

## Activity 11

### Specific Heat of Metals

#### Objectives

- ◆ To understand what a characteristic physical property is and how it can be used to help find out what an unknown substance might be
- ◆ To understand how heat is transferred between substances
- ◆ To understand thermal equilibrium

#### Materials

- ◆ TI-73
- ◆ Unit-to-unit cable
- ◆ CBL 2™
- ◆ Temperature sensor
- ◆ Unknown sample
- ◆ Goggles
- ◆ Balance
- ◆ Hot plate
- ◆ Tongs
- ◆ Room temperature water
- ◆ 250 ml beaker
- ◆ Ring stand and clamp
- ◆ Styrofoam cup calorimeter
- ◆ Data Collection and Analysis Pages (p. 99 - 101)

#### *In this activity you will*

- ◆ Learn what specific heat is.
- ◆ Use the CBL 2™ with a temperature sensor to collect data and apply the data to determine what a substance is.

#### **Problem**

How can you determine the specific heat of an unknown material? Based on its specific heat, can you identify an unknown sample?

#### **Introduction**

Specific heat, measured in  $\text{J/kg}\cdot\text{C}$ , is the amount of heat energy needed to change the temperature of 1 kilogram (kg) of a substance by  $1^\circ$  Celsius. An example is the specific heat of water, which is  $4190 \text{ J/kg}\cdot\text{C}$ . This means that if you had 1 kg of water, it would take 4190 J (joules) of heat energy to raise its temperature by  $1^\circ\text{C}$ .

Specific heat is a characteristic physical property of a substance and can be used to help find out what the substance is. As a characteristic property, it means that the specific heat will be the same no matter how much of the material you have.

The formula for calculating the amount of heat energy,  $Q$  in joules, needed to change the temperature of an object is:

$$Q = mC\Delta T$$

A way to remember this formula is “ $Q$  equals  $mc\Delta T$ ” where  $m$  is the mass of the object,  $C$  is its specific heat, and  $\Delta T$  is its change in temperature in Celsius.

## Procedure

**Note:** You must wear goggles during this lab.

1. Plug the temperature sensor into Channel 1 (CH 1) on the CBL 2™.
  2. Start the DATAMATE program.
  3. The Main Screen is displayed. If CH 1:TEMP(C) is displayed at the top of the screen, go to step 7. If CH 1:TEMP(C) is not displayed, go to step 4.
- |                      |           |
|----------------------|-----------|
| CH 1:TEMP(C)         | 25.2      |
| MODE: TIME GRAPH-180 |           |
| 1:SETUP              | 4:ANALYZE |
| 2:START              | 5:TOOLS   |
| 3:GRAPH              | 6:QUIT    |
4. Select 1:SETUP.
  5. Select CH1. Select 1:TEMPERATURE.
  6. If you are using the TI stainless steel temperature sensor, select 4:STAINLESS TEMP(C). If you are using a different temperature sensor, select the appropriate item from the menu. Select 1:OK to return to the Main Screen.
  7. Select 1:SETUP. Select MODE, and then select 2:TIME GRAPH.
  8. The TIME GRAPH SETTINGS are displayed. If the screen shows TIME INTERVAL: 10, NUMBER OF SAMPLES: 18, and EXPERIMENT LENGTH: 180, go to step 10. If not, go to step 9.
- |                        |            |
|------------------------|------------|
| TIME GRAPH SETTINGS    |            |
| TIME INTERVAL:         | 10         |
| NUMBER OF SAMPLES:     | 18         |
| EXPERIMENT LENGTH:     | 180        |
| 1:OK                   | 3:ADVANCED |
| 2:CHANGE TIME SETTINGS |            |
9. Select 2:CHANGE TIME SETTINGS. For ENTER TIME BETWEEN SAMPLES IN SECONDS, enter 10. For ENTER NUMBER OF SAMPLES, enter 18 to sample for 180 seconds (3 minutes). The TIME GRAPH SETTINGS screen reappears, showing the new settings.
  10. Select 1:OK twice to return to the Main Screen.
  11. Use the triple beam balance to find the mass of the unknown sample, and record it in the table on the Data Collection and Analysis page.
  12. Place the ring stand with a clamp on it near the hot plate.

- Put 150 ml of water in the 250 ml beaker and place it on the hot plate. Gently place the unknown sample in the water using the tongs. Turn the hot plate to its medium-high setting and bring the water to a boil.

Complete steps 14 through 16 while waiting for the water to boil.

- Find the mass of the empty calorimeter and record it in the table on the **Data Collection and Analysis** page.
- Place 100 ml of room temperature water in the calorimeter. Find the mass of the water and calorimeter, and then subtract the mass of the calorimeter from this value to determine the mass of the water. Record the mass of the water in the table on the **Data Collection and Analysis** page.
- Place the temperature sensor in the water to find the initial temperature ( $T_i$ ) of the water, reading the temperature directly from the top right corner of the TI-73 Main Screen. Record the temperature in the table on the **Data Collection and Analysis** page.
- Using the clamp on the ring stand, carefully suspend the temperature sensor in the beaker of water on the hot plate to measure the temperature of the water once it starts boiling.

**CAUTION:** Make sure that no part of the temperature sensor touches the hot plate. This is very important since the sensor will be ruined if it touches the hot plate for even a short period of time.

- When the water starts to boil, find its temperature. The sample's temperature will be the same as the water. Record this temperature as the substance's initial temperature ( $T_i$ ) in the table on the **Data Collection and Analysis** page.
- Using the tongs, remove the object from the boiling water and gently but quickly place it in the calorimeter. Be careful not to let any water splash out of the calorimeter. Place the top on the calorimeter immediately.
- Insert the temperature sensor into the water through the hole in the top of the calorimeter.
- Select **2:START**. The CBL 2™ beeps twice and displays a graph. At the end of each 10-second interval, the data point is plotted on the graph.
- When the CBL 2 finishes collecting the data, it beeps again and a line graph is displayed. Use  $\blacktriangleright$  and  $\blacktriangleleft$  to find the highest temperature reached in the calorimeter, and record it as the final temperatures ( $T_f$ ) for both the water and the sample.
- Press **ENTER** to return to the Main Screen.
- Select **6:QUIT** and press **ENTER**.

## Data Analysis

After testing, answer the questions on the **Data Collection and Analysis** page to evaluate your results.

***Extension***

Repeat this activity with an unknown substance. Then use the chart on the **Data Collection and Analysis** page to figure out what the substance is.

# Data Collection and Analysis

Name \_\_\_\_\_

Date \_\_\_\_\_

## Activity 11: Specific Heat of Metals

### Problem

How can you determine the specific heat of an unknown material? Based on its specific heat, can you identify an unknown sample?

### Data Collection

As you collect the data, complete the table below. Add the correct unit labels for each data column.

	Mass ( )	T <sub>i</sub> ( )	T <sub>f</sub> ( )	ΔT ( )	C ( )
Calorimeter					
Water					
Sample					

### Data Analysis

1. Calculate the specific heat of the substance and record it in the table above. Use the following equations:

$$Q_w = m_w C_w \Delta T_w$$

$$Q_s = m_s C_s \Delta T_s$$

where *w* is the water and *s* is the sample. You must show every step of your work. Be sure to use the correct unit for each number.

2. Using the following table of specific heats, what is your substance most likely made of?

\_\_\_\_\_

Substance	Specific Heat (J/kg°C)
Water	4190
Aluminum	920
Iron	450
Copper	380
Silver	235

3. Compare your results to your hypothesis. Discuss.

\_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

4. If you had an object three times the mass of the first sample you used, but made of the same material, what would its specific heat be? Explain your answer.

\_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

5. You used the temperature of the boiling water bath as the temperature for your sample. Explain why you were able to do this.

\_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

- 
6. Draw a heat flow diagram of how the heat energy transferred between the sample and the water in the calorimeter.

7. Based on what you know about specific heat, why was the sample's  $\Delta T$  greater than the  $\Delta T$  for the water in the calorimeter?

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## Teacher Notes



## Activity 11

### Specific Heat of Metals

## Objectives

- ◆ To understand how heat is transferred between substances
- ◆ To understand thermal equilibrium
- ◆ To understand what a characteristic physical property is and how it can be used to help find out what an unknown substance might be

## NSES Standards

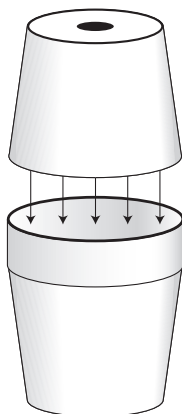
- ◆ Physical Science: Properties and changes of properties in matter
- ◆ Physical Science: Transfer of energy

The math required in this lab may be above the level of many students in Middle School. Students taking Algebra should be able to handle it, but other students will probably require assistance. You may also decide to have your students perform the lab and then do the math calculations as a class before having the students answer the analysis questions.

This lab activity gives students the chance to explore a characteristic physical property of matter, specific heat. They also will have the opportunity to see two examples of thermal equilibrium: when they heat the sample in boiling water and when they place the sample in the water in the calorimeter.

### Preparation

- ◆ You will need two 8-ounce styrofoam cups for each lab group. Take one cup and trim the top approximately 1 inch below the rim. Poke a small hole large enough for the temperature sensor to fit through in the center of the bottom of the cup you just cut. This is the top for the calorimeter. To assemble the calorimeter, invert the cup with the hole in its bottom and place it inside the other cup.





## Management

- ◆ The students need to understand that the sample's temperature when it is taken from the boiling water will be the same as the water's temperature; therefore, it is important that they move the substance as quickly as possible. Secondly, they need to understand that for the same reason, the water and the substance inside the calorimeter will be at the same temperature once that temperature stabilizes.
- ◆ To solve for the specific heat, the formula for calculating the amount of heat energy,  $Q$  in joules, needed to change the temperature of an object is:  $Q = mC\Delta T$  (a mnemonic to help remember this formula is "mcat") where  $m$  is the mass of the object,  $C$  is its specific heat, and  $\Delta T$  is its change in temperature in Celsius.

There are two ways for the students to find the sample's specific heat.

(1) The two initial equations are:

$$Q_w = m_w C_w \Delta T_w$$

$$Q_s = m_s C_s \Delta T_s$$

Before beginning the lab, it is critical that the students understand that the heat transferred from the substance to the water in the calorimeter is the same as the heat absorbed by the water. Once they understand this, it will be possible to explain that:

$$Q_w = Q_s$$

They can solve for  $Q_w$  using the known information and the data collected for the water in the calorimeter and then substitute the value for  $Q_w$  into the equation for  $Q_s$ .

(2) The other method for solving this problem is to combine the equations before substituting any numbers from the table.

$$Q_w = m_w C_w \Delta T_w$$

$$Q_s = m_s C_s \Delta T_s$$

Since  $Q_w = Q_s$ , then  $m_w C_w \Delta T_w = m_s C_s \Delta T_s$

By taking this a step farther, you can set up an equation to solve for the sample's specific heat,  $C_s$ , as follows:

$$\frac{m_w C_w \Delta T_w}{m_s \Delta T_s} = C_s$$

At this point, the values from the table can be substituted into the equation and it can be solved for  $C_s$ . For many students, solving each equation separately may make the process more understandable. After they solve the two equations separately, you may want to explain the process for combining the equations to them as an extension activity.

- ◆ Assign these student jobs for this lab:
  - Materials/setup person (sets up samples, sensor)
  - Tech person (operates CBL 2™ and TI-73)
  - Data recorder (reads temperatures from the TI-73 at each collection interval)
  - Runner (brings CBL 2 and TI-73 to the computer to print graphs with TI-GRAPH LINK™ or TI™ Connect and brings **Data Collection and Analysis** pages to the teacher)
- ◆ Clear covered plastic shoeboxes will hold the CBL 2, temperature sensors, and other equipment neatly at each station.
- ◆ Students can record data points in their lab journals as they are displayed on the TI-73. This keeps them engaged throughout the data collection period and if they lose the data/graph later, they can still write up their lab reports. Students can also access the data in the TI-73 lists after data collection. You can send lists to all students' calculators using **[APPS] 1:Link**.
  - a. Press **[APPS]**.
  - b. Press **[ENTER]** to select **1:Link**.
  - c. Select **4:List** and press **[ENTER]**.
  - d. Press **▾** to move the **▶** beside the list you wish to send. Press **[ENTER]**.
  - e. Repeat step d for each list you wish to send.
  - f. Set the receiving unit by pressing **[APPS] [ENTER] ▶** to select **RECEIVE**. Press **[ENTER]**. **Waiting...** displays on the TI-73 screen.
  - g. On the sending unit, press **▶** to select **TRANSMIT** and press **[ENTER]**.

For more permanent storage of data, use TI-GRAPH LINK or TI Connect to save the lists in a computer folder. However, students may inadvertently lose their data or overwrite it in the next trial, so recording data in journals is a good option.
- ◆ Students can assess each other using a teamwork rubric after the lab. Provide a checklist of positive and negative behaviors. Copy these on quarter sheets of paper.