TEMPERATURE, HEAT, AND SPECIFIC HEAT

INTRODUCTION

Temperature and heat are two topics that are often confused. **Temperature** measures how hot or cold an object is. Commonly this is measured with the aid of a thermometer even though other devices such as thermocouples and pyrometers are also used. Temperature is an intensive property; it does not depend on the amount of material present. In scientific work, temperature is most commonly expressed in units of degrees Celsius. On this scale the freezing point of water is 0°C and its boiling point is 100°C.

**Heat** is a form of energy and is a phenomenon that has its origin in the motion of particles that make up a substance. Heat is an extensive property. The unit of heat in the metric system is called the calorie (cal). One calorie is defined as the amount of heat necessary to raise 1 gram of water by 1°C. This means that if you wish to raise 7 g of water by 4°C, \((4)(7) = 28\) cal would be required. A somewhat larger unit than the calorie is the kilocalorie (kcal) which equals 1000 cal. The definition of the calorie was made in reference to a particular substance, namely water. It takes 1 cal to raise the temperature of 1 g of water by 1°C. Does this imply perhaps that the amount of heat energy necessary to raise 1 g of other substances by 1°C is not equal to 1 cal? Experimentally we indeed find this to be true. In the modern system of international units heat is expressed in joules and kilojoules. One calorie equals 4.184 joules.

The amount of heat required to raise the temperature of a substance by 1°C is defined as the **specific heat** and is given in units of cal⋅g\(^{-1}\)⋅°C\(^{-1}\) (calories per gram per degree Celsius). Specific heat is an intensive property and for a given substance is constant.

Earlier, we had calculated the heat required to raise the temperature of a mass of water a certain number of degrees. If we let

\[ Q = \text{quantity of heat energy in cal} \]
\[ m = \text{mass of the substance in grams} \]
\[ C = \text{specific heat of the substance in cal} \cdot g^{-1} \cdot °C^{-1} \]
\[ ΔT = \text{the temperature change in °C (always positive in this experiment)} \]

then we can express the heat required as

\[ Q = m \cdot C \cdot ΔT \quad (1) \]
If we solve Equation (1) for "C" we obtain

\[ C = \frac{Q}{m \cdot \Delta T} \]  

(2)

Notice that the units of "C" are cal g\(^{-1}\)°C\(^{-1}\) in agreement with our previous statement.

**PROCEDURE**

The purpose of this experiment is to determine the specific heats of three different metals. A metal block is heated to 100°C by immersion into a beaker of boiling water. It is then quickly removed and placed into an insulated container filled with water whose temperature has previously been determined. The hot metal block will raise the water temperature to some maximum. At this time the water and the metal will be at the same temperature and are said to be in **thermal equilibrium**. The amount of heat given off by the metal block, as it decreases in temperature, is equal to the amount of heat gained by the water.

\[ Q_{\text{metal}} = Q_{\text{water}} \]  

(3)

\[ m_{\text{metal}} \cdot C_{\text{metal}} \cdot \Delta T_{\text{metal}} = m_{\text{water}} \cdot C_{\text{water}} \cdot \Delta T_{\text{water}} \]  

(4)

The mass of the metal and the water can be determined by weighing both objects prior to the experiment. "C\(_{\text{water}}\)" is known to have a value of 1 cal g\(^{-1}\)°C\(^{-1}\) and the two different temperature changes are determined experimentally. Equation (4) can be solved for "C\(_{\text{metal}}\)".

**Step 1.** Boil some distilled water in a beaker.

**Step 2.** Weigh a metal block to the nearest 0.1 g and record its weight.

**Step 3.** Weigh a styrofoam cup and record its weight. Fill the cup at least half full with distilled water and weigh the cup again. Record the weight. Measure and record the temperature of the water to the nearest 0.5°C.
Step 4. Place the metal block into the boiling water and leave it there for two or three minutes. After this time quickly remove it and place it into the styrofoam cup containing the water.

Step 5. At 15 second intervals measure and record the water temperature. In order to get uniform readings, you may stir the water with your thermometer, but be careful not to hit it against the metal. Keep on recording the water temperature until you begin to see a significant drop in the water temperature.

Step 6. Repeat the same procedure for the other two metals provided. Be sure to start out with a new, cool, and weighed amount of water in the styrofoam cup.

CALCULATIONS

Do the following with your experimental data.

1. Make a graph of water "temperature" versus "time".
   Place the time values on the horizontal axis.
2. Take as the final equilibrium temperature the highest temperature recorded in each case.
3. For each metal calculate the amount of heat absorbed by the water.
4. Give the amount of heat given up by the metal block.
5. Calculate the amount of heat released per gram of metal in each of the three cases.
6. Calculate the specific heats of all three metals.
QUESTIONS

1. If you have 500 g of water at 25°C and wish to heat it to 74°C, how much heat is required?

2. What is the specific heat of water?

3. If you have 11.0 g of lead and wish to increase its temperature by 27.0°C, how much heat will have to be added to the lead? (The specific heat of lead is 0.0300 cal·g⁻¹·°C⁻¹.)

4. A piece of a metal weighing 140 g is initially at 23.0°C and then absorbs 585 cal of heat. The metal has a specific heat of 0.0200 cal·g⁻¹·°C⁻¹. What is the final temperature of the metal piece? Assume that all the heat goes to heating the metal.

5. How do the specific heats of the three metals you used in the experiment compare to that of water?