MND Physics

Specific Heat

One property of a substance is the amount of heat it can absorb per unit of mass. This property is called specific heat. Every substance has its own unique specific heat or capacity for heat energy.

By definition, specific heat is the amount of energy (in joules) needed to raise the temperature of 1 kg of material 1 degree Celsius.

You will use a device called a calorimeter to measure the specific heat of two metals. Calorimeter equipment can be quite complex. However, we will use a very simple but effective calorimeter, 2 Styrofoam cups. Styrofoam has great insulating properties especially when doubled up, one cup inside another with a pocket of air in between. A cup lid of Styrofoam will also be utilized. This simple device limits heat loss and offers the opportunity for good data capture.

The Simple 2-Cup Calorimeter

PROCEDURE OVERVIEW:

The purpose of this lab is to calculate the specific heat of two of the following three metals: ALUMINUM, COPPER, and/or ZINC. Because of time constraints, you will work with only two of these three metals (your choice).

You will heat the metal sample by suspending it in a beaker of boiling water. If the sample remains in the water bath long enough, we can assume that the water and the metal reach thermal equilibrium. Therefore, by measuring the temperature of the boiling water, you are in effect, measuring the initial temperature of the metal sample.

The metal sample is then transferred to a prepared calorimeter. A prepared calorimeter contains a known mass and known temperature of room temperature water. The hot metal will cause the room temperature water in the calorimeter to rise. By recording this temperature change, we can calculate the specific heat of the metal sample:

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

$$\text{but since} \quad Q = mC\Delta T$$

$$-(m_{metal}\, C_{metal}\, \Delta T_{metal}) = (m_{water}\, C_{water}\, \Delta T_{water})$$

OR, rearranging:

$$C_{metal} = \frac{m_{water}\, C_{water}\, \Delta T_{water}}{-(m_{metal}\, \Delta T_{metal})}$$

(mass is in kg, temperature in Celsius, C_{water} in J/ kg C)

EQUIPMENT:
CBL digital thermometer with temperature probe, calculator, 2-cup calorimeter, Styrofoam top, specific heat set (2 masses), triple beam balance, tap water, 600 ml beaker, hot plate, string, wood dowel, tongs.

PROCEDURE:

1. **CAUTION:** Use caution around the hot plate surfaces, the hot glassware, the boiling water and the hot metal samples themselves. DO NOT TOUCH THE HOT METAL SAMPLES WITH YOUR BARE HANDS OR FINGERS WHILE TRANSFERRING THEM TO THE CALORIMETER!.

2. Fill a 600 ml beaker about $\frac{3}{4}$ full with tap water. Turn the hot plate on and bring the water to a boil. The metal samples will be placed in the boiling water and will be allowed to reach thermal equilibrium.

3. Measure the mass of the metal sample using a triple beam balance.

4. Tie a loop of string around a wooden dowel. Connect the string loop to the metal sample hook and suspend the sample in the boiling water. NOTE: The metal sample should <u>not</u> rest on the bottom of the beaker. Allow the metal to reach thermal equilibrium with the water (the metal sample needs to remain in the boiling water for a minimum of 5 minutes).

5. Prepare your 2-cup calorimeter.
    a. Place a Styrofoam cup securely inside a second one. Measure the mass of the 2-cup calorimeter using the triple beam balance.

    b. Fill the 2-cup Styrofoam calorimeter with enough room temp water to insure the metal sample can be completely immersed (room temp calorimeter water will be supplied- see Mr. P.).
    c. Find the mass of the calorimeter and water using the triple beam balance.
    d. Cover the calorimeter and keep it away from the hot plate.
    e. Have the calorimeter, lid, tongs and temperature probe ready to utilize for the transfer of the metal sample.

6. Prior to transferring the metal to the calorimeter, record the temperature of the boiling water bath; since the metal and the water are in thermal equilibrium, record this temperature in your data table as the initial temperature of the metal. NOTE: Allow the probe to cool off 5 minutes prior to placing it into the calorimeter (prior to step 7).

7. Place the cool temperature probe into the calorimeter and record the initial water temperature; very slowly swirl the probe in the water until you get a constant temperature reading (about a half a minute).

8. Once you are assured that the metal is in thermal equilibrium with the boiling water, transfer the metal quickly to the prepared calorimeter taking care to remove excess water from the sample. DO NOT SPLASH WATER OUT OF OR ONTO THE UPPER INTERNAL WALLS OF THE CALORIMETER DURING THE TRANSFER AS THIS WILL AFFECT YOUR RESULTS. **CAUTION:** The metal is VERY HOT!

9. Place the cover on the calorimeter. Very gently swirl the calorimeter taking temperature readings every 30 seconds.

10. Record the temperature values for 8 minutes.

11. Repeat steps 3-10 with a different metal sample. NOTE: FRESH CALORIMETER WATER IS REQUIRED FOR THE NEXT TRIAL. You must empty the calorimeter, dry it, re-weigh it both empty and with fresh room temperature water. You do not need to use new water in your hot water bath (however, you may need to replace lost bath water due to evaporation).

DATA TABLE:

	Trial 1 (metal sample 1) METAL:__________	**Trial 2** (metal sample 2) METAL:_________
1.Mass of metal sample (kg)		
2.Mass of dry 2-cup calorimeter (kg)		
3.Mass of calorimeter and water (kg)		
4. Mass of water (step 3 - step 2) (kg)		
5. Initial temp of water (°C)		
6. Initial temp of metal (°C)		
7. Final temp of water and metal (°C)		
8. ΔT metal (step 7 – step 6) (°C)		
9. ΔT water (step 7 – step 5) (°C)		

CHANGE IN CALORIMETER TEMPERATURE

Elapsed Time (s)	Temperature (°C) Trial 1	Trial 2
30		
60 (1 minute)		
90		
120 (2 minutes)		
150		
180 (3 minutes)		
210		
240 (4 minutes)		
270		
300 (5 minutes)		
330		
360 (6 minutes)		
390		
420 (7 minutes)		
450		
480 (8 minutes)		

Final Accepted Temperature of Metal and Water:

Trial 1:

__________ °C

Trial 2:

__________ °C

ANALYSIS:

1. Determine the final temperature of the metal and water. IMPORTANT: The final temperature is not necessarily the last temperature reading i.e. the reading taken at 480 seconds. Did your temperature readings peak anywhere? What significance is this max or peak temperature?

2. Calculate the specific heat of your metals. Show all work.

3. Calculate % error using known values in your textbook.

4. Discuss all causes of error.