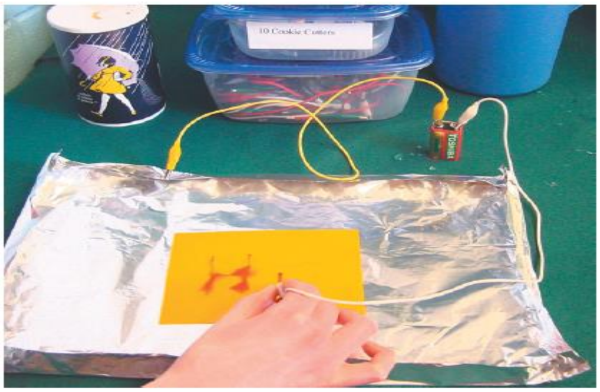
# Writing With Electricity

*Students will be able to brand designs and write on goldenrod paper while exploring*

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



### Necessary materials:

- 1 9V battery
- 2 alligator clips
- 1 aluminum foil sheet or baking pan
- 1 uncoated metal cookie cutter
- Several sheets of goldenrod paper soaked in salt water

## Doing the Activity

Hook one end of the first alligator clip to the positive terminal of the 9V battery and then hook the other end to the aluminum foil or the aluminum baking dish.

- Place a sheet of the salt water-soaked goldenrod paper on the foil of in the bottom of the baking dish
- Take the second alligator clip and hook it to the negative terminal of the 9V battery
- Touch the other end of the second alligator clip to the goldenrod paper and write or draw on it. What happens? (The goldenrod paper turns red wherever the negative electrode touches it.)
- Attach the cookie cutter to the loose end of the second alligator clip and use it to press designs on the paper like a brand.
- Try switching how the alligator clips are attached to the 9V battery so you're reversing the polarity. What happens now? (The red marks move to the bottom side of the paper.)

## Active Questioning, Explanation, and Discussion

What is going on?

Goldenrod paper has a chemical from the goldenrod plant used in the dye. Since the yellow part of this molecule is positive and is attracted to the negative electrode, it leaves the red part of the molecule in the paper.

When you hook the up the alligator clips so you are writing with the positive electrode instead, the yellow part of the molecule is repelled from the positive electrode and collects under the paper at the aluminum foil which is now the negative side, leaving the red part of the molecule in the underside of the paper.)

Will this work with dry goldenrod paper or goldenrod paper soaked only in water?

No. Dry paper or paper soaked in plain water are not good conductors, so the circuit is not completed or closed. Salt water is an electrolyte solution that allows the circuit to be completed and electricity to flow.

## Resources:

How to make goldenrod paper:
http://www.ehow.com/how_5869678_make-goldenrod-paper.html

More information about goldenrod paper:
http://blog.teachersource.com/2009/10/01/goldenrod-paper/

Where to buy goldenrod paper (sometimes called Astrobright Galaxy Gold):
https://www.teachersource.com/
https://www.stevespanglerscience.com/

CSU Little Shop of Physics:
http://lsop.colostate.edu/index.html

## Books at Poudre River Public Library (http://www.poudrelibraries.org/)

Gardner Conklin, Barbara and Gardner, Robert
*Chemistry science fair projects using french fries, gumdrops, soap, and other organic stuff*
Call No. 547.0078 Gardner, R. 2004

Gardner, Robert
*Melting, freezing, and boiling science projects with matter*
507.8 Gardner, R. 2006

Newmark, Ann
*Chemistry*
Call No.: 540 Newmark, A. 2005

Stille, Darlene R.
*Temperature: heating up and cooling down*
eBook

Stine, Megan
*Who was Marie Curie?*
Call No.: Curie, M, 2014

Ignotofsky, Rachel
*Women in science: 50 fearless pioneers who changed the world*
Call No.: 509.525 Ignotofsky, R. 2016

# How can freezing make something warmer?

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

## 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.

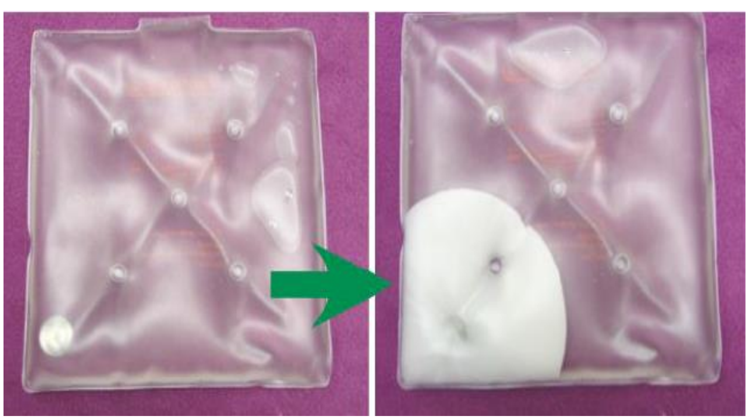
When you pop the disk in the pack, the solution freezes, releasing heat. But you can melt the resulting solid by adding heat. This is a simple matter of placing the pack in a pan on the stove and boiling it for 20 minutes.

## 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. To turn a solid into a liquid means breaking bonds, and that takes energy. As the ice melts, it cools off its surroundings.



*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://cmmap.colostate.edu

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

# Homemade Ice Cream

## Ingredients

½ c. whole milk
3 sugar cubes
½ t. vanilla
Chocolate syrup (optional)

## Equipment

Large sealable storage bag
Small sealable storage bag
Rock salt

## Procedures:

1. Put a handful of ice into the large storage bag.
2. Measure carefully and put milk, vanilla, and sugar cubes into the small storage bag (leave out the sugar if you are making chocolate.)
3. Carefully squeeze all the air out of the small bag and seal it.
4. Place the sealed smaller bag (with the milk mixture) into the larger bag with the ice.
5. Add 6 tablespoons rock salt to the large ice bag and seal the large bag
6. Squeeze the ice bag gently, shifting from side to side, until the milk mixture looks thick
7. Remove the small Ziploc bag and rinse off the outside.
8. Open the bag and eat your ice cream

# Los Alamos National Laboratory Chemistry Division

## Periodic Table of the Elements

| 1A | 2A | 3B | 4B | 5B | 6B | 7B | 8B | | | 11B | 12B | 3A | 4A | 5A | 6A | 7A | 8A |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 H $1s^1$ hydrogen 1.008 | | | | | | | | | | | | | | | | | 2 He $1s^2$ helium 4.003 |
| 3 Li $[He]2s^1$ lithium 6.94 | 4 Be $[He]2s^2$ beryllium 9.012 | | | | | | | | | | | 5 B $[He]2s^22p^1$ boron 10.81 | 6 C $[He]2s^22p^2$ carbon 12.01 | 7 N $[He]2s^22p^3$ nitrogen 14.01 | 8 O $[He]2s^22p^4$ oxygen 16.00 | 9 F $[He]2s^22p^5$ fluorine 19.00 | 10 Ne $[He]2s^22p^6$ neon 20.18 |
| 11 Na $[Ne]3s^1$ sodium 22.99 | 12 Mg $[Ne]3s^2$ magnesium 24.31 | | | | | | | | | | | 13 Al $[Ne]3s^23p^1$ aluminum 26.98 | 14 Si $[Ne]3s^23p^2$ silicon 28.09 | 15 P $[Ne]3s^23p^3$ phosphorus 30.97 | 16 S $[Ne]3s^23p^4$ sulfur 32.06 | 17 Cl $[Ne]3s^23p^5$ chlorine 35.45 | 18 Ar $[Ne]3s^23p^6$ argon 39.95 |
| 19 K $[Ar]4s^1$ potassium 39.10 | 20 Ca $[Ar]4s^2$ calcium 40.08 | 21 Sc $[Ar]4s^23d^1$ scandium 44.96 | 22 Ti $[Ar]4s^23d^2$ titanium 47.88 | 23 V $[Ar]4s^23d^3$ vanadium 50.94 | 24 Cr $[Ar]4s^13d^5$ chromium 52.00 | 25 Mn $[Ar]4s^23d^5$ manganese 54.94 | 26 Fe $[Ar]4s^23d^6$ iron 55.85 | 27 Co $[Ar]4s^23d^7$ cobalt 58.93 | 28 Ni $[Ar]4s^23d^8$ nickel 58.69 | 29 Cu $[Ar]4s^13d^{10}$ copper 63.55 | 30 Zn $[Ar]4s^23d^{10}$ zinc 65.39 | 31 Ga $[Ar]4s^23d^{10}4p^1$ gallium 69.72 | 32 Ge $[Ar]4s^23d^{10}4p^2$ germanium 72.64 | 33 As $[Ar]4s^23d^{10}4p^3$ arsenic 74.92 | 34 Se $[Ar]4s^23d^{10}4p^4$ selenium 78.96 | 35 Br $[Ar]4s^23d^{10}4p^5$ bromine 79.90 | 36 Kr $[Ar]4s^23d^{10}4p^6$ krypton 83.79 |
| 37 Rb $[Kr]5s^1$ rubidium 85.47 | 38 Sr $[Kr]5s^2$ strontium 87.62 | 39 Y $[Kr]5s^24d^1$ yttrium 88.91 | 40 Zr $[Kr]5s^24d^2$ zirconium 91.22 | 41 Nb $[Kr]5s^14d^4$ niobium 92.91 | 42 Mo $[Kr]5s^14d^5$ molybdenum 95.96 | 43 Tc $[Kr]5s^24d^5$ technetium (98) | 44 Ru $[Kr]5s^14d^7$ ruthenium 101.1 | 45 Rh $[Kr]5s^14d^8$ rhodium 102.9 | 46 Pd $[Kr]4d^{10}$ palladium 106.4 | 47 Ag $[Kr]5s^14d^{10}$ silver 107.9 | 48 Cd $[Kr]5s^24d^{10}$ cadmium 112.4 | 49 In $[Kr]5s^24d^{10}5p^1$ indium 114.8 | 50 Sn $[Kr]5s^24d^{10}5p^2$ tin 118.7 | 51 Sb $[Kr]5s^24d^{10}5p^3$ antimony 121.8 | 52 Te $[Kr]5s^24d^{10}5p^4$ tellurium 127.6 | 53 I $[Kr]5s^24d^{10}5p^5$ iodine 126.9 | 54 Xe $[Kr]5s^24d^{10}5p^6$ xenon 131.3 |
| 55 Cs $[Xe]6s^1$ cesium 132.9 | 56 Ba $[Xe]6s^2$ barium 137.3 | * | 72 Hf $[Xe]6s^24f^{14}5d^2$ hafnium 178.5 | 73 Ta $[Xe]6s^24f^{14}5d^3$ tantalum 180.9 | 74 W $[Xe]6s^24f^{14}5d^4$ tungsten 183.9 | 75 Re $[Xe]6s^24f^{14}5d^5$ rhenium 186.2 | 76 Os $[Xe]6s^24f^{14}5d^6$ osmium 190.2 | 77 Ir $[Xe]6s^24f^{14}5d^7$ iridium 192.2 | 78 Pt $[Xe]6s^14f^{14}5d^9$ platinum 195.1 | 79 Au $[Xe]6s^14f^{14}5d^{10}$ gold 197.0 | 80 Hg $[Xe]6s^24f^{14}5d^{10}$ mercury 200.5 | 81 Tl $[Xe]6s^24f^{14}5d^{10}6p^1$ thallium 204.4 | 82 Pb $[Xe]6s^24f^{14}5d^{10}6p^2$ lead 207.2 | 83 Bi $[Xe]6s^24f^{14}5d^{10}6p^3$ bismuth 209.0 | 84 Po $[Xe]6s^24f^{14}5d^{10}6p^4$ polonium (209) | 85 At $[Xe]6s^24f^{14}5d^{10}6p^5$ astatine (210) | 86 Rn $[Xe]6s^24f^{14}5d^{10}6p^6$ radon (222) |
| 87 Fr $[Rn]7s^1$ francium (223) | 88 Ra $[Rn]7s^2$ radium (226) | ** | 104 Rf $[Rn]7s^25f^{14}6d^2$ rutherfordium (267) | 105 Db $[Rn]7s^25f^{14}6d^3$ dubnium (268) | 106 Sg $[Rn]7s^25f^{14}6d^4$ seaborgium (269) | 107 Bh $[Rn]7s^25f^{14}6d^5$ bohrium (270) | 108 Hs $[Rn]7s^25f^{14}6d^6$ hassium (277) | 109 Mt $[Rn]7s^25f^{14}6d^7$ meitnerium (278) | 110 Ds $[Rn]7s^15f^{14}6d^9$ darmstadtium (281) | 111 Rg $[Rn]7s^15f^{14}6d^9$ roentgenium (282) | 112 Cn $[Rn]7s^15f^{14}6d^9$ copernicium (285) | 113 Nh $[Rn]7s^27p^15f^{14}6d^{10}$ (predicted)[1] nihonium (286) | 114 Fl $[Rn]7s^27p^25f^{14}6d^{10}$ (predicted)[2] flerovium (289) | 115 Mc $[Rn]7s^27p^35f^{14}6d^{10}$ (predicted)[1] moscovium (289) | 116 Lv $[Rn]7s^27p^45f^{14}6d^{10}$ (predicted)[1] livermorium (293) | 117 Ts $[Rn]7s^27p^55f^{14}6d^{10}$ (predicted)[4] tennessine (294) | 118 Og $[Rn]7s^27p^65f^{14}6d^{10}$ (predicted)[1][2] oganesson (294) |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lanthanide Series* | 57 La $[Xe]6s^25d^1$ lanthanum 138.9 | 58 Ce $[Xe]6s^24f^15d^1$ cerium 140.1 | 59 Pr $[Xe]6s^24f^3$ praseodymium 140.9 | 60 Nd $[Xe]6s^24f^4$ neodymium 144.2 | 61 Pm $[Xe]6s^24f^5$ promethium (145) | 62 Sm $[Xe]6s^24f^6$ samarium 150.4 | 63 Eu $[Xe]6s^24f^7$ europium 152.0 | 64 Gd $[Xe]6s^24f^75d^1$ gadolinium 157.2 | 65 Tb $[Xe]6s^24f^9$ terbium 158.9 | 66 Dy $[Xe]6s^24f^{10}$ dysprosium 162.5 | 67 Ho $[Xe]6s^24f^{11}$ holmium 164.9 | 68 Er $[Xe]6s^24f^{12}$ erbium 167.3 | 69 Tm $[Xe]6s^24f^{13}$ thulium 168.9 | 70 Yb $[Xe]6s^24f^{14}$ ytterbium 173.0 | 71 Lu $[Xe]6s^24f^{14}5d^1$ lutetium 175.0 |
| Actinide Series** | 89 Ac $[Rn]7s^26d^1$ actinium (227) | 90 Th $[Rn]7s^26d^2$ thorium 232 | 91 Pa $[Rn]7s^25f^26d^1$ protactinium 231 | 92 U $[Rn]7s^25f^36d^1$ uranium 238 | 93 Np $[Rn]7s^25f^46d^1$ neptunium (237) | 94 Pu $[Rn]7s^25f^6$ plutonium (244) | 95 Am $[Rn]7s^25f^7$ americium (243) | 96 Cm $[Rn]7s^25f^76d^1$ curium (247) | 97 Bk $[Rn]7s^25f^9$ berkelium (247) | 98 Cf $[Rn]7s^25f^{10}$ californium (251) | 99 Es $[Rn]7s^25f^{11}$ einsteinium (252) | 100 Fm $[Rn]7s^25f^{12}$ fermium (257) | 101 Md $[Rn]7s^25f^{13}$ mendelevium (258) | 102 No $[Rn]7s^25f^{14}$ nobelium (259) | 103 Lr $[Rn]7s^25f^{14}6d^1$ lawrencium (262) |

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CHEMISTRY

element names in **blue** are liquids at room temperature
element names in **red** are gases at room temperature
element names in **black** are solids at room temperature

3/13/17