Lab 04: Specific Heat

The red-hot coil heats up quickly, and has a much higher temperature than the water in the pan. But why does the handle of the saucepan stay cool enough to grasp?

Introduction

Not everything heats up the same way; if you have ever boiled water, you probably already know this. The metal saucepan gets very hot very quickly; it is soon too hot to touch. But the water in the pan takes much longer to get warm. Heat is energy, and what you are seeing is that the metal pan needs less energy to increase its temperature, and the water requires more energy. There are two things to consider: the metal pan is a different material than the water, and there is a different amount of each material. Typically, the water will weigh more than the pan. However, in this case we want to compare the materials themselves, not the relative amounts.

Specific heat is defined as the amount of energy, or heat, required to raise the temperature of 1 gram of substance by 1 degree Celsius. For water, 1 calorie of heat is needed to raise 1 gram of water by 1°C, so by definition its specific heat is $c_w = 1$ **cal/g·°C.** The specific heat of aluminum is $c_{Al} = 0.217$ cal/g·°C, iron has $c_{Fe} = 0.113$ cal/g°C, lead has $c_{Pb} = 0.031$ cal/g·°C, and for brass $c_{br} = 0.092$ **cal/g·°C.** This means that is takes less heat energy to raise the temperature of one gram of aluminum than one gram of water, and even less heat to raise the temperature of one gram of lead.

Objectives

- Observe the difference between heat and temperature
- Monitor the transfer of heat from one substance to another
- Use these observations to calculate the specific heat of an unknown substance
- Calculate the amount of error in an experimental value
- Examine a procedure for sources of experimental error

Do not measure the hot water in the boiler cup.
Definitely measure the cold water in the calorimeter.

Equipment

- LabQuest
- Temperature probe
- Electric hot plate
- Heat-safe boiler cup
- Metal sample cubes
- Calorimeter
- Graduated cylinder
- Triple-beam balance

Experimental Procedure

- Work in groups of three; you will need that many people cooperating simultaneously to use the apparatus correctly and record accurate measurements.
- Fill the boiler cup with sufficient water to submerge a metal sample cube. Use just enough water to completely cover the cube (you don't want to wait forever for that water to boil). Set the water to boil on the hot plate while you make other measurements.
- Choose a sample cube. Measure and record the mass (m_s).
- Submerge the sample in the open boiler cup and let it heat until the water boils. Allow the water to come to a full, rolling boil. At this point, the water and the cube will be 100°C.
- While the sample is heating, prepare the calorimeter by adding a known mass of cold water.
- Weigh an empty beaker and record its mass (m_1). Add cold water (colder than room temperature) until you have about 200ml of volume. Measure and record the mass (m_2), then pour the water into the inner cup of the calorimeter.

- Connect the temperature probe to the LabQuest and switch it on. Use the instantaneous display of the temperature under the **Meter** tab to monitor the temperature. You do not need to collect data over a timed trial. Wait until the temperature has stabilized, and record the value on the LabQuest display.
- Measure the initial temperature of the water (T_w) just before adding the cube to the calorimeter, and record it. Add the sample to the calorimeter. Watch the LabQuest display, and when it stabilizes, record the final temperature of the water + sample mixture (T_f).
- Repeat the experiment using a different cube. While it is heating, prepare the calorimeter again as previously, replacing the water with fresh cold water (do not forget to re-measure the mass of the water). Repeat the measurements of water T_w, and combined T_f.

Data & Analysis

If you have not already, organize your measurements into a neat table similar to the example shown below.

Trial	Sample Mass m_s (g)	Sample Temp T_s (°C)	Empty Beaker m_1 (g)	Full Beaker m_2 (g)	Water Mass $m_w = m_2 - m_1$ (g)	Water Temp T_W (°C)	Final Temp T_F (°C)	Specific Heat c_s (cal/g·°C)
1		100°						
2		100°						

1. Subtract the mass of the empty calorimeter cup from the mass of the full calorimeter to determine the mass of the water:

$$m_w = m_2 - m_1$$

2. Calculate the specific heat of the sample for each trial, using the premise that whatever heat is lost by the sample cube must be gained by the water:

energy lost by cube = energy gained by water

$$m_s c_s (T_s - T_f) = m_w c_w (T_f - T_w)$$

Solving for the specific heat c_s:

$$c_s = \frac{m_w c_w (T_f - T_w)}{m_s (T_s - T_f)} = \frac{m_w (1)(T_f - T_w)}{m_s (100° - T_f)}$$

3. Average the values of c_s for the two trials. Using this average value, determine which material the cube is made of.
4. Calculate the percent error for your average value:

$$\%error = \frac{(true\ \ value - your\ \ value)}{(true\ \ value)} \times 100$$

5. What heats up more quickly, a material with a high or low specific heat? When you go to the beach, what do you notice about the temperature of the sand compared to the temperature of the sea? Which has the higher specific heat? Why?
6. If you raised two **same–sized** cubes of metal (one iron, the other aluminum) from 20° to 100°, which cube required more energy? If each is then submerged in a separate beaker of ice water (just at 0°), which beaker would have a higher final temperature when they stabilize? Why?
7. If you raised two **same–mass** cubes of metal (one iron, the other aluminum) from 20° to 100°, which cube would require more energy? If each is then submerged in a separate beaker of ice water (just at 0°), which beaker would have a higher final temperature when they stabilize? Why?
8. Is your value for the specific heat close (within about 5%) to the predicted value? Are you over or under? Do you think it is more likely to get an experimental value that is too low or too high? Explain why.
9. Suggest some ways to improve your measurements and increase the accuracy of your results. Think carefully here: we do not need to improve the precision of the tools–think about technique! Specifically, think about the idea of transporting energy, and whether the assumption that we started with is strictly accurate.
10. Please be sure to complete the quiz worksheet and submit it before you leave. No worksheets will be accepted for credit after the end of the lab period.