LAB 13. HEAT CAPACITY

Introduction

The property of matter that describes temperature's response to applied heat is called the *specific heat capacity*. A *calorie* is defined as the quantity of heat needed to raise the temperature of one gram of water by one degree C. Consequently, the specific heat of water is exactly 1 cal/g °C. (Note that one calorie does not equal one joule; it equals 4.184 joules, so keep track of your units.) In this experiment, you will determine the specific heat capacity of a metal sample.

Theory

When the hot metal contacts the cool water, heat flows from the hot metal to the cool water until they come to thermal equilibrium at the same temperature. We will make the approximation that there is no heat flow between the system (water + metal) and the surroundings (everything else). Thus, the energy lost from the metal as it cools is exactly the same as the energy gained by the water as it warms.

The heat input q to the water raises its temperature an amount $\Delta T_{\text{w}} = \frac{q}{c_{\text{w}} M_{\text{w}}}$, where c_{w} is the specific heat capacity of water and M_{w} is the water's mass. Correspondingly, the heat output q from the metal lowers its temperature an amount $\Delta T_{\text{m}} = -\frac{q}{c_{\text{m}} M_{\text{m}}}$, where c_{m} and M_{m} are the metal's specific heat capacity and mass. These two equations contain two unknown quantities between them: q and c_{m}. Your job is to find c_{m}.

Experiment

You will heat a metal piece to a known temperature (that of boiling water) and then measure how much it cools off when it is placed in a cup of cool water. The measured change in temperature will allow you to calculate the block's heat capacity.

Materials

Tongs, boiling water pot, metal sample, foam cup, thermometers, tongs

Data Collection

1. Measure the mass of your metal object. Record this and subsequent data in Table 3.
2. Measure the mass of the empty foam cup.

   Mass of cup: _______________
3. Place the metal block in the cup and add just enough water to cover the block.
4. Remove the block and transfer into the pan of boiling water. Record the temperature T_{m} of the boiling water. Record it in the Table.

5. Make sure that there is enough water in the pan that the block is completely covered. Heat the block in boiling water for at least three minutes. If the water stops boiling when you add the block, wait until it resumes boiling and start timing then.
6. While the water is boiling, add a little bit of ice to the water in the calorimeter. Once all the ice has melted (if any ice remains, remove it), measure the mass of the calorimeter containing the cool water.

   Mass of calorimeter and water: ______________
7. Subtract the mass of the empty calorimeter to find the mass M_w of the water inside. Enter this value in the Table.
8. Just before removing the metal block from the boiling water, stir the cold water in the calorimeter cup and measure its temperature T_1. Record this value in the Table.
9. Use tongs to remove the metal block from the boiling water and immediately place it in the calorimeter cup. Stir until the temperature of the water in the calorimeter stops increasing. Record this value T_2 in the Table.
10. Calculate the temperature changes of the calorimeter water and the metal block. The temperature change of each substance is its final temperature minus its initial temperature.

Make sure you have the correct signs for the two ΔT's! Enter these values in the Table.

Table . Metal piece in water

Description of object:	
Mass of object (M_m):	
Mass of water in calorimeter cup (M_w):	
Temperature of boiling water (T_m)	
Temperature of cool water before immersion of object (T_1):	
Final temperature of equilibrated calorimeter water + object (T_2):	
Temperature change of calorimeter water $\Delta T_w = T_2 - T_1$	
Temperature change of object $\Delta T_m = T_2 - T_m$	

Data Processing

1. The following equation expresses the conservation of thermal energy between the water and the block, assuming that no energy goes anywhere else or enters from anywhere else. Solve this equation for c_m. Show your steps.

$$M_w \cdot \Delta T_w \cdot c_w = -M_m \cdot \Delta T_m \cdot c_m$$

2. Calculate the specific heat capacity of the unknown metal (c_m) using the formula you just derived. (Don't forget the units!)