Experiment 3: Specific Heat Capacity Of Metals
Law Of Dulong & Petit – Summer 2005

Chemistry 113 Lab Preparation Form

Name___________________ Lab Section__________________

Purpose of Experiment:

Objectives:

Key Terms:

Calorimetry

Specific Heat Capacity

Molar Heat Capacity

Dulong and Petit's Law

Calculations:

$$q = m\ C\ \Delta T$$

$$q_{metal} = -\ q_{water}$$

Safety Warnings:

Procedure Notes:

Questions before starting experiment?

Comments from Briefing:

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Prelab Exercise

Name__________________________ Lab Section______________________

1. If 31.34 grams of water showed a temperature increase of 2.04 °C upon addition of hot metal, what is the heat change for the water?

2. Did the water absorb or give off heat?

3. What is the heat change by the metal in question 1?

4. Did the metal absorb or give off heat?

5. If the hot metal in question 1 has a mass of 6.28g, and the metal underwent a temperature decrease of 21.64 ^{O}C, what is the specific heat capacity of the metal object?

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(adapted from "Calorimetry" by Dr. James Jung, Campbell University)

Introduction:

Calorimetry is the measure of heat flow into or out of a system. The heat flow is measured in a device called a calorimeter. An ideal calorimeter would insulate the substance in the calorimeter so well that NO HEAT would be lost to the surroundings. The calorimeter you will use in this experiment (two nested Styrofoam coffee cups) is far from an ideal one, but we will "assume" that no heat flows in or out of the calorimeter.

When heat flows into or out of a substance the temperature of the substance usually changes. This change can be used to monitor the flow of heat energy. In order to determine the exact amount of heat (q) that flows, we need to know the temperature change in the substance (ΔT), the mass of the substance (m), and the specific heat capacity (C) of the substance.

Specific heat capacity is defined as the amount of heat (in joules) required to raise the temperature of one gram of the substance by $1^{o}C$. The mathematical relationship relating the three quantities above is:

$$q = m\ C\ \Delta T$$

In this experiment you will measure the specific heat capacity of several metals by placing the hot metal in cold water. Heat will flow from the metal to the water until they reach the same final temperature.

The amount of heat absorbed by the water, q_{water}, can be calculated using the equation of

$$q_{water} = m_{water}\ C_{water}\ \Delta T_{water}$$

The amount of heat absorbed by the water is the amount of heat given off by the metal. The heat change for the two processes is the same, but with opposite signs.

$$- q_{metal} = q_{water}$$

The amount of heat the metal absorbed can be used to calculate C_{metal} using

$$q_{metal} = m_{metal}\ C_{metal}\ \Delta T_{metal}$$

(Note: The negative sign in the equation accounts for the fact that metal decreases in temperature and the water increases in temperature; i.e., an exchange of heat.)

The value $C_{water} = 4.184\ J/g^{o}C$. After performing the experiment, the only unknown will be C_{metal}. This will be calculated from the other experimental data.

You will also experimentally validate **Dulong and Petit's Law**, which says that metals will have a Molar Heat Capacity of about 24.9 J/mol°C. (Molar Heat Capacity = Specific Heat Capacity x Molar Mass.)

Experimental: *(Work in pairs)*

Set up a hot water bath and "coffee cup calorimeter" as described by your instructor.

Weigh out 60 to 80 grams of your metal into a dry 100-mL beaker. Then transfer the metal into a large dry test tube. Place this test tube into your boiling water bath, making sure that the metal in the tube is beneath the water level in the water bath. *(Note: Take care not to splash any of the water into the test tube; the metal should remain absolutely dry.)* Allow the metal to heat for about 15 to 20 minutes, thereby reaching the temperature of the boiling water (100°C). Measure and record the actual temperature with your thermometer to the nearest 0.1°C. This will be the initial temperature of the metal.

While your metal is heating, dry your coffee cup calorimeter with a paper towel. Then determine the mass of about 40 mL of distilled water by weighing it directly into the calorimeter. Record the mass.

Carefully assemble your calorimeter and read the temperature of your water to the nearest 0.1°C. This is the initial temperature of your water. *

Now, remove the test tube from the boiling water, wipe off the tube, and quickly empty the metal into your calorimeter without undue splashing. Cover the calorimeter and stir the contents with the special stirring rod provided. Monitor the temperature of the contents and record the HIGHEST temperature reached. This is the final temperature of the metal and the water.

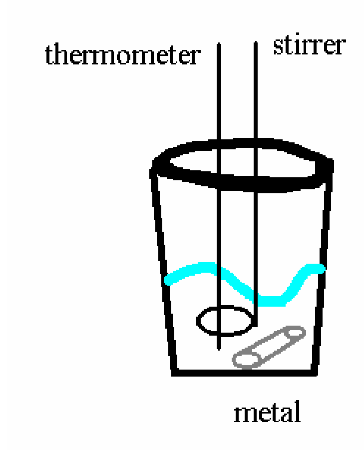


Figure 1: Coffeecup Calorimeter with metal

Now carefully decant the water off of the metal, collect your metal in a paper towel and pat it as dry as possible. After drying the metal perform the experiment above for a second, and then a third trial.

Calculate the average Specific Heat Capacity for your metal. *Record your value on the chalkboard beside the name of your metal, and then copy down the values of two different metals performed by other students.* Finally, calculate the Molar Heat Capacity (MHC) for the three metals. How close is your MHC to Dulong and Petit's 24.9 J/mol^{o}C? Calculate the % difference of your value to Dulong and Petit's value.

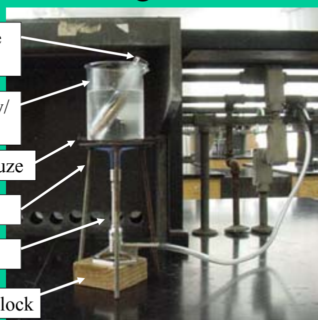
$$\% \text{ difference} = \frac{24.9 - \text{experimental value}}{24.9} \times 100$$

**Note: After measuring the boiling water temperature, dry your thermometer and allow it to cool to room temperature before placing it in your calorimeter! Cooling the thermometer can be accomplished by placing the thermometer under cool running water. Again, be certain the thermometer is dry before measuring the temperature of water in the calorimeter.*

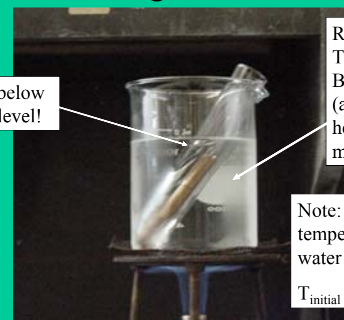
WASTE DISPOSAL:

Return the metals to their original location. Pour the water down the drain.

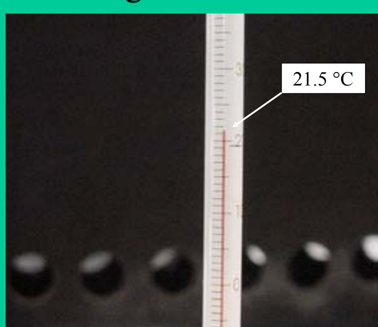
Heating of Metals



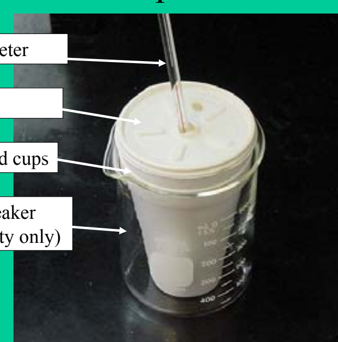
Heating of Metals



Reading Thermometers



Coffee Cup Calorimeter



Calorimeter with water and metal

Calculating Heat Change

$$q = mC\Delta T$$

$$q_{water} = -q_{metal}$$

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

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

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Data Sheet

Name______________________________ Lab Section__________________

Lab Instructor________________________ Lab Partner__________________

Name of Your Metal__________________ Metal's Molar Mass____________

	Trial 1	Trial 2	Trial 3
Mass of Metal Sample	_____	_____	_____
Mass Of Water in Calorimeter	_____	_____	_____
$T_{initial}$ of Metal (^oC) (temperature of boiling water)	_____	_____	_____
$T_{initial}$ of Water (^oC) (in calorimeter)	_____	_____	_____
T_{final} of Metal and Water (^oC)	_____	_____	_____
ΔT_{water}	_____	_____	_____
ΔT_{metal}	_____	_____	_____
Specific Heat Capacity of Metal	_____	_____	_____
Average Specific Heat Capacity		_____	

Metal	Molar Mass	SHC*	MHC**
1. _________	__________	___________	___________
2. _________	__________	___________	___________
3. _________	__________	___________	___________

Average MHC__________ % Difference ___________

*SHC = Specific Heat Capacity **MHC = Molar Heat Capacity

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Postlab Exercise

Name____________________________ Lab Section____________________

1. If ______grams of water at 23.4^{O}C increased to ________ ^{O}C upon addition of 12.43g of metal at 50.32 ^{O}C. How much heat did the water absorb?

2. What is the specific heat capacity of the metal in question 1?

3. If equivalent amounts of heat are absorbed by 1 mol of Metal A (Molar Mass = 78g/mol) and 1 mol of Metal B (Molar Mass = 100 g/mol) which shows the greatest rise in temperature? (Hint: Assume the metals obey Dulong & Petit's Law.)