Cryotech STEM Demo

Freeze Point Depression and Ice Cream Treat

Item list:

* 5 oz. of white vinegar
* 12 g. baking soda (1 lb is 454 g., but they’re not going to be able to measure it accurately, and it’s not expensive, so figure on a box for about 20-25 kids)
* 3 oz. salt (any variety—table salt, canning salt, Kosher, whatever…it doesn’t matter)
* 4 fl. oz. (1/2 cup) of whole milk
* 2 Tbsp sugar
* ½ tsp of vanilla extract (get the cheap stuff)
* 6-7 ice cubes (or about 2 cups if you just get bags of ice).  If you need a cooler or two, I have about a billion of them.
* 1 Dixie cups—the small ones for bathrooms (3 oz)—for scooping the ice cream into to eat
* 1 quart size plastic ziploc-style bag
* 1 gallon size plastic ziploc-style bag
* 2 plastic spoons
* 1 16-oz plastic cup (clear Solo cups if you can get them because they have indentations on the sides and can be used to measure)
* some paper towels

Videos shown during demo:

<https://vimeo.com/465774850/b67552274d>

<https://weather.com/storms/winter/video/the-science-of-deicing-a-plane>

Script:

Hi. I’m Kim Engle. I’m a chemist at Cryotech Deicing Technology.

Cryotech is located in Fort Madison and we make deicing chemicals mostly for airports. Some are for deicing the airplanes themselves to get all the ice and snow and frost off the wings before they take off. And some are for the pavements—the runways, taxiways, and aprons where the airplanes park to load passengers.

Today I’m going to be talking to you about the chemistry of freeze point depression and how that works to remove ice from pavement, and also how you can use the same chemistry to make a tasty treat.

First we’re going to prepare the base of our tasty treat.

1. In the cup, add about an inch of milk. (~1/4 cup)
2. Add about a spoonful of sugar (plastic picnic spoon)
3. Add about a half spoonful of vanilla flavoring and stir.
   1. Here’s a useful chemistry tip that allows me to yap long enough to get all the sugar dissolved: Vanilla flavoring comes in two varieties—pure vanilla extract (comes in a tiny bottle that’s about $8) and imitation vanilla (comes in a big bottle for $2). Buy the cheap stuff. Both get their flavor from a chemical called vanillin. Chemists can easily make vanillin in a lab--chemically identical to natural vanilla. But they don’t. In the imitation stuff, they make a very slight improvement to it.

Vanillin is a fragile molecule and breaks down when you heat it They add an extra carbon atom and make a compound called ethyl vanillin which is a lot more stable and has about 4x the vanilla flavor as natural vanillin. So if you make a cake with pure vanilla extract, by the time you take it out of the oven, the vanillin is mostly long gone, and you’ll have hardly any flavor. But if you make the same cake with the imitation vanilla, the compound will still be there and your baked good will taste a lot better. So, for “better living through chemistry”, buy the cheap stuff. It’s a better product.

1. Now carefully pout that into the smaller (qt. size Ziploc), seal the bag and set it aside.

Cryotech specializes in pavement deicers based on acetate chemistry. Acetates are basically a special type of salt made from acetic acid. Acetic acid is the acid in vinegar. We combine acetic acid with sodium hydroxide to make sodium acetate. Sodium acetate is one of our main products. And you’re going to make it now using vinegar (which is very diluted acetic acid) and baking soda (which is sodium bicarbonate). This isn’t exactly how Cryotech makes it—we use much more concentrated acetic acid and sodium hydroxide. But the end product is exactly the same—sodium acetate.

1. First fold a couple paper towels in half and set them aside. They’re for later.
2. In the big (gallon size) Ziploc bag, add 4 spoonfuls of baking soda (level or just slightly rounded).
3. Then, we’re going to add a little regular salt to it here even though Cryotech doesn’t do this. This is because here we’re using much more dilute (weaker) ingredients than we do in our plant. So add about 4 heaping spoonfuls of salt (any kind…table salt, Kosher, etc.). Set that aside.
4. In the cup, add about an inch of vinegar (~1/4 cup)—don’t worry if there’s a little milk schmutz left in the cup. It won’t hurt anything.
5. Now, carefully pour the vinegar into the large bag and watch all the bubble action. This is carbon dioxide from the sodium bicarbonate leaving quickly. That’s fine, we don’t need it. We want the sodium part, which stays behind. As the bubbling calms down, gently slosh it around a little.
6. When the bubbling has stopped, add about 7 ice cubes.
7. Then drop in the bag of milk and seal up the top.

Now we slosh back and forth and mix with our hands—very gently.

While we’re sloshing, I can tell you a little about the types of jobs we have available at Cryotech that require STEM skills.

* **Plant operators.** These are the people who run the equipment that actually makes the acetate deicers. A lot of the equipment is automated, but it needs smart people with good computer and science skills to make it work. These jobs don’t usually require a college degree, but you definitely need at least decent grades in high school chemistry and some specialized training which is often available at a community college like SCC or experience on-the-job. A lot of times, we hire people as baggers and packagers and then cross-train them if they have interest and ability to become plant operators.
* **Chemical technicians** to run the lab instruments that tell us if we’re making good in-spec product. This job requires at least an associated degree in chemistry—like you can get at a community college.
* **Chemists.** These jobs require at least a bachelor’s degree in chemistry and entail a lot of problem solving—to answer any questions customers might have when using our products and also R&D to continuously make improvements to the products.
* **Chemical and Mechanical engineers.** These jobs help design the big tanks and the plant equipment (pumps, piping, how to move large quantities of materials safely) and also require a bachelor’s degree.
* **Environmental and safety engineers.** This job is specially trained in occupational health and safety and environmental protection. We use some very strong chemicals and we need to make sure we protect our workers and also make sure we are not releasing anything hazardous into the environment.

By now you should be noticing that your mixture is getting very cold—colder than when you started. Why?

It is because of a property called Freeze Point Depression.

If you had a mixture of equal amounts of ice and water in some kind of extremely efficient cooler that completely prevented any heat from getting in or out, you would find that it would remain that way indefinitely. It would stay at exactly 32°F—the freeze point of water. Ice on the surface would melt, but water would also refreeze on the ice surface at the same rate, so that you would always have the same amount of ice and water you started with.

But what happens when you add other soluble particles like sodium acetate or sodium chloride to water? Those particles are bigger than water molecules and they get between them and prevent them from being able to find each other to link up to form ordered ice crystals. So the ice melts, but can’t refreeze.

It’s like if you and were friends were in an empty room, it would be easy for you to find each other to hang out. But you were in a room full of giant boxes (like refrigerators come in) that blocked pathways, you would have a harder time getting together into a group. Or only a couple of you could get together at a time to “freeze” into an ordered group. So that’s what going on with the ice in your bag. The water molecules are like you and your friends. But the boxes are like the deicer molecules.

Heat is being lost because the ice is melting. Melting requires heat. This heat mostly comes from the inside of the ice cubes traveling to the ice surface because it’s easier for heat to travel through a solid than through liquid or gas. It’s weird to think of ice cubes holding heat, but they do. They are the temperature of the freezer they just came out of. Most freezers are are about 0-5°F, but Cryotech has some that are -80°F.

But the heat isn’t returned because the ice isn’t refreezing. This is because the sodium acetate and chloride particles prevent the water molecules from joining back up. So, the ice cubes themselves are losing heat faster than they’re gaining it back and they’re getting colder and colder—as you can probably start to feel and you’re probably switching hands more. And here’s where those folded paper towels might come in handy. Use them like an oven mitt to protect your hands from the cold.

And this is exactly how these same chemicals work to melt ice on roadways and runways. The melted ice cannot refreeze and the pavement stays clear of ice and snow.

Ok, it’s going to take a few more minutes for the milk to freeze as its heat is being transferred to the cold ice/salt mixture you have. While you’re sloshing, make sure you have at least some solid ice left in the bag. If all your ice melts, no problem--just carefully open your bag and add another ice cube and continue sloshing.

So here are a couple videos that show our Fort Madison Cryotech plant and one from the Weather Channel that shows how airplanes themselves are deiced in the winter. (That’s different chemistry than we are doing here, but it’s cool and Cryotech make those kinds of products, too.)

Ok, by now, your milk mixture should be pretty frozen and thick and you can carefully take it out and enjoy!