Water to Vapor; Water to Ice
The Process Is Amazing

Setting the Scene: Holding On To Heat

If you leave a cup of cold water on a counter, it will warm up very quickly. If you put ice in the same glass, the water will stay cold for a long time before all the ice melts and the water starts to get warm. The difference results from the difference in "heat" and "energy."

Here is a simple way to think of the difference. If you strike a match, it gets very hot. If you hold the burning match under a straight pin, the pin might get so hot that it glows red and too hot to touch it without getting burned. This whole process only takes a few seconds. Soon both the match and the pin are completely cool again. Both the match and the pin reached a very high temperature, but neither of them held very much energy.

Now imagine what would happen if you held a match under a brick. Almost nothing. What if you put that brick in the hot sun for an hour? Chances are that it would never get so hot that you could not touch it. However, when you remove it from the sun, it will stay warm for a long time. Since the brick never gets anywhere near as hot as the pin, it does not reach a very high temperature. Because it is able to stay hot for a long time, though, it is storing a lot of energy.

Energy is measured in calories or BTUs (which stands for "British Thermal Units). Heat is measured in degrees, usually Celsius or Fahrenheit. A <u>calorie</u> is defined as the amount *energy* needed to raise the *temperature* of one <u>gram</u> of water by one degree <u>Celsius</u> (in specific atmospheric conditions). (A <u>BTU</u> is the amount of *energy* needed to raise the *temperature* of one <u>pound</u> of water by one degree <u>Fahrenheit</u>.)

As long as a substance stays in only one phase – solid, liquid, or vapor – the temperature changes in line with the energy that goes in or comes out. (Putting energy in raises the temperature; taking energy out, drops the temperature.) Strange things happen, though, at the point of phase change.

The Basic Science: Phase Change and Refrigeration

As substances change phase (turn from solid to liquid to vapor), their energy content changes dramatically while their temperature remains constant. In other words, once water reaches the freezing point or the boiling point, it will stay at that temperature until it has all frozen or boiled away into vapor. Only after it has changed phase completely will the temperature start to change again.

As water freezes into solid ice, it releases heat energy. As the ice melts, it absorbs heat energy. It continues absorbing energy until it has all turned to vapor and escaped into the atmosphere. There it will eventually connect with other molecules of water vapor, turn into clouds, condense back into its liquid phase, and then return to earth as precipitation!

Phase Change in Your Life

You may not realize it, but you experience the physical wonders of the phenomena of phase change every single day in your life. On a simple level, you experience it when you fill your glass with ice to keep your drink cold longer. On a more complex level, though, you experience it when you walk into an air-conditioned building or keep food cold in your refrigerator/freezer. Some buildings are even heated with a device called a "heat pump," which is simply an air conditioner working backwards: it extracts heat from the outdoors and delivers it indoors. The "refrigeration" cycle works because a special chemical inside the air conditioner or freezer – called a "refrigerant" – boils and condenses at temperatures well below the temperature needed to boil water.

To understand how refrigeration and air conditioning work, you need one more piece of scientific information: When gases are compressed, they get warmer. When they are expanded, they get colder.

Here's what happens. "Refrigerant" flows through your refrigerator, air conditioner, or heat pump. It flows through an expansion valve, which lowers the pressure of the refrigerant, thus lowering the temperature. The cold refrigerant then flows through coils that come into contact with the space you are cooling. When it does, it picks up heat energy. It then carries that heat energy to a place where it can be dumped – inside your kitchen, in the case of a refrigerator, or outside, in the case of an air-conditioner. When it is ready to dump its heat energy, it flows through a "condenser" where it turns from vapor back into liquid and gives up its heat in the process. As the refrigerant cycles around, it keeps picking up heat and dumping it. Over time, the inside of the house, refrigerator, or freezer gets colder and colder because more and more heat energy is being removed.

If not for the large amount of energy stored in the refrigerant as it changes phases, the process would never work. The temperature of the refrigerant never changes very much, but it is still able to move a lot of energy. You can get a basic understanding of this process simply by watching the behavior of water as it changes phases.

Materials

- Two thermometers with a temperature range from below freezing to the boiling point. (You may need two different thermometers to measure the full range, an indoor / outdoor thermometer for the lower range and a cooking thermometer for the upper.)
- A one-quart metal saucepan half filled with water
- Access to your family's freezer and stove

Procedure for making the model

1. Fill the saucepan about half full with tap water. Measure and record the temperature.

2. Put the saucepan in the freezer. Leave one thermometer in the water and the other thermometer inside the box of the freezer.

3. Measure and record the temperature every 15 minutes until the water in the saucepan has frozen solid, and the ice has reached the temperature inside the freezer. (Take care not to leave the refrigerator door open for more than a few seconds. Doing so will allow heat to escape.)

4. Remove the ice from the freezer (along with the thermometer in the freezer compartment).

5. Measure the rate of change on the thermometer that is not in the water/ice by recording the temperature every 15 seconds or so until that thermometer reads room temperature.

6. Continue to observe and measure the temperature of the ice every 15 minutes as it melts and the water reaches room temperature.

7. Make a graph plotting the temperature changes of the water at each 15 minute interval.

8. When the water has reached room temperature, put the saucepan on the stove over medium to high heat. Continue observing the water and measuring the temperature (this time every minute because it will go much faster than the freezing) for a few minutes. It will go much faster than the freezing, but DO NOT let the water boil away completely. The pan will get dangerously hot!

9. Make a graph of your findings.

Suggested Projects

1. Write a paper describing the graph you have drawn and the temperature changes you observed. Explain your observations in terms of phase change, heat, and energy. (Remember, your sample will be releasing or absorbing heat even when the temperature is not changing.)

2. Research the refrigeration cycle and create a poster that explains the process.

3. Research the evolution of refrigerants. Scientists and engineers continually work to find better refrigerants. Some refrigerants that work well in cooling also create an environmental problem by contributing to the degradation of the earth's protective ozone layer.

4. Research the use of heat pumps in use in Florida to provide heat during the winter. Are heat pumps more or less energy efficient than other types of heating devices in Florida? Could they be used in other parts of the world, such as regions that have colder, harsher, longer winters? Devise a public information/advertising campaign that either tells people about the benefits of using heat pumps or warns them of the dangers.

5. If you use an electric stove or hotplate to boil your water, you can measure the energy efficiency of the process. To do this, you must know the amount of energy produced by the burner. A hotplate and electric stove have labels that tell you the energy they use to get hot.

1 kWh	=	1 kilowatt operating for one hour
1 kWh	=	341 BTUs
1 kWh	=	360,420 calories
1 calorie	=	the energy needed to raise the temperature of one gram of water by one degree Celsius
1 BTU	=	the energy needed to raise the temperature of one pound of water by one degree Fahrenheit
1 gram	=	1 cubic centimeter or 1/1,000 of a liter
1 pound	=	approximately one pint of water

If you divide the energy that actually gets into the water by the energy used by the heat source, the answer will be the efficiency of the heat transfer … as long as the water in the pan stays below the boiling point.

6. Use the Internet to learn more about phase change, refrigeration, heat pumps, and refrigerants

Putting it Together

Make a model of the refrigeration system of a refrigerant or air conditioner, or make a model of a heat pump. Use your data to make charts showing how temperatures change during phase change. Add an explanation about how phase changes are used in refrigeration, air conditioning, and heat pumps. Prepare a written or oral report about your project.

7th Grade Science Standards from the Sunshine State Standards

The Nature of Matter

- Understands that changes in energy cause phase changes.
- Extends and refines knowledge of uses of forms of energy to improve the quality of life.

Energy

- Knows examples of natural and man-made systems in which energy is transferred from one form to another.
- Knows that energy conversations are never 100% efficient
- Understands that as energy is transferred from one system to another there is a reduction in the amount of useful energy.