

Class _____

Name _____

Date _____

Partner(s) _____

LATENT HEAT OF FUSION



Materials

LoggerPro Software and Real Time Physics Thermodynamics Experiment Files

Stainless Steel Temperature Probes (2)

Styrofoam Cup

Film Container with Lid

Mass Balance

Steam Generator

Ice

Paper Towels

Stainless Steel Forceps

CAUTION: You will use boiling water in this experiment. Take care not to burn yourself. Be especially careful not to burn yourself with the steam produced by your boiling water.

Introduction

Generally when you add heat (with a flame or electric heater for instance) to a material, its temperature increases. If “Q” represents the heat flow into or out of a given mass “m” and “ ΔT ” represents the change in temperature, we define the *specific heat capacity* “c” by the relationship.

$$c = Q/(m\Delta T)$$

If the heat energy is measured in calories, the mass in grams and the temperature in degrees Celsius ($^{\circ}\text{C}$), then the specific heat capacity specifies how many calories it takes to change the temperature of one gram of the material by one degree. The calorie is defined as the amount of heat energy required to raise the temperature of 1 gram of water by 1°C . Hence, the specific heat capacity of water is $1.00 \text{ cal / (g }^{\circ}\text{C)}$.

Note: We use these units rather than SI units to give “c” a numerical value of “1”.

When a substance undergoes a phase change from solid to liquid (melting), energy is required to break the bonds holding the molecules “rigidly” in place. In this case, it is possible for heat energy to be added *with no change of temperature*. We define the *latent heat of fusion* “ L_f ” as follows.

$$L_f = Q/m$$

The latent heat of fusion represents the energy required to melt one gram of a material when its temperature is already at the melting point.

Q1 Given the above definitions, make the following prediction. Rank in the order of how much energy is required from *greatest energy to least energy*. If you think that any take the same energy, circle their numbers in your ranking.

- (1) Raising the temperature of 1 gram of water 1°C.
- (2) Raising the temperature of 1 gram of water 2°C.
- (3) Raising the temperature of 2 grams of water 1°C.
- (4) Raising the temperature of 1 gram of water from 0°C to 100°C.
- (5) Changing 1 gram of ice at 0°C to 1 gram of water at 0°C (melting).

RANKING: _____ _____ _____ _____ _____ _____

Activity 1 Measuring Temperature

1. Fill your Steam Generator 1/2 to 3/4 full to start. Turn the dial to “high” and switch on.
2. Plug one temperature probe into **CH1** and the other probe into **CH2** of the LabPro Open **L01A2-1(Cooling Water).cmbl** located in the **RealTime Physics : Heat and Thermodynamics** folder. You will now see temperature readouts. These readouts will correspond to the Celsius temperature scale, where water freezes at 0°C and boils at 100°C at sea level.

Patience is the key to good temperature measurements Keep in mind:

- Thermometers do not respond instantly. For example, when taking your body temperature with a standard liquid-in-glass thermometer, you wait MINUTES for the thermometer reading to stabilize.
- An ideal system is perfectly thermally isolated, i.e., has no heat gain or loss with the outside environment. This is never 100% true in the real world. For example, your ice-water bath is not at exactly 0°C since heat energy from the room and cup is continually being added to the bath. To get the most accurate reading, surround the thermometer sensor with ice-water in the middle of the cup where it is less affected by the outside environment. Likewise with the boiling water.
- For better temperature uniformity, stir gently and continuously.

3. Place both probes into the air. The temperature readings appear continuously above the graph whether you are collecting data or not. Record the temperature of the air by reading the probe 1. Make sure the reading is stable.

Room Temperature: _____ °C

Activity 2 Temperature Change and Heat Flow

Prediction

Q2 Suppose you have a mass of hot water and a larger mass of water at room temperature. The two samples are mixed together. What do you predict about the final equilibrium temperature if the hot water is 70°C and the room temperature is 20°C? Will it be midway between the two temperatures? Or will it be closer to 70°C? Or closer to 20°C? Explain.

Test Your Prediction

You will setup to separately keep track of “hot” water in your film container and room temperature water in your styrofoam cup. By placing the film container into the cup, the hot and cool water in thermal contact will eventually reach an equilibrium temperature without mixing.

1. Set up the cup and film container.
 - a. Measure the mass of the styrofoam cup and the film container *with its cap off*.

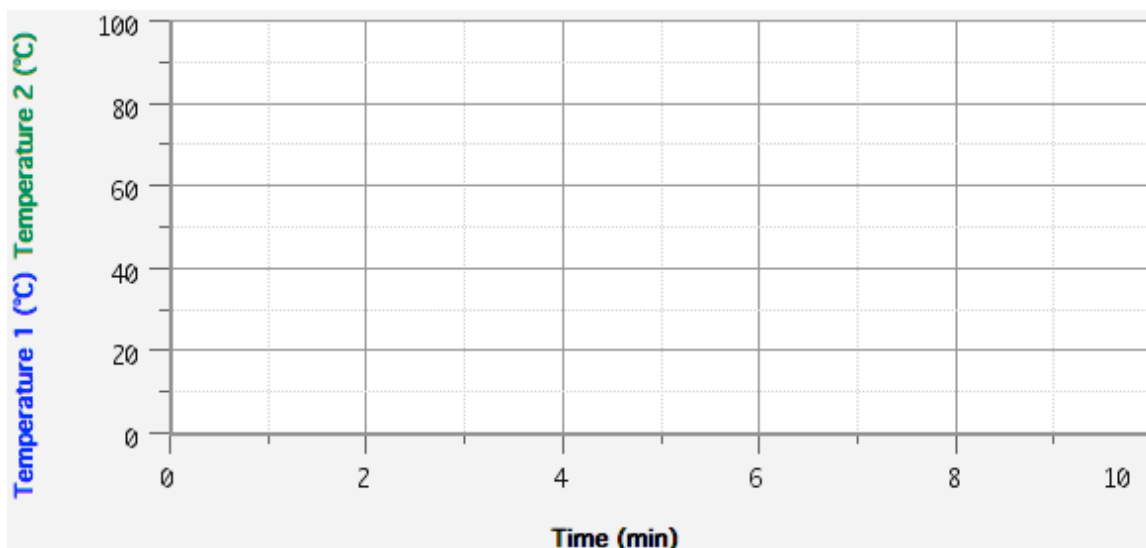
Mass of film container _____g
Mass of styrofoam cup _____g
 - b. Pour room temperature water into the styrofoam cup. Fill it enough so that when the *covered* film container is placed into the styrofoam cup, the film container is completely submerged. Determine the mass of the water in the cup.

Mass of styrofoam cup with water _____g
Mass of water in styrofoam cup _____g
 - c. Place one temperature probe in the water of the styrofoam cup. Put the other probe through the hole in the film container cap to test for a tight fit. Let your instructor know if it’s not tightly sealed.
2. Carry out the investigation.
 - a. Grasp the film container with the stainless steel forceps. Lower the film container into the hot water in the steam generator so that it is almost full. *With its cap off*, determine the mass of the water in the film container.

Mass of the film container with water _____g
Mass of water in the film container _____g
 - b. Seal the film container with its cap. The temperature probe should be set so that its sensor is in the middle of the water in the container. **Immediately before** you place the film container into the water of the styrofoam cup, record the initial temperatures:

HOT _____ °C
COOL _____ °C
 - c. Click **Collect** and **THEN** submerge the film container in the cup.

- d. **Gently** move the container up and down to mix the water in the cup *for the rest of the investigation*. Make sure the film container stays submerged as you stir.
- e. When you are done, sketch your graphs on the axes below.



3. Record the final equilibrium temperatures of both samples. This may occur before the end of the 10 minutes.

Final Temperatures Cup _____ °C

Film Container _____ °C

Do your results agree with your prediction (Q2)? _____

Q3 As the hot water cooled down, what happened to the cool water? Explain this in terms of heat flow (energy transfer).

Q4 When thermal equilibrium has been reached, what evidence is there that there is no longer a net flow of energy from one container of water to the other?

Q5 Using the information in the introduction and your measurements, calculate the energy lost by the hot water. Show your calculation and include units.

Energy lost by hot water _____ cal

Q6 Using the information in the introduction and your measurements, calculate the energy gained by the cool water. Show your calculation and include units.

Energy gained by cool water _____ cal

Q7 Ideally, the energy lost by the hot water and the energy gained by the cool water should be equal. How much of an energy difference is there? Explain what happened to the “extra” energy.

Activity 3 Melting Ice

You start this activity with a prediction and then test your prediction.

Q8 Predict what will happen when an ice cube is dropped in a styrofoam cup containing warm water. Describe any changes to the ice and water that might take place.

Test your prediction. In this activity, you will put some ice in the cup of water you used in the last activity and measure temperature changes. You will need small ice cubes whose surfaces are not wet. You can dry them off with paper towels.

Q9 Why are “dry” ice cubes important for this activity?

1. Reset the time axis for 2 minutes and the temperature scale from 0°C to 50°C. Leave one probe in the cup of water.
2. Prepare some ice cubes (dry them off). Use about four pieces (a small enough mass of ice cubes so that the ice will melt). You can determine their mass after you run the experiment.
3. Carry out the investigation.

a. Fill the styrofoam cup with water around 40°C. Measure the mass and temperature of the styrofoam cup filled with water. *The initial temperature must be measured immediately before the ice cubes are added.*

Mass of the styrofoam cup filled with water _____ g

Initial temperature of water in styrofoam cup _____ °C

b. **Start** graphing and **THEN** carefully transfer the dried ice **directly** into the cup. **Do not use the film container.** Gently stir until the temperature stops changing (equilibrium). Record the final temperature.

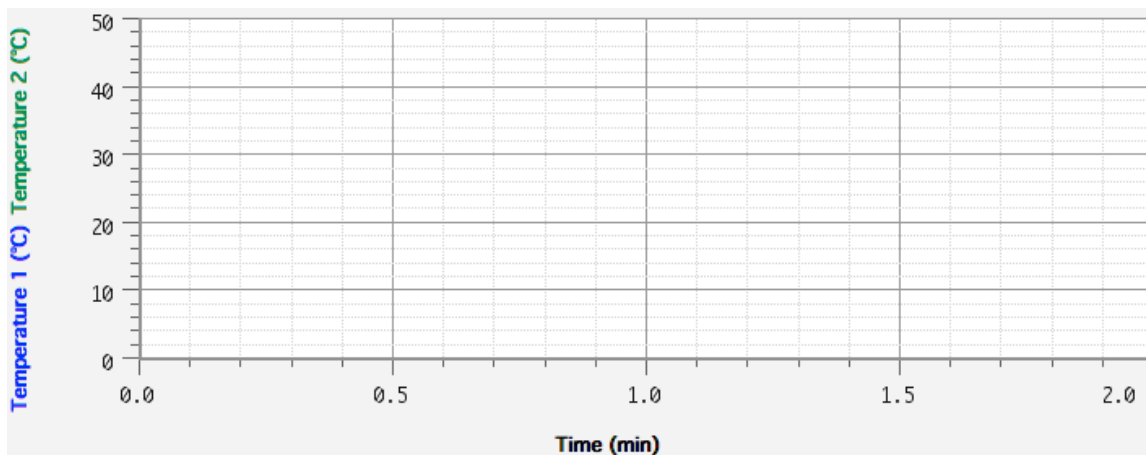
Final temperature of water in styrofoam cup _____ °C

c. To get the mass of the ice, first measure the mass of the cup and its contents.

Mass of the styrofoam cup and contents _____ g

Mass of ice _____ g

d. When you are done, sketch your graph on the following axes. Only record the graph for the temperature of the contents in the styrofoam cup.



Q10 As the water cooled down, what happened to the ice? Explain in terms of energy transfer.

Q11 How much energy was “lost” by the water in the cup? Show your calculation.

Energy lost by water in cup _____ cal

Q12 How much energy did it take to raise the melted ice from 0°C to the equilibrium temperature? Show your calculation.

Energy to warm melted ice _____ cal

Q13 Calculate the energy difference between your values of the previous two questions. Show your calculation.

Energy difference _____ cal

Q14 Where did this energy (Q13) go or what did it do?

Q15 Take your energy difference (Q13) and divide by the mass of the ice. Show your calculation (**WITH UNITS!!**).

Q16 What are the units of this last quantity and what does its numerical value tell you?

Q17 What is the standard name for the above idea?

POST LAB QUESTIONS

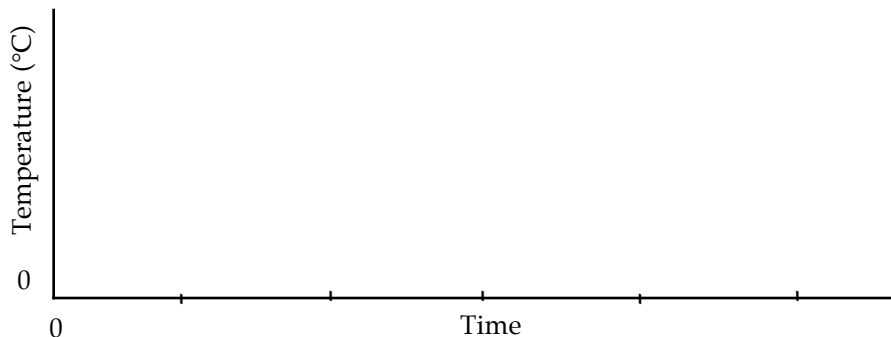
1. Rank in the order of how much energy is required from *greatest energy to least energy* (if you think 2 or more take the same energy, circle their numbers in your ranking):

- (1) Raising the temperature of 1 gram of water 1°C.
- (2) Raising the temperature of 1 gram of water 2°C.
- (3) Raising the temperature of 50 grams of water 1°C.
- (4) Raising the temperature of 1 gram of water from 0°C to 100°C.
- (5) Changing 1 gram of ice at 0°C to 1 gram of water at 0°C (melting).
- (6) Changing 2 grams of ice at 0°C to 1 gram of water at 0°C with 1 gram of ice at 0°C floating in it.

RANKING: _____

Explain your reasoning:

2. Describe what happens to the temperature of a water-ice mixture originally at 0°C when heat energy is transferred to it at a constant rate. Sketch a temperature history on the axes below. Indicate on your graph where the ice disappears.



3. Explain what happens to the heat energy transferred to the ice and water mixture if the temperature does not rise while the ice is melting. How does the internal energy of the ice and water mixture change during this process? Does it increase, decrease or remain the same? Explain.

4. Suppose you start with 250 grams of ice at 0 °C. Calculate the amount of heat energy that must be transferred to melt the ice. (Use 334×10^3 joules/kg for the Latent Heat of Fusion of ice.) Show your calculations.

5. A mixture of 150 grams of ice and 300 grams of water is at 0 °C. How many joules of heat energy must be transferred to bring this mixture to a final temperature of 75 °C? Assume the heat energy transferred to the room is very small. Show your calculations. [Use 334×10^3 J/kg (334 J/g) for the Latent Heat of Fusion of Ice and 4190 J/kg°C (4.19 J/g°C) for the Specific Heat Capacity of water.]