TITLE: OBSERVING LATENT HEAT WITH A PORTABLE HAND WARMER

TOPIC: Phase changes in matter – latent heat

GRADE LEVEL: 7-12

CONTENT OBJECTIVE & SHORT DESCRIPTION: Students will observe a teacher-directed demonstration that provides a conceptual understanding of latent heat.

CONTENT STANDARD:
5 8:Content Standard B Physical Science Standards: Properties and changes of properties in matter
5 8:Content Standard B Physical Science Standards: Transfer of energy
9 12:Content Standard B Physical Science Standards: Interactions of energy and matter
9 12:Content Standard D Earth and Space Science Standards: Energy in the earth system

RESOURCE TYPE: Classroom Demonstration

TIME REQUIRED: 45 minutes

MATERIALS NEEDED:
- a portable hand warmer (sodium acetate type)
- heat source (gas flame or electric hot plate)
- Pyrex beaker
- ice
- water
- thermometer

DIRECTIONS FOR INSTRUCTION/ACTIVITY:
Introduction
I have found that a reusable hand warmer can serve as a wonderful aid in demonstrating the difficult concept of latent heat. These pocket hand warmers can be found in most sporting good or ski equipment shops, generally at a price of about $10 each. Please be sure, however, to get the kind that uses a solution of sodium acetate (see the back of the package when purchasing).

At normal room temperatures and pressures the saturated sodium acetate solution exists as a hydrated crystalline solid. When these packets are heated in a microwave oven, or placed in a container of boiling water, heat is added to the solid and a phase change from solid to liquid takes place. However, when the temperature drops back down to room temperature the cooled fluid does not return to its normal solid-state. At this point the liquid is called a supersaturated fluid.

The liquid within the sealed packets will remain a supercooled fluid until its equilibrium is upset. In the case of the commercial hand warmer unit, this process is activated by pressing the metal button that is contained within the fluid. While the exact mechanism for initiating this change is not known, various representatives of the manufacturer have suggested various plausible explanations. These include:

- that the mechanism is related to that heat that is generated from the bending of the metal button,
- the changing geometry of the surface of the metal desk provides a more suitable base on which crystals may grow,
- or that the release of microscopic fragments of metal that small from the bending metal serve as condensation nuclei around which the crystals grow.

Regardless of the underlying mechanism, once the button is pushed the liquid within the packet immediately undergoes a phase change from liquid to solid and in the process releases a great amount of latent heat. In order to reuse the hand warmer the crystal within the packet must be melted down again. This requires the addition of heat, which is stored in the material as long as the saturated solution of sodium acetate remains in its liquid state.

Procedure

Begin the demonstration by showing students a hand warmer that has not been activated (liquid inside). Press the button inside the package to activate the hand warmer. Pass the hand warmer to students to let them directly feel the heat release from the package, Ask the students for their ideas as to where the heat might come from when the unit was activated. Accept all logical answers, but do not offer a "correct" explanation at this point.

Show students a piece of ice and ask the question "what is needed to turn solid water (ice) into liquid water?" Accept all logical answers, but summarize that heat must be added to turn solid ice into liquid water.

Show students a glass of water and ask the question "what is needed to turn the liquid water into water vapor (a gas)?" Accept all logical answers, but summarize that heat must be added to liquid water to turn it into water vapor.

Place a beaker with water over a heat source. Place a thermometer in the water and have the students observe that the temperature steadily increases over time. Ask the students why the temperature of the water changes over time. Work towards an understanding that as heat is added the temperature will rise.

Place another beaker with ice and water over the same heat source. (The beaker should be prepared in advance of the demonstration by placing ice in the water to bring the ice and beaker down to freezing temperature. However, immediately before the demonstration, remove most of the ice so that there is only a small amount of ice remaining in the water. The more ice in the beaker the longer it takes for it to melt and eventually have the water temperature rise.) Place a thermometer in the ice water near the surface and stir regularly. Have the students observe that the temperature of the ice water does not rise as long as there is still ice in the solution. Once the ice has completely melted, the temperature will start to rise. Ask students to the following questions:

- Was heat steadily added to the ice water? (yes)
- When does the temperature of the water start to rise? (only after the ice had melted)
- What happened to the heat that was added to the beaker when there was still ice in the water? (Large amounts of heat were needed to change 32-degree ice into 32-degree water. Although the temperature did not change, the water underwent a phase change from solid to liquid).

Hold the hand warmer (which is now a solid crystal) up in front of the class. Ask the students " what is needed to change the crystalline solid back to liquid". Accept all answers, but guide them to the fact that heat must be added.

Now for the tricky part. Ask the question "what happened to all of the energy that went into changing the solid to the liquid". Students may be tempted to say that somehow the energy disappeared as the liquid cooled. However, the important concept to develop is that in order for the sodium acetate (or any material, for that matter) to stay in liquid form the atoms and molecules in the substance needs to stay in a higher state of energy than for atoms and molecules in a solid. By their very nature liquids contain much more energy than do solids, and gases more energy than liquids.

The Grand Finale - ask the question " what must happen in order for a liquid to change to a solid?" The important part of this activity is to have the students understand that the heat energy contained within the liquid must be given up in order to have the substance turn into a solid. The liquid sodium acetate in the packet gives up its energy very rapidly, and we experience that energy release as a significant increase in the temperature of the package. This "hidden heat", otherwise known as latent heat, is present in all changes from one phase to another.

EVALUATION: While there are a number of ways in which to evaluate the learning associated with this activity, one technique that is very useful with teacher-led demonstrations is for students to write a lab report of the demonstration. I ask them to do four things:

I. What did the teacher use? (a materials list)
II. What did the teacher do? (a step-by-step list of procedures)
III. What did you observe? (see, hear, feel)
IV. Offer an explanation (explain in their own words why something happened)

LESSON PLAN AUTHOR & CONTACT INFO:

Bryan L. Aivazian
Science Instructor
Natrona County School District
1425 S. Ash
Casper, Wyoming 82601
307-235-1536
bryana@trib.com