Experiment: Heat and Energy

Objective: In this laboratory, the properties of heat and temperature will be investigated to measure the specific heats of common metals.

Required:

- electric hot plate
- specific heat specimen
- 800 or 1000 mL beaker
- tongs
- 2 styrofoam cups & cover
- digital gram balance
- 2 stainless steel temperature probes
- LabPro Interface
- cold deionized water
- CRC Handbook of Chemistry & Physics

Discussion

Have you ever held a hot piece of pizza by the crust only to have the moister parts burn your mouth when you take a bite? The meats and cheese have a high specific heat capacity, whereas the crust has a low specific heat capacity. How can you compare the specific heat capacities of different materials?

In this experiment you will increase the temperature of metal specimens in boiling water and then place them in Styrofoam cups or calorimeters that contain a mass of water equal to the specimen at room temperature. The heat lost by the hot specimen as it cools equals the heat gained by the water as it warms up. *{Note: heat lost by the specimen is the same as minus heat gained by the specimen}*

$$Q_{\text{lost by specimen}} = -\,Q_{\text{gained by specimen}} = Q_{\text{gained by water}}$$

$$-\,m_s s_s \Delta T_s = m_w s_w \Delta T_w$$

Solving for the specific heat capacity of the specimen (s_s) we get

$$s_s = -\,\frac{(m_W s_W \Delta T_W)}{(m_S \Delta T_S)}$$

For water the specific heat capacity (s_w) is 1.000 cal/g^{o}C. If the mass of the water is the same as the mass of specimen, then the specific heat of the sample is

$$s_s = -\left(1.000\ \frac{\text{cal}}{\text{g}^\text{o}\text{C}}\right)\times\frac{\Delta T_W}{\Delta T_S}$$

Procedure

1. Turn-on the computer.
2. Connect 2 temperature probes to the LabPro interface in CH 1 and CH 2, respectively.
3. Start the LoggerPro software.
4. Place a Styrofoam cup inside a second cup. You have just constructed an inexpensive double-walled calorie meter, called a *calorimeter*. Locate a plastic-sealed cardboard square to use a lid for your calorimeter.
5. Record the identity and measure the mass of your specimen individually. The mass value will be needed for the following steps.
6. Insert the specimen into a beaker with cold water and place the beaker onto an electric hot plate. Turn on the hot plate and bring the water to boiling temperature.
7. Add the same mass of DI water to your calorimeter as the specimen. Use the digital gram scale to measure the water mass. Place the Styrofoam cups onto the gram scale and zero it. Pour the water into the calorimeter and record the mass of the water.
8. Use a temperature probe to measure the temperature of the water in the calorimeter.
9. Heat the specimen in the water on the hot plate (to near boiling) for more than a minute until you are convinced that they are in thermal equilibrium with the water. Measure and record the temperature of the boiling water. ***This should be the same temperature as the specimen, since it is in thermal equilibrium.***
10. Using tongs, quickly remove the selected specimen from the boiling water and place it in the calorimeter. Be sure to shake any droplets of water from the specimen. Place a cover over the calorimeter to minimize excess heat loss then insert the 2nd temperature probe through the cover into the calorimeter.
11. Gently swirl the calorimeter to assist the heat transfer from specimen to water. When the water temperature inside the calorimeter reaches a stable value, record the final temperature (***which should also be the final temperature of the specimen as well!***).

    Note: *Be sure to allow the specimen enough time to transfer its heat energy to the water. This may take several minutes. Be patient and continue swirling the calorimeter until the temperature reaches its highest value and begins to cool down. Record the highest temperature value in the provided data table.*

12. Repeat steps 7-11 for a total of at least 3 trials with the same specimen.

Table A: Your Data

Specimen:	**Calorimeter**	**Specimen**	**Both**	**Temperature Changes**	
Mass (g):	$T_{initial}$ (°C)	$T_{initial}$ (°C)	T_{final} (°C)	ΔT_w (°C)	ΔT_s (°C)

Analysis

1. Calculate the specific heat capacity values for your specimen using the equation on page 1 (in cal/g°C) and record the values in Table B.
2. Convert the specific heat capacity values to units of J/g°C. Note: The units J/g°C are the same as J/g·K, since a temperature change in °C is the same as a temperature change in K units. *You will only need to convert the cal units to J.*

Table B: Analysis

s (cal/g°C)	**s (Joules/g°C)**	**Average s**	**Accepted s Value**	**% Error**
				% Range

Summing Up:

1. Look up the specific heat capacity values for all of the elements in Table C (back page). Fill in the corresponding accepted value in the table above.
2. Convert the specific heat capacity values in Table C from J/g°C to cal/g°C.
3. Compare <u>your</u> value for the average specific heat to the accepted value from Table C for the corresponding substance. Conceptually, how do your values compare?

4. Determine the % error between the measured value and the accepted value for your specimen. Record % error value in Table B.

5. Determine the % range for your measured s values and record in Table B.

6. Based on your % error values, how do your measured values of specific heat capacity compare to the accepted CRC values? What would be your criteria for "good" agreement between those values?

7. Is your calculation in Question 4 a measure of accuracy or precision? Explain.

8. Is your calculation in Question 5 a measure of accuracy or precision? Explain.

Table C: {from Specific Heats of Elements @ 25 ^{o}C (CRC)}

Specific Heat Capacity		
Substance	**s** (cal/g^{o}C)	**s** (Joules/g^{o}C)
Aluminum		
Cadmium		
Copper		
Gold		
Iron		
Lead		
Silver		
Tin		
Zinc		
Mercury		
Water		