THERMODYNAMICS & ICE CREAM

From Wikipedia

Thermodynamics is the branch of physics concerned with heat and temperature and their relation to energy and work. The behavior of these quantities is governed by the four laws of thermodynamics, irrespective of the composition or specific properties of the material or system in question.

Thermodynamics is principally based on a set of four laws which are universally valid when applied to systems that fall within the constraints implied by each. In the various theoretical descriptions of thermodynamics these laws may be expressed in seemingly differing forms, but the most prominent formulations are the following:

- **Zeroth law of thermodynamics**: ***If two systems are each in thermal equilibrium with a third, they are also in thermal equilibrium with each other.***

This statement implies that thermal equilibrium is an equivalence relation on the set of thermodynamic systems under consideration. Systems are said to be in equilibrium if the small, random exchanges between them (e.g. Brownian motion) do not lead to a net change in energy. This law is tacitly assumed in every measurement of temperature. Thus, if one seeks to decide if two bodies are at the same temperature, it is not necessary to bring them into contact and measure any changes of their observable properties in time.[24] The law provides an empirical definition of temperature and justification for the construction of practical thermometers.

The zeroth law was not initially recognized as a law, as its basis in thermodynamical equilibrium was implied in the other laws. The first, second, and third laws had been explicitly stated prior and found common acceptance in the physics community. Once the importance of the zeroth law for the definition of temperature was realized, it was impracticable to renumber the other laws, hence it was numbered the *zeroth law*.

- **First law of thermodynamics**: ***The internal energy of an isolated system is constant.***

The first law of thermodynamics is an expression of the principle of conservation of energy. It states that energy can be transformed (changed from one form to another), but cannot be created or destroyed.[25]

The first law is usually formulated by saying that the change in the internal energy of a closed thermodynamic system is equal to the difference between the heatsupplied to the system and the amount of work done by the system on its surroundings. It is important to note that internal energy is a state of the system (see Thermodynamic state) whereas heat and work modify the state of the system. In other words, a change of internal energy of a system may be achieved by any combination of heat and work added or removed from the system as long as those total to the change of internal energy. The manner by which a system achieves its internal energy is path independent.

- **Second law of thermodynamics**: ***Heat cannot spontaneously flow from a colder location to a hotter location.***

The second law of thermodynamics is an expression of the universal principle of decay observable in nature. The second law is an observation of the fact that over time, differences in temperature, pressure, and chemical potential tend to even out in a physical system that is isolated from the outside world. Entropy is a measure of how much this process has progressed. The entropy of an isolated system which is not in equilibrium will tend to increase over time, approaching a maximum value at equilibrium. However, principles guiding systems that are far from equilibrium are still debatable. One of such principles is the maximum entropy production principle.[26][27] It states that non-equilibrium systems behave such a way as to maximize its entropy production.[28]

In classical thermodynamics, the second law is a basic postulate applicable to any system involving heat energy transfer; in statistical thermodynamics, the second law is a consequence of the assumed randomness of molecular chaos. There are many versions of the second law, but they all have the same effect, which is to explain the phenomenon of irreversibility in nature.

- **Third law of thermodynamics**: ***As a system approaches absolute zero, all processes cease and the entropy of the system approaches a minimum value.***

The third law of thermodynamics is a statistical law of nature regarding entropy and the impossibility of reaching absolute zero of temperature. This law provides an absolute reference point for the determination of entropy. The entropy determined relative to this point is the absolute entropy. Alternate definitions are, "the entropy of all systems and of all states of a system is smallest at absolute zero," or equivalently "it is impossible to reach the absolute zero of temperature by any finite number of processes".

Absolute zero, at which all activity would stop if it were possible to happen, is −273.15 °C (degrees Celsius), or −459.67 °F (degrees Fahrenheit), or 0 K (kelvin), or 0° R (degrees Rankine).

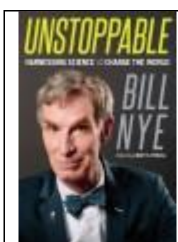
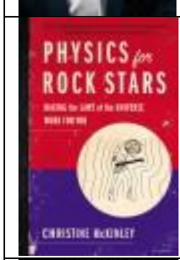
Definitions:

Entropy

1. PHYSICS: a thermodynamic quantity representing the unavailability of a system's thermal energy for conversion into mechanical work, often interpreted as the degree of disorder or randomness in the system.

2. lack of order or predictability; gradual decline into disorder.
   "a marketplace where entropy reigns supreme"
   synonyms: deterioration, degeneration, crumbling, decline, degradation, decomposition, breaking down, collapse; More

Additional Reading Material Available at the Library:

	**Unstoppable : harnessing science to change the world / Bill Nye ; edited by Corey S. Powell** Nye, Bill, BOOK | 2015
	**Physics for rock stars : making the laws of the universe work for you / Christine McKinley** McKinley, Christine (Mechanical engineer), BOOK | 2014
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ICE CREAM THERMODYNAMICS LAB

http://www.scott.k12.ky.us/userfiles/1110/Classes/18674/Ice%20Cream%20Thermodynamics%20Lab%20modified.docx

SCIENCE NIGHT OBJECTIVES: To use both the laws of thermodynamics and properties of solutions to aid in freezing an ice cream mixture.

STATE THE QUESTION: How can you lower the freezing point of water in order to freeze an ice cream mixture?

GATHER INFORMATION: It's 35˚ C in the shade and to cool off, you are eating an ice cream cone. As you sit there you wonder just how ice cream is made. One area of chemistry that helps to explain the making of ice cream is thermodynamics. There are three laws of thermodynamics:

1. **The total amount of energy in the universe is constant.**
2. **The entropy (which is a measure of disorder) of the universe is always increasing.**
3. **Everything with a temperature above 0˚ K has energy.**

In making ice cream you remove about 1000 calories of heat from the milk/sugar (chocolate milk) mixture and transfer it to the salt/ice mixture. *Energy is conserved* and the first law is satisfied. Heat is always transferred from a hot object to a cooler one. Imagine your surprise if you had a glass of water and the water froze and the glass got hot. *The 2nd law determines the direction of heat transfer and states heat always moves from a hot object to a cooler one.*

Another aspect of chemistry involved is the properties of solutions as compared to pure solvents. The presence of solute (the thing being dissolved) particles in a solution will raise the boiling point and lower the freezing point of the solvent (the dissolver). Therefore, because the ice cream mixture is mainly a solution of sugar and water, its freezing point is depressed below 0˚ C.

Before refrigerators were invented, ice cream was made using ice. In this method, the "hot" ice cream mixture has to lose energy to the "cold" ice. Since ordinary ice is only 0˚ C, this is the lowest temperature that the ice cream could become. The ice cream mixture would still be a liquid.

To freeze the ice cream mixture, it is necessary to use "colder" ice. Again, properties of solutions provide the answers. A salt-ice mixture has a lower freezing point than pure ice, so it acts as "colder" ice. The more salt added to the ice, the lower the freezing point. The ice cream mixture can then lose more energy to the salt-ice mixture and freeze.

CONDUCT THE EXPERIMENT

MATERIALS:

ICE CREAM MIXTURE:

- Quart size Ziploc bag
- 1 cup of milk
- Sugar
- Vanilla

MAKING THE ICE CREAM MATERIALS:

- Gallon size Ziploc bag
- Ice
- Rock salt

PROCEDURE:

PART 1:

1. Add 1 cup of milk to smaller size Ziploc bag.
2. Seal the bag well. Try to make sure all of the air is out of the bag.
3. Mix the ingredients until they are blended.

PART 2:

4. Fill the gallon-sized Ziploc bag about half to three-fourths full with ice.
5. Add rock salt so that it is lightly coating the ice cubes, 2 tsp. is good.
6. Put the Ziploc sandwich bag with the ice cream mixture in it **(keep it sealed!)** into the gallon sized Ziploc bag.
7. Seal the gallon sized bag with as much of the air out as possible.
8. Wrap it in newspaper (insulator) and shake for 5 minutes really fast. it will be COLD!

PART 3:

9. Keep shaking until the ice cream reaches the consistency you prefer.
10. Get a plastic spoon, and enjoy your tasty thermal treat.

How Ice Cream Works

BY [ED GRABIANOWSKI]
HTTPS://SCIENCE.HOWSTUFFWORKS.COM/INNOVATION/EDIBLE-INNOVATIONS/ICE-CREAM3.HTM

There are many recipes out there for making your own ice cream at home, but did you know that you can make your own ice cream in five minutes using two Ziploc bags?

Here's what you'll need for this experiment:

- 1 tablespoon sugar
- ½ cup milk, cream, or half and half
- ¼ teaspoon vanilla extract (or other flavoring)
- 6 tablespoons salt
- Enough ice to fill the gallon-sized bag halfway
- 1 gallon-sized Ziploc bag
- 1 pint-sized Ziploc bag

STEP 1:

Photo courtesy Ed Grabianowski

Fill the gallon-sized bag halfway with ice. Add the salt.

STEP 2:

Photo courtesy Ed Grabianowski

Pour the milk, sugar, and vanilla extract into a bowl or other container and mix.

STEP 3:

Photo courtesy Ed Grabianowski

Carefully pour the mixture into the pint bag.

Step 4:

Photo courtesy Ed Grabianowski

Close the bag, making sure it is completely sealed.

STEP 5:

Photo courtesy Ed Grabianowski

Put the pint bag into the gallon bag.

Make sure the pint bag gets buried in the ice. Seal the gallon bag. Shake the bags vigorously for five minutes. You might want to use a towel to hold them, since they will be very cold and slippery from condensation.

STEP 6:

Photo courtesy Ed Grabianowski

Remove the pint bag, open it up, and grab a spoon.

Tips:

- Milk will provide a less rich, lower calorie ice cream, while using heavy cream will have the opposite effect.
- Ordinary table salt will work, but salt that has larger crystals, such as kosher salt or rock salt, will work much better. Mix the salt around in the ice and set aside.
- This method will make a small amount of ice cream, about enough for two people to enjoy. Experimenting with other methods can allow you to make more. One version uses two coffee cans of differing sizes instead of plastic bags.
- Flavor combinations are almost limitless. Chocolate syrup is a basic option, while various flavor extracts available in your grocery store's baking section can lead to more exotic variations. Try combining mint extract with chocolate, or adding small chocolate chips.

Science Sushi

At Home Science: Ice Cream Chemistry

By Christie Wilcox | February 26, 2013 9:00 am
http://blogs.discovermagazine.com/science-sushi/2013/02/26/at-home-science-ice-cream-chemistry/#.W5mWes5Kjcv

Here on Oahu this weekend, Sacred Hearts Academy is hosting it's 19th annual Science Symposium for Girls. It's a day full of fun science-y workshops that are free to attend for girls in 5th through 8th grade. Dr. Kira Krend, my roommate and a kick-butt, PhD-wielding biology teacher at Sacred Hearts Academy, is one of the awesome science teachers and professionals helping out with this year's symposium. So, a few weeks ago, we sat around the house brainstorming fun, short science experiments that the girls might enjoy. When I mentioned my favorite lab from high school chemistry, making ice cream, my roommie's eyes lit up. When she told her bosses her idea, they loved it — and so did the local news. They chose her symposium workshop as the feature for their advanced coverage. Which, of course, meant only one thing: the protocol had to be perfect.

Here's the general protocol for the experiment:

- Mix together 1/2 cup of half & half (or 1/4 cup of cream and 1/4 cup of milk), one tablespoon of sugar, and 1/4 tablespoon of vanilla and put in a quart-sized ziploc
- Fill a gallon ziploc 1/3 of the way with ice
- Add salt (rock salt or large granules, ideally)
- Place the ice cream ziploc inside the bag of ice and seal the bag
- Mix the ice/water around the inner bag for ten minutes

…and voilà! The bag of liquid ingredients is frozen into delicious ice cream!

Kira had never made ice cream in a bag before, so she wanted to make sure everything ran smoothly for the cameras, and since I was the one who suggested the lab in the first place, she turned to me for advice. Problem was, it had been over a decade since my last attempt at ice cream making. As it turns out, there are many variations on the recipe, from what type of cream to use to how much salt to add to the ice to achieve maximal freezing temperature. So what did two scientists decide to do? Experiment, of course!

First things first: how much salt? We decided to take the recipe and try three different amounts of salt to ice ratios. Using two solo cups of ice in each gallon ziploc, we added either 1/8, 1/4, or 1/2 a cup of sea salt. We then placed the same premixed ice cream recipe in a sealed bag inside, and got to mixing. Ten minutes (and pairs of freeeeezing hands) later, we compared the consistency of the ice cream in each bag. The one with the least salt was visibly less solid, while the 1/4 and 1/2 cup tests were roughly the same. So, we erred on the side of extra salt, and set the amount to 1/2 a cup.

Then it was time for the real test: taste. The various recipes we had suggested either half & half or milk and cream, and we decided to try a fun third option: chocolate milk instead of regular milk. We also decided that we'd be holding our bags with hand towels this time, to save our hands. Another 10 minutes later it was time for the taste test… yum!

The end result was not surprising: the recipes with cream and whole milk tasted creamier. But, the difference was pretty minimal, and since half & half is easier to buy in bulk, she decided to go with that. For the record, the chocolate milk also worked, and added a nice, subtle chocolate flavor to the ice cream. It was my personal favorite:

But perhaps it's time to answer the real question: why does this work?

For those who have never tried making ice cream in a bag, it's one of the easiest and tastiest science experiments you can do at home, taking advantage of what chemists call Freezing Point Depression.

We say that pure water freezes at 32 degrees Fahrenheit (0 degrees Celsius), but it is actually an equilibrium point: at that temperature, liquid water freezes as quickly as ice melts, so to create ice, we have to continue to remove heat. When the water isn't pure, however, things are different. Other particles (for example, salt) disrupt the process of freezing because they disrupt the forming of the crystalline structure that is ice. Thus, the freezing temperature of a solution is lower than pure water.

When you add the salt to the ice cubes in this experiment, the salt particles interact with the water molecules, beginning the process of melting. But, the lower the freezing point of something, the more energy has to be absorbed by it to melt; which is why, though it might seem strange, the moment you add salt, ice-and-forming-water's temperature drops to *colder* than freezing and starts absorbing heat from its surroundings. In fact, adding salt to ice water can lower the temperature to as low as -15 °C! To chemists, processes that require heat, like melting ice, are known as *endothermic*. Meanwhile, the water that is forming in the bag is just as cold — that is, below freezing. Because liquids conduct heat more readily than solids, the super-cooled water sucks heat away from the ice cream faster than the ice would alone, making it possible to make ice cream without the machine.

So there you have it: a little bit of delicious chemistry you can do at home. Have fun with it!

Special thanks to Joan Kaufmann, my high school chemistry teacher (who still teaches at my high school!) for doing this in our chemistry class — and for not failing me, even though I wrote the entire lab report in an "Irish" accent (I wish I was kidding. The report began "Methinks it was a wee bit chilly to be faring an ice cream labbin today". Methought I was cool).