## Experiment 10

# Specific Heat and Heat of Fusion

**Preparation**

Study for this week's quiz by reviewing harmonic motion and by reading the sections of your book that cover heat, heat of fusion, and specific heat capacity. Look up the definition of a mole.

**Principles**

**Temperature and Heat**

Temperature and heat are not the same thing. **Heat** is a measure of the **total thermal energy** in an object. Heat is usually represented by the letter *Q*. **Temperature** is a measure of the **average kinetic energy** of the individual molecules of a substance.

Two substances with the same amount of thermal energy can have different temperatures. A large cool piece of metal can have the same total thermal energy as a small hot rock. Two substances at the same temperature can have different amounts of thermal energy. For example, a cup of lake water and the water in the lake may be at the same temperature but the total energy of all the water in the lake will be enormously greater than the thermal energy of the water in the cup.

Heat is thermal energy which can flow from a hotter object to a cooler one because of the temperature difference between them. Heat flows through conduction, convection, radiation, or some combination of these processes. If two objects at different temperatures are brought together heat will flow from the warmer to the cooler object until the temperatures are equal. This process is called heat exchange. The heat lost by the warmer object must equal the heat gained by the cooler one:

$$Q_{lost} = Q_{gained}$$

**Specific Heat**

This can be used to find another property called specific heat. **Specific heat** *(c)* is defined as t**he amount of heat required to change the temperature of one kilogram of a substance 1°C.**

$$c = \frac{Q}{m\Delta T}$$

The unit for specific heat is J/kg°C, Joule per kilogram - degree. The equation for heat can then be rewritten:

$$Q = mc\Delta T$$

In mechanical or electrical measurements energy is usually measured in Joules, but in thermal measurements the **"calorie"** is usually used as the energy unit. The calorie is defined as the amount of thermal energy required to raise the temperature of one gram of pure water from 14.5 °C to 15.5°C.  One calorie is equal to 4.186 Joules.  Thus the specific heat of water in this temperature range is 1.00 calorie/gram °C or 1.00 kilocalorie/kg °C.  The "dietary calorie" or "Calorie" (spelled with a capital "C") which is used to define the energy equivalent of foods, is equal to a kilocalorie.  Thus

$$1\ kcal = 1\ Cal = 10^3\ cal = 4186\ J$$

In this experiment you will use the known specific heat of water to find the specific heat of copper.

**Heat of Fusion**

When a substance is undergoing a phase transition, that is, changing from one physical state to another, it will gain or lose heat without a change in temperature until the phase transition is complete.  The amount of heat necessary to melt a substance is called the **latent heat of fusion** **($L_f$)** and has units of **J/kg**. The amount of heat necessary to completely change a substance from solid to liquid, without changing its temperature is given by:

$$Q = mL_f$$

In this experiment you will find the latent heat of fusion of ice.  When ice at 0°C is mixed with warm water at some temperature, $T_i$, the water will cool to a final temperature, $T_f$.  In the process it will lose heat equal to $m_{water}c(T_i - T_f)$.   Some of the lost heat will be used to melt the ice, $m_{ice}L_f$, and the rest will raise the temperature of the melted ice to the final temperature of the water.  Therefore:

$$m_{water}c(T_i - T_f) = m_{ice}L_f + m_{ice}c(T_f - 0°)$$

In this experiment you will use a calorimeter which is a device that thermally isolates enclosed substances from their surroundings so that no heat flows in or out.  A thermos bottle is a fairly good example of a calorimeter.

**Equipment**

*1    thermometer*
*1    calorimeter*
*1    graduated cylinder*
*1    pan balance*
*paper towels*
*ice*
*ice water*
*hot copper shot*

**Procedure**

Use SI units. Measure temperature to .1°; measure mass to .001 kg.
Note that you must do all the steps of this experiment in the right order. If you miss a step you will have to start over from the beginning.

**Specific Heat**

1. Find the mass of the calorimeter, including the cover, and the dry, empty calorimeter cup. These can all be massed together.

2. Your instructor will have a pitcher of ice water ready for you. Use the graduated cylinder to measure out about 100 ml of cold water. Be sure that there is no ice in the water you use. Find the mass of the calorimeter with the water in it. Record the temperature of the water.

3. Your instructor will have cups of heated copper shot ready for you. Use a paper towel to handle the cup so that you don't burn yourself. Get a cup of shot and quickly measure and record its temperature and then pour the shot into the water in the calorimeter.

4. Measure and record the mass of the calorimeter with the water and shot .

5. Use the thermometer to gently stir the shot and water. Within a few minutes the shot and water will reach their final temperature. Record this.

6. Pour the water and shot through the strainer and place the wet shot in the beaker on the cart. Do not mix wet shot with the dry shot.

**Heat of Fusion**

7. Fill the calorimeter cup about half full of warm water. Place the cup in the calorimeter and find the mass as you did in Procedure 1. Stir the water and record its temperature.

8. Get 7 or 8 ice cubes. Dry each piece with a paper towel and carefully slide the ice into the water, one piece at time, until the water temperature drops about 15°. Stop adding ice at this point. Be sure that no water splashes out of the cup.

9. When all the ice has melted, stir the water. Record its final temperature and again find the mass of the cup and calorimeter.

**Analysis**

**Specific Heat**

1. Use your three masses to find the mass of the water and of the shot in the calorimeter.

2. Calculate the experimental specific heat of copper. Find your percent error from the accepted value of 92 cal/kg °C.

**Heat of Fusion**

3. Find the mass of the water and ice in the calorimeter.

4. Calculate the experimental latent heat of fusion for water. Find your percent error from the accepted value of 333 kJ/kg.