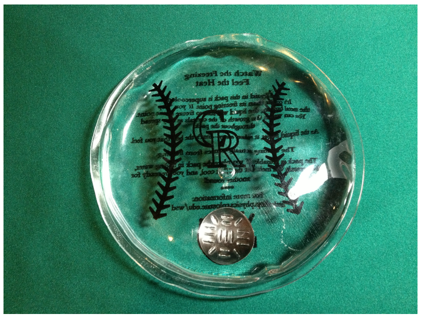
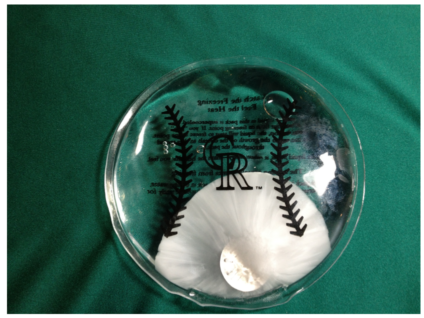
How does freezing make something warmer?

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

Once the disk is popped, the heat pack begins to freeze.

Grade Level

- 3rd and above

Science Focus

- Supercooled
- Phase transition
- Energy out

Time Required

- 15 minutes

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!

Necessary materials:

- 30 reusable heat packs
- Hot plate and kettle, or crockpot, tongs, and cloth

The reusable heat pack is the key element. The pack is filled with a solution of sodium acetate. When you pop the disk in the pack, the supercooled solution freezes, releasing heat. But you can melt the resulting solid by adding heat. This is a simple matter of placing the pack on a cloth in a pan, then boiling it on a stove for 20 minutes. Remove with tongs, place on a paper towel, and let cool to room temperature before using again.

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 as 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.

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 will be done as a very short activity, in which students simply induce freezing and then watch the process. 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.

Pass out the heat packs. Ask your students to tell you what phase of matter is in the packs. Have them note the temperature–how they feel.

Now have them watch the packs closely and pop the disk. Let them observe for a few minutes. Some of the disks in these packs are very stiff and difficult to pop. You may need to assist your students.

Have your students explain what they see and feel.

You may want to ask them the follwing questions: What happened after you clicked the metal disk inside? (It started to turn white near the metal and eventually, the whole heat pack turned white.) What happened to the temperature? (It went up.) How did the pack feel? (Hot, squishy, could bend it some) What phase change is happening? (It's changing from a liquid to a solid.)

Why do you think it is giving up heat as it is freezing? (All phase changes involve heat energy–taking it in or giving it off. If something is moving from higher energy to lower energy state–liquid to solid–the molecules are becoming less energetic and they give off their thermal energy.

Discuss what is inside the heat packs.(A food preservative called Sodium Acetate. It freezes at 60˚C so when it is liquid at the room temperature of the classroom, it is below it's freezing point. We call it **supercooled**).

Why do you need to snap the metal disk to start the freezing process? (When you flex the metal disk, it creates a a small region of rapid expansion and becomes very cold in that spot. A small bubble forms, creating a nucleation site for the crystals to form. One crystal forms, then more, and more.)

Help your students put energy back into the heat packs by cooking them on low in a crockpot, or boiling them for about 20 minutes in a kettle. By doing this, they will observe another phase transition–solid to liquid. If the molecules are moving from lower energy to a high energy state–solid to liquid–they are becoming more energetic and taking in heat energy from the surroundings.)

Summing Up:

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.

For More Information:

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

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