

## EXPERIMENT 3

### THE LATENT HEAT OF FUSION OF ICE

A small amount of ice is placed in a calorimeter containing water. By knowing the masses of the ice, the water, and the calorimeter, and the resulting temperature change after the ice melts, the latent heat of fusion of ice is found.

#### THEORY

When heat is added to a substance, a temperature change is generally observed to occur. The heat added,  $Q$ , that causes a temperature change  $\Delta T$  is

$$Q = mc\Delta T \quad (1)$$

where  $m$  is the mass of the substance and  $c$  is its specific heat, which is assumed to be constant over the temperature change,  $\Delta T$

However, situations exist where heat added to a substance does not cause a change in the temperature. In these cases, the added heat causes a change in phase to occur. Two common changes in phase are from solid to liquid and from liquid to gas. The amount of heat required to accomplish a phase change is called the heat of transformation. More specifically, for a solid to liquid phase change, it is referred to as the heat of fusion; and for a liquid to gas phase change, the heat of vaporization. The heat of fusion or vaporization can be expressed mathematically as

$$Q = mL \quad (2)$$

where  $L$  is the latent heat of fusion or vaporization, depending on the phase transition that occurs.

In this experiment, an ice cube of mass  $m_t$ , assumed to be at  $0^\circ\text{C}$ , is placed in a calorimeter containing a mass of water  $m_w$  at temperature  $T_1$ . After the ice cube melts, the temperature of the system is  $T_2$ . When the heat lost is equated to the heat gained, and the resulting equation solved for the latent heat of fusion  $L$ , the result is

$$L = \frac{m_w c_w (T_1 - T_2) + m_c c_c (T_1 - T_2) - m_t c_w T_2}{m_t} \quad (3)$$

where  $c_w$  is the specific heat of water ( $4.19 \text{ J/g } ^\circ\text{C}$ ) and  $m_c c_c$  is the water equivalent of the calorimeter.

In order to calculate the heat of fusion of ice from (3), it is necessary to first determine the water equivalent of the calorimeter. The value  $m_c c_c$  is found by mixing known quantities of warm water and cool water in the calorimeter.

Suppose the Calorimeter contains a mass of warm water  $m_{ww}$ , at temperature  $T_w$ . If a mass of cool water  $m_{cw}$ , at temperature  $T_c$  is mixed with the warm water in the calorimeter. thermal equilibrium will be established at an intermediate temperature  $T$  When the heat lost and the heat gained are equated, and the resulting equation solved for the water equivalent of the calorimeter. the expression becomes

$$L = \frac{m_{cw} c_w (T - T_c) - m_{ww} c_w (T_w - T)}{T_w - T} \quad (4)$$

where  $c_w$  is the specific heat of water.

## APPARATUS

- o calorimeter with cork stopper
- o slotted weights
- o container for water
- o crushed ice
- o double-pan balance
- o 0-50 °C thermometer,  $\pm 1$  °C
- o 0-100 °C thermometer,  $\pm 2$  °C
- o ice cubes

## PROCEDURE

There is an attempt in this experiment to minimize heat losses and gains by using a calorimeter. Heat transfers can be further minimized by removing the cork stopper from the calorimeter only when necessary and only for a short time. Compensation is made for the heat losses -or gains that inevitably occur. By starting the calorimeter and contents at a temperature above room temperature, the heat loss to the environment by the warm water is offset by the heat gained by the cool water or ice that is added to the calorimeter. An attempt is also made to produce a final equilibrium temperature at or close to room temperature.

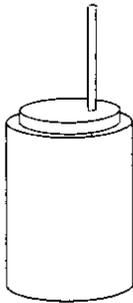


Figure 1. The Calorimeter

- a) Find the mass of the empty calorimeter with the 0-50°C thermometer inserted in the cork. (Refer to Figure 1.)
- b) Obtain water from the tap that is approximately 10 °C above room temperature. Pour this water into the calorimeter until it is 1/3 full. Wait for thermal equilibrium to be established, then record the

- temperature,  $T_w$ . Find the mass of the calorimeter with the warm water.
- c) Cool some water in a container with crushed ice until its temperature is approximately  $10\text{ }^\circ\text{C}$  below room temperature. Record the temperature of the cool water,  $T_c$ , with the  $0\text{-}100\text{ }^\circ\text{C}$  thermometer
  - d) Pour the cool water from step (c) into the calorimeter until the calorimeter is  $2/3$  full. Wait for thermal equilibrium and record the equilibrium temperature  $T$ . Find the mass of the calorimeter with the added water.
  - e) Calculate the water equivalent of the calorimeter from equation (4) using the data collected in steps (a) through (d). If the value of the water equivalent is negative, then carefully repeat steps (a) through (d) until a positive value is obtained.
  - f) Empty the calorimeter and fill it until it is  $1/3$  full of warm water that is approximately  $15\text{ }^\circ\text{C}$  above room temperature. Wait for thermal equilibrium and record the temperature  $T_1$ . Find the mass of the calorimeter with the warm water.
  - g) Dry an ice cube and add it to the water. Be sure to agitate the water to ensure the complete melting of the ice cube. Continue to add "dried" ice cubes until the final temperature is at or near room temperature. Record the temperature  $T_2$ , and find the mass of the calorimeter and contents. From data collected in steps (a), (f), and (g), the latent heat of fusion of ice can be calculated from equation (3).
  - h) Repeat the procedures (f) and (g) two more times for a total of three trials.

## ANALYSIS

Calculate the value of the water equivalent of the calorimeter and the three values of the latent heat of fusion of ice. Report in a table the values of the water equivalent, the three experimental values of the latent heat of fusion, the average of these values, the book value, and the percentage error between the book value and the average experimental value of the latent heat of fusion.

## QUESTIONS

1. Set up the expressions representing the heat lost and the heat gained, and subsequently derive 3).
2. What does the water equivalent of the calorimeter represent?
3. Set up the expressions for the heat lost and the heat gained, and subsequently derive (4).
4. Before the ice is placed in the calorimeter, the ice is dried. Why did it need to be dry? If the ice was not dry, would the experimental value of the latent heat of fusion be higher or lower than the expected value? Explain.
5. If ice cubes are taken from a freezer and used immediately in the experiment, then will the value of the latent heat of fusion be less than or greater than the theoretical value? Explain.