

How can freezing make something warmer?

A laboratory experiment from the Little Shop of Physics at Colorado State University



Overview

We normally think of water as freezing at 0°C (32°F). But this is an oversimplification. Liquid water can be cooled to a temperature as low as -40°C (-40°F) without freezing. Water, or any other liquid, that is still liquid at a temperature below its freezing point is *supercooled*.

Once a supercooled liquid begins to freeze, it will freeze quickly. And as it freezes it gives off heat energy. This experiment uses a heat pack as the central element. Once you create one solid crystal, the rest of the liquid will quickly turn solid—it will freeze. As it does so, it gives off heat energy. This *freezing* makes the heat packs *warmer!* A freezing liquid keeps your hands warm!

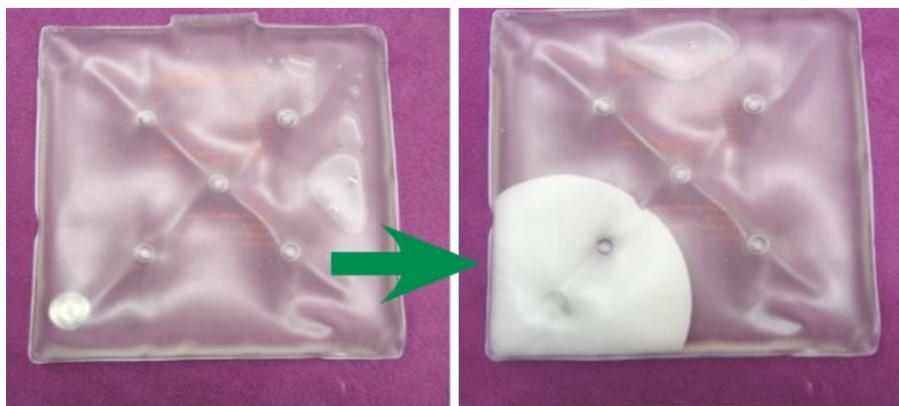
Theory

You know that an ice cube will cool your drink. As the ice cube melts, it absorbs heat energy from its surroundings. Water molecules frozen in the form of ice are tightly bound. Water molecules in the form of liquid aren't. So to turn a solid into a liquid means breaking bonds, and that takes energy. As the ice melts, it cools off its surroundings.

Necessary materials:

- Sodium acetate reusable heat pack
- Thermometer

The heat pack is the key element. These are pretty easy to find; look for “reusable heat pack.” The pack is filled with a solution of sodium acetate. When you pop the disk in the pack, the solution freezes, releasing heat. But you can melt the resulting solid by adding heat. This is a simple matter of placing the pack in a pan on the stove and boiling it for 20 minutes.



Once the disk is popped, the heat pack freezes.

Now, think about freezing. When you make ice cubes, you put liquid water in the freezer. The freezer cools the water, taking energy out. When ice melts, it takes in energy; when it freezes, it must release energy.

This taking in and releasing of energy is a very important process for the earth. Ice can melt in one

place (taking in heat) then the resulting water can flow to another place and freeze there (giving off heat). Not only has water moved from one place to another, so has the heat energy.

The heat packs for this experiment contain a sodium acetate solution that freezes at 60 °C, but that can be easily supercooled. If you boil the packs in water, the sodium acetate melts. As the packs cool, it stays liquid; at room temperature, it is well below its freezing point, but it is still liquid. When you “pop” the metal disk, you create a small region of rapid expansion and cooling, forming a single crystal of frozen sodium acetate which “seeds” the rest of the pack, which will quickly begin to freeze.

The key thing to notice is this: As the pack freezes, it gives off heat, as it must. Some of the liquid freezes, warming the pack to 60 °C. Now the freezing continues; the pack will stay at 60 °C, the freezing point, as this happens, giving up heat as the freezing proceeds. The pack will stay at 60 °C until it is all frozen.

You can melt the solid sodium acetate again by boiling a heat pack on the stove. When you do this, you put heat in. This heat is released when the pack freezes again. The packs thus move heat from one place to another. You put heat in using the stove in your kitchen; the liquid stores this heat which is then released when the pack freezes. *The heat that warms your hand ultimately came from someone’s stove!*

Doing the Experiment

This can be done as a very short activity, in which students simply induce freezing and then watch the process, or you could do a more involved experiment involving detailed measurements.

We’ll start with the simple version. First, the usual safety note:

SAFETY NOTE: The contents of the packet aren’t toxic; this is food-grade sodium acetate. But when the packet freezes, it gets quite hot. (It is a heat pack, after all!) It can be hot enough to be uncomfortable, and may cause minor burns if you aren’t careful.

The short version of the experiment goes like this:

- Pass out the heat packs. Ask your students to tell you what phase of matter is in the packs. Have them note the temperature.
- Now have them watch the packs closely and pop the disk. Let them observe for a few minutes.
- Have your students explain what they see.

Here’s the crucial piece:

The packs are freezing, but they warm up and give off heat energy as they do so.

This can be the basis for a good discussion of supercooling, phase transitions and energy.

If you want to do more, measure the temperature as a function of time. And then try this with an insulate pack. As the packs freeze, they stay at the freezing point. If you insulate a pack, it will stay warm for a longer time. To freeze the pack, all of the heat released in the freezing must be released. If there is insulation, this takes longer!

Summing Up

This is a quick and dramatic experiment that you can use as a springboard from some great discussions of the physics behind the transport of energy in the atmosphere.

For More Information

CMMAP, the Center for Multi-Scale Modeling of Atmospheric Processes: <http://cmmmap.colostate.edu>

Little Shop of Physics: <http://littleshop.physics.colostate.edu>