Getting Specific About Specific Heat

Math / Chemistry
High
Regressions / Data Collection

Introduction: Specific heat is the characteristic of a substance that describes how it holds or disperses heat energy. Water has a high specific heat. It takes a lot of energy to warm water and it takes a long time for water to cool down (compared to other substances). Aluminum, however, has a low specific heat. It warms and cools very quickly.

In the laboratory, heat transfer is measured by using calorimeter. A calorimeter is a container that holds the substances that are losing or gaining heat energy. Calorimeters are insulated to reduce the chance of energy being lost or gained from the surrounding environment. The amount of heat lost from one substance should equal the heat gained by another within the closed system. In this activity, water will be used as the substance to gain heat energy. The sample will be the substance to lose heat energy.

This simple relationship can be expressed as:

$$\text{heat loss} = \text{heat gain}$$

$$q_{\text{lost}} = q_{\text{gained}}$$

For the sake of this activity, a Styrofoam cup will be used as a calorimeter. The calorimeter will be half filled with room temperature water. The substance losing heat will be a metal shot sample that has been heated to 100 degrees Celsius by keeping it in boiling water. The metal shot sample will then be transferred to the calorimeter. The change in temperature of the water will be recorded. The mass of the substances is related to the amount of heat energy it can hold (a tub of hot water takes longer to cool than a cup. Therefore, the mass of the sample and the mass of the water must be measured. The amount of heat energy gained by the water is:

$$q_{\text{gained}} = m_{\text{water}} \text{ x } (T_{\text{final}} - T_{\text{initial}})_{\text{water}} \text{ x } C_{\text{water}}$$

The metal sample will lose heat by the equation:

$$q_{\text{lost}} = m_{\text{sample}} \text{ x } (T_{\text{final}} - T_{\text{initial}})_{\text{sample}} \text{ x } C_{\text{sample}}$$

The heat loss will equal the heat gained, therefore:

$$m_{\text{sample}} \text{ x } (T_{\text{final}} - T_{\text{initial}})_{\text{sample}} \text{ x } C_{\text{sample}} = m_{\text{water}} \text{ x } (T_{\text{final}} - T_{\text{initial}})_{\text{water}} \text{ x } C_{\text{water}}$$

Solving this equation for C_{sample} , we get:

$$C_{\text{sample}} = \frac{m_{\text{water}} \text{ x } (T_{\text{final}} - T_{\text{initial}})_{\text{water}} \text{ x } C_{\text{water}}}{m_{\text{sample}} \text{ x } (T_{\text{final}} - T_{\text{initial}})_{\text{sample}}}$$

Objectives: Students will be able to…

1. Collect data by following an experimental procedure.
2. Input data in a graphing calculator.
3. Compare results.
4. Draw conclusions.
5. Make predictions.
6. Discuss the relationships in thermodynamic systems.

Related Key Words:
specific heat
heat flow
heat capacity
conduction
calorimetry
radiation
heat of transformation
convection

Materials:
CASIO CFX-9850G Color Graphing Calculator
EA-100 with temperature probe
Electronic balance with +/- .01g accuracy
Large beaker (400, 600, or 800 mL)
Distilled water
Styrofoam cup and appropriately sized beaker the cup can fit into for added support and insulation
Bunsen burner and ring stand or hotplate
Brass shot sample and any one of the following: aluminum, copper, lead, zinc shot, or glass beads
Large test tube, utility clamp and ring stand
Strainers and pie pans for removing sample and drying samples in drying oven

Procedures: The purpose of this lab is to experimentally determine the specific heat of a sample (Csample) by measuring all the quantities from the final equation stated above.

<u>STEP 1—</u> With the EA-100 off, plug in the temperature probe into Channel 1. The EA-100 should be set to collect one data point every 2 seconds for 200 data points. This will give you 400 seconds of data gathering which is 6 and 2/3 minutes of data. The EA-100 can also be programmed from the calculator using the "Real Temp" program.

STEP 2— Fill the large beaker to about ¾ full with distilled water. Place it on the ring stand over the Bunsen burner or on the hot plate and bring water to a rolling boil.

STEP 3— Write the names of the samples selected in the spaces provided on the data table.

STEP 4— Place a clean dry test tube on the scale and zero the scale. Fill the test tube to about 1/3 full with the sample shot to be used. Carefully determine and record the mass of the sample.

STEP 5— Attach the test tube to the utility clamp and immerse in the boiling water. Attach the clamp to the ring stand and let it heat for 5 to 10 minutes.

STEP 6— Place s clean, dry Styrofoam cup on the balance and zero it. Fill the cup to about ½ full with distilled water. Be careful not to spill any on the balance pan. Read and record the mass of the water. Place the cup in an appropriately sized beaker for support and added insulation.

STEP 7— Immerse the temperature probe into the water in the cup and once the reading is stable, record as the initial temperature of the water on the data table.

STEP 8— Immerse the temperature probe into the boiling water and wait for the reading to stabilize. Once the reading is stable, record as the initial temperature of the sample.

STEP 9— Detach the clamp holding the test tube and remove the test tube from the boiling water. Pour the sample into the water in the in the Styrofoam cup and immediately hit the [Trigger] button on the EA-100.

STEP 10— Gently stir the contents of the calorimeter until the temperature stabilizes and record as the final temperature of the water and the sample on the data table.

STEP 11— Pour the water and the sample into a strainer for draining.

STEP 12— Repeat the procedure for a second sample. Complete the data table for the calculations for heat capacity. Use you periodic table to determine the accepted values and calculate the percent error.

STEP 13— To see the graph of the data, press [EXIT] then [MENU] on you calculator. Select the STAT menu and hit [EXE]. Select GRPH by pressing [F1], then [F1] again for GPH1. Select the MED regression by pressing [F2]. Copy the equation to the GRAPH menu by pressing [F5] for COPY.

Questions and Problems:

Level 1: Answer the following questions in complete, well-structured sentences.

1. Give an example of each of the three ways heat energy can be transferred.
2. In what way is the heat transferred from the sample to the water?
3. What is the explanation of why the sample changed the water temperature?
4. What type of graph does the data make. Are there other regression options that create a more accurate best-fit curve?

Level 2:

1. The accepted value for the specific heat of brass is 234 j/g*C. Explain three reasons why your results may not be the same as the accepted value.
2. Discuss how the procedures might be improved to reduce the percent error.
3. Why is it important to know the heat capacity of different materials?
4. Based on your data and that of your classmates, which sample had the greatest specific heat? Which had the lowest? Is there a relationship between the sample's density and heat capacity, or is it governed by some other factor. Explain fully using data to support your position.

Extension: Have students research the topic of thermal insulators and thermal conductors.

Data Table

Getting Specific about Specific Heat

	First Sample	Second Sample
Sample Name		
Mass of Sample		
Mass of water		
Initial temp. of water		
Initial temp. of sample		
Final temp. of system (water and sample)		
Sample's calculated C		
Sample's accepted C		
Percent Error		

Calculations

I. Specific Heat (C of 1st Sample)

1.

2.

3.

II. Percent Error (1st Sample)

1.

2.

I. Specific Heat (C of 2nd Sample)

1.

2.

3.

II. Percent Error (2nd Sample)

1.

2.