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 scale
- 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}*

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

$$-\,m_s c_s \Delta T_s = m_w c_w \Delta T_w$$

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

$$c_s = -\frac{(m_W c_W \Delta T_W)}{(m_S \Delta T_S)}$$

For water the specific heat capacity (c_w) is 1.000 cal/g°C (or 4186 J/kg·K in SI units). If the mass of the water is the same as the mass of specimen, then the specific heat of the sample is

$$c_s = -\left(1.001\ \frac{\text{cal}}{\text{g}^{\circ}\text{C}}\right) \times \frac{\Delta T_W}{\Delta T_S}$$

Preliminary Questions

1. A 100.0 g metal sample is heated to a temperature of 120°C then placed into a "calorimeter" containing 100.0 g of pure water (at initial temperature of 20°C). After the sample and water reach thermal equilibrium, their final temperature is 23.0°C.

   a. Determine the specific heat capacity of the metal sample, in units of cal/g°C

   b. Calculate the specific heat capacity of the metal sample in units of J/kg·K.

c. What is the identity of the metal sample? *{Fill out the table on page 4 the use it to answer this question…}*

d. What is the % Error between your answer in (a) and the accepted value?

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 then open the following experiment file from the local network: "I:\\SCIENCE\PHYSICS\ZABLE\PHY202\Phy202-SpecHeat".
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 temperature probe 1 to measure the temperature of the water in the hot beaker and probe 2 to measure the water in the calorimeter. Place them into the appropriate containers.
9. Heat the specimen in the water on the hot plate (to near boiling) for more than a minute.
10. Begin data collection then using tongs gently swirl the specimen (in the hot water) until you are convinced that they are in thermal equilibrium with the water. ***This should be the same temperature as the specimen, since it is in thermal equilibrium.***
11. Quickly remove the 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 with temperature probe over the calorimeter to minimize excess heat loss.
12. Gently swirl the calorimeter to assist the heat transfer from specimen to water. When the water temperature inside the calorimeter reaches a stable value (***which should also be the final temperature of the specimen as well!***). Stop data collection. If you run out of collection time, store the run then start collection again.

    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.*

13. Store the data run in LoggerPro.

14. Using the statistics function, determine the initial and final temperatures for the specimen and calorimeter water from the graph, including uncertainty.
15. Cut-and-paste the graphs for probes 1 and 2, with statistics boxes, into Word.
16. Repeat steps 9-15 for a total of at least 3 trials with the same specimen.
17. Print out the graphs on a single page.

Table A: 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 (also calculate the experimental uncertainty).
2. Convert the specific heat capacity values to units of J/kg·K and record in the table.

Table B: Analysis

c_s (cal/g°C)	**c_s (Joules/kg·K)**	**Average c_s (Joules/kg·K)**	**Accepted c_s Value**	**Uncertainty (±)**
				% Error

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. For water, you will need to approximate the corresponding value using values at 20 °C and 30°C.
2. Convert the specific heat capacity values in Table C from J/g·K to J/kg·K.
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. Based on your % error value and the experimental uncertainty, how does your average value of specific heat capacity compare to the accepted CRC value? What would be your criteria for "good" agreement between those values?

6. If your average specific heat capacity value was low, the presence of the temperature probe may have affected your measurements. Estimate the influence of the temperature probe on your measurements.

   To do this, assume your specimen has the "accepted" value of specific heat capacity from the CRC. Using your measurements above, calculate the experimental value for specific heat capacity you <u>would expect</u> to obtain given the presence of the temperature probe. ***Note:*** *The mass of the metal probe is approximately 5 grams and the specific heat capacity for the stainless steel probe is 450 J/kg·K.*

7. Does your prediction in question 6 explain the error between your measurements and the accepted value? Explain.

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

Specific Heat Capacity		
Substance	**c** (J/g°C)	**c** (J/kg·K)
Aluminum		
Cadmium		
Copper		
Gold		
Iron		
Lead		
Silver		
Tin		
Zinc		
Mercury		
Water		