you blow into the leaked space, you can see your breath condensate which looks very cool.

6. And that's a wrap! (<5 minutes)

Thank the class for their hard work, and as a wrap up (if there's left over time), you can ask the class if they have any physics related questions.