SPECIFIC HEAT

Reminder – Goggles must be worn at all times in the lab

PRE-LAB DISCUSSION:

The amount of heat required to raise the temperature of a solid body depends on its change in temperature (ΔT), its mass (m), and an intrinsic characteristic of the material forming the body called specific heat (c_p). The heat is calculated from the equation

$$Q = c_p \times m \times \Delta T$$

The unit for c_p is thus heat per unit mass per unit temperature. The value of c_p does depend on the temperature. However, for the small temperature range we are interested in, it is a good approximation to regard c_p as temperature independent. Historically, heat (Q) was measured in terms of calories. The calorie was defined as the amount of heat required to raise the temperature of 1 gram of water by 1 °C from 14.5 °C to 15.5 °C at 1 atmosphere pressure. With this definition, the specific heat of water is 1.00 cal/(g·°C). The use of the calorie began before it was established that heat is a form of energy and 1 calorie is equivalent to 4.18 J. The joule (J) has become the more favored unit in recent years. Thus, the units for c_p that we will use are J/(g·°C). The specific heat of water is then 4.18 J/(g·°C).

When two bodies in an isolated system, initially at different temperatures, are placed in intimate contact with each other, in time they will come to equilibrium at some common intermediate temperature. Because of energy conservation, the quantity of heat lost by the hot object is equal to that gained by the cold object provided that no heat is lost to the surroundings. This is the basis for the method of calorimetry through mixture: A metal sample whose specific heat is to be determined is heated in boiling water to 100 °C. It is then quickly transferred to a Styrofoam calorimeter cup that contains a known volume of water of known temperature. When the metal specimen and the calorimeter (including the water) come to equilibrium, the final temperature is measured with a thermometer. It is assumed that the heat loss to the Styrofoam cup and thermometer is negligible and if the heat exchange with the environment is kept small, then the heat lost by the metal sample is equal to the total heat gained by the water.

PURPOSE:

To apply the experimental methods of calorimetry in the determination of the specific heat of a metal.

MATERIALS

Brass plumbing fixtures
Styrofoam cup
100 mL graduated cylinder
Bunser burner and ringstand
Thermometer
Milligram balance
Crucible tongs

PROCEDURE:

1. Set up a ring stand with Bunsen burner, and begin heating approximately 200 mL of water in a 400 mL glass beaker. Heat the water to boiling.
2. Get a brass object from the counter. Determine its mass, and record the results in the data section.
3. Lower the brass object into the water with your crucible tongs. Be careful not to <u>drop</u> the piece of brass into the beaker (you might crack the beaker).
4. Obtain a Styrofoam cup "calorimeter" and add to it 50.0 mL of water. Remembering that the density of water is 1 gram per mL, record the mass of the water in your data table.
5. It is often helpful to place the Styrofoam cup within a larger glass beaker in order to keep it from tipping over during the experiment.

6. Place a thermometer in the Styrofoam cup to get an initial temperature for the water. Record this value (initial, T_1) in your data table.
7. When the brass object has been in the <u>boiling</u> water for 3 minutes, quickly move the piece of brass to the calorimeter using your large crucible tongs (NOT a test tube holder or tweezers). DO NOT try to handle the brass object with your hands. Do not allow the thermometer to come in direct contact with the piece of brass. You may want to stir the water gently with the thermometer in order to get a more even distribution of heat within the cup.
8. Continue observing the temperature on the thermometer as the heat is transferred to the water. Note the highest temperature reached for the water (final, T_2). Record this value in your data table.

9. Repeat the ENTIRE procedure two more times (three total) recording new values for change in temperature.
10. When done, return the brass and the Styrofoam cup to the counter. Disassemble the ring stand and water beaker when the water in the beaker has cooled enough to allow handling of the beaker. This will usually be at least 30 minutes!

OBSERVATIONS AND DATA:

	Trial #1	Trial #2	Trial #3
1. Mass of the brass object	g	g	g
2. Volume of water in the calorimeter	mL (grams)	mL(grams)	mL(grams)
3. Initial temperature of water in calorimeter(T_1)	°C	°C	°C
4. Final (highest) temperature of calorimeter(T_2)	°C	°C	°C

CALCULATIONS: <u>Show your work</u>! You will repeat the first four calculations <u>three times</u>, once for each trial you perform.

	Trial #1	Trial #2	Trial #3	Average
ΔT_{water} (T_2 - T_1)				
ΔT_{brass}, (T_2 - 100 °C)				

1. Copy the table above, and calculate the temperature change of the water, ΔT_{water}, $T_2 - T_1$ for each trial. Then calculate the average of these values for water.
2. In the same table, calculate the temperature change of the brass, ΔT_{brass}, T_2 - 100 °C (Yes your answer, will be negative). Then calculate the average of these values for brass.
3. Calculate the amount of energy absorbed by the water. In order to do this, we use the specific heat (c_p) of pure water, 4.18 J/(g·°C), and we assume the density of the water was 1.00 gram/mL. Express your final answer in joules.

$$Q_{water} = c_{p\ water} \times m_{water} \times \Delta T_{water}$$

4. Next, we assume that the energy ***absorbed*** by the water is equal to the energy ***lost*** by the brass.

$$-Q_{water} = Q_{brass}$$

On this assumption, we can calculate the specific heat of brass using the mass of the brass (m), the value of Q calculated above, and ΔT_{brass}.

$$c_{p\ brass} = \frac{Q_{brass}}{m_{brass} \cdot \Delta T_{brass}}$$

5. Using the known value of the specific heat of brass, 0.380 J/(g·°C), calculate the absolute error in your averaged experimental result.
6. Calculate your relative error (<u>PERCENT ERROR</u>). Remember that:

$$\%\ Error = \frac{Absolute\ Error}{Accepted\ Value} x100$$

QUESTIONS FOR DISCUSSION

1. Describe at LEAST three sources of experimental error, and the effect that each would have on the magnitude of the specific heat calculated from your experimental results.
2. Brass is a homogeneous mixture of copper and zinc, in a 60:40 mixture, respectively. However, much of the brass produced today has other elements alloyed with it, altering the mixture. What effect might this have on the absolute error and the percent error that you calculated?