Experiment 3

Energy and Heat Capacity

Pre-lab Assignment

Before coming to lab:

- Read the lab thoroughly.
- Answer the pre-lab questions that appear at the end of this lab exercise.

Purpose

The goal of this lab is to determine the specific heat capacity of two metals and compare your results to the known values. You will also gain experience using common laboratory equipment such as thermometers, balances and graduated cylinders.

Background

The goal of this lab is to determine the specific heat capacity of two metals and compare your results to the known values. Specific heat capacity is defined as the amount of heat energy (in Joules) required to raise the temperature of one gram of the substance by 1°C. Specific heat capacity takes into account that different substances require different amounts of heat in order to be warmed up, or we could say different substances release different amounts of heat as they cool down. Using specific heat capacity, we can relate the temperature change of a substance to the amount of heat energy the substance is gaining as it warms up (or releasing as it cools down) using the equation.

$$q = m \times C \times \Delta T \qquad \text{Equation 1}$$

where q= heat gained or lost *(Joules)*
m = mass of the substance *(grams)*
C = the specific heat capacity *(Joules/ g * °C)*
ΔT = change in temperature of the substance ($T_{final} - T_{intitail}$) *(°C)*

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

The amount of heat absorbed by the cool water (q_{water}) will equal the amount of heat given off by the hot metal (q_{metal}). The heat change for both is the same, but has an opposite signs since the water is gaining heat and the metal is losing heat. To represent this idea we can say that

$$q_{water} = -q_{metal} \qquad \text{Equation 2}$$

Now considering the relationship we discussed in Equation 1, we substitute to obtain the equation

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

Note that $\Delta T = T_{final} - T_{initial}$. If we replace ΔT, we come up with the equation

$$m_{water} \times C_{water} \times (T_{f\,water} - T_{i\,water}) = -m_{metal} \times C_{metal} \times (T_{fmetal} - T_{i\,metal}) \qquad \text{Equation 3}$$

We will rearrange Equation 3 to solve this equation for C_{metal}. Then, using 4.184 J/g °C for the specific heat of water, we will measure all of the other variables in the equation during the experiment to find the specific heat of the metal (C_{metal}). The known values of specific heat are given in Table 1 below.

The heat that is taken from a hot sample such as our metal and absorbed by a cooler surrounding material, such as water, can be measured in an insulated container called a **calorimeter**. We will be using two Styrofoam coffee cups with a lid as our calorimeter. Heat flows from the hot substance into the cooler water, until the sample temperature and the water temperature become equal. (This final temperature will be somewhere in between the initial temperatures of the two substances, and will be the same for the metal and the water.)

Table 1. Specific heat capacities of various metals and other substances.

Metal	Specific Heat Capacity, C_s (J/g·°C)		Metal	Specific Heat Capacity, C_s (J/g·°C)
Lead	0.129		Cobalt	0.421
Gold	0.129		Nickel	0.444
Tungsten	0.132		Iron	0.449
Platinum	0.133		Chromium	0.450
Neodymium	0.191		Stainless steel	0.460
Tin	0.228		Titanium	0.522
Silver	0.235		Potassium	0.757
Strontium	0.306		Aluminum	0.897
Copper	0.385		Magnesium	1.02
Zinc	0.388		Sodium	1.23
Water	4.184		Wood (oak)	2.00

Example 1:
Calculate the heat required to warm 65.0 g of water from 24 °C to 75 °C.

First calculate the change in temperature: ΔT = 75 °C-24°C = 51 °C

Next, Calculate heat using equation 1:

$$q = m \times c \times \Delta T$$

q = (65.0 g)(4.184 J/g °C)(51 °C) = 14000 J (rounded to 2 sig. figs)

Procedure:

Safety: Be sure to wear your safety goggles and take care with hot glassware.
Be sure that the cord for the hot plate does not touch the surface of the hot plate.
Waste: This lab will not generate any hazardous waste.

General note on your thermometer-

This will be the first time you have used your thermometer. Inspect your thermometer and make sure that the red or blue liquid inside the glass is continuous with no breaks in the liquid "line". If you see any "broken lines" let your Instructor know.
Be sure to record all temperature readings to the precision of your thermometer (tenth of a degree or xx.x °C).

1. Fill a 600 mL beaker 2/3's full of tap water and begin heating the water using a hot plate. Be sure the beaker and hot plate are safely secured.

2. As the water is heating up on the hot plate, weigh a dry metal cylinder on the balance, being sure to record all of the digits on the display and zeroing the balance before use. Record the name of the metal you are working with on the top of the data table.

3. Attach a piece of twine to the hook on the metal cylinder and suspend the metal in the beaker of warming water. Be sure that the metal it completely covered by water, and that the metal is not touching the sides or bottom of the beaker. If the metal is in contact with anything other than water, your metal may not heat up properly. Continue to heat the water and metal sample on the hot plate as you prepare the calorimeter in the following steps.

4. Obtaining two Styrofoam coffee cups and a cut Styrofoam cup to be used as a lid. Place one coffee cup inside of the other and then place the cup to form your calorimeter.

5. Weigh the empty dry cups and lid, being sure to record all of the digits from the scale and zeroing the balance before using.

6. Add approximately 50 mL of tap water to the cups using your large graduated cylinder and determine the mass of the water by subtraction. *(Note: If you are using Aluminum as your metal, you will need to use 100 mL of water instead of 50 mL because of its larger size.)*

7. After the metal has been in the beaker of **boiling** water for 10 minutes, record the temperature of the boiling water. This will also be the initial temperature of the metal since the metal and water should be at the same temperature. Be sure to record all temperatures to the nearest 0.1 °C.

8. Record the temperature of the water in your coffee cup calorimeter. This will be the initial temperature of the water. You may want to place the thermometer in a slit stopper and clamp in order to support it. (See Figure 3)

9. Remove the lid and the thermometer from the coffee cups. Carefully and quickly transfer the hot metal sample from the beaker of boiling water to the coffee cups. Take care to not splash any water out of the calorimeter. Replace the lid and thermometer to the cups.

10. Gently stir the water in the coffee cup calorimeter with the thermometer or a stir rod, and monitor the temperature of the water in the cups for several minutes. Record the highest

temperature you observe in your data table. This will be the final temperature of **both** the metal and the water.

11. Dry off the metal and dump out the water in the coffee cup calorimeter. Repeat steps 2-10 for a second trial with the same metal, being sure to use new water in the coffee cup calorimeter for each experiment.

12. Repeat the experiment with another metal--two trials-- for a total of four experiments.

13. Calculate the specific heat of the metals, the average of your two trials and the percent error using

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

Name ________________

Data Table

Name of sample metal #1 ______________________________

DATA	Trial 1	Trial 2
1. Mass of Metal	g	g
2. Mass of Empty Cups + Lid	g	g
3. Mass of Cups + Lid and Water	g	g
4. Mass of Water	g	g

Show Calculation for Mass of Water for Trial 1:

DATA	Trial 1	Trial 2
5.Initial Temperature of Water in cups	°C	°C
6. Initial Temperature of Metal in boiling water	°C	°C
7. Final Temperature of Water + Metal	°C	°C
8. Specific Heat Capacity of the Metal	J/g °C	J/g °C

Show Calculation for Specific Heat Capacity of the Metal for Trial 1:

Average Specific Heat Capacity of the Metal (show calculation): ________

Percent Error (show calculation) ________

Name of sample metal #2: ______________________________

DATA	Trial 1	Trial 2
1. Mass of Metal	g	g
2. Mass of Empty Cups + Lid	g	g
3. Mass of Cups + Lid and Water	g	g
4. Mass of Water	g	g

Show Calculation for Mass of Water for Trial 1:

DATA	Trial 1	Trial 2
5.Initial Temperature of Water in cups	°C	°C
6. Initial Temperature of Metal in boiling water	°C	°C
7. Final Temperature of Water + Metal	°C	°C
8. Specific Heat Capacity of the Metal	J/g °C	J/g °C

Show Calculation for Specific Heat Capacity of the Metal for Trial 1:

Average Specific Heat Capacity of the Metal (show calculation): _________

Percent Error (show calculation) _________

Post-Lab Questions

1. Why is it necessary to transfer the metal quickly from the hot water bath to the water in the coffee cups?

2. How many Joules are required to raise the temperature of 124 grams of water from 21.3^{o}C to 45.6 ^{o}C?

3. Calculate the temperature change when 32 grams of tungsten has 21 Joules of heat added to it.

4. Calculate the heat lost (in Joules) by 115 g of water as it cools from 71.4 ^{o}C to 34.4 ^{o}C

5. If a sample of wood and the same mass of water were placed in direct sunlight for 6 hours, which one will have a higher temperature change at the end of 6 hours? Why? Assume that they both absorb the same amount of energy. *(Hint: Refer to Table 1)*

6. A block of metal weighing 65 grams was heated to 100.0˚C. The warm metal was quickly transferred to an insulated container holding 75g of water at 15.0˚C. The metal and water temperature finally reached 18.7˚C. Calculate the specific heat of the metal, in J/g ˚C.

7. What are some possible sources of error in this experiment?

Name ______________________

Pre-lab Assignment for Energy and Heat Capacity Experiment

Show all work and round all answers.

Review of Density Experiment

1. What is the density (g/mL) of an object that has a mass of 42.1 grams and, when placed into a graduated cylinder, causes the water level to rise from 33.2 mL to 59.1 mL?

2. A marble ball is placed on a scale and is found to has a mass of 32.2 g. If the radius of the marble ball is 1.2 cm, what is the density of the marble ball? *Volume of sphere =* $\frac{4}{3}\pi r^3$

3. A flask and stopper have a mass of 91.5511 grams. A 25.0 mL sample of liquid is pipetted into the flask and the flask, stopper, and liquid has a mass of 121.6743 grams. What is the density (g/mL) of the liquid?

4. Which one of the following substances will float in gasoline, which has a density of 0.74 g/mL? The density of each substance is shown in parentheses.

A) table salt (D = 2.16 g/mL)
B) balsa wood (D = 0.16 g/mL)
C) sugar (D = 1.59 g/mL)
D) aluminum (D = 2.70 g/mL)
E) mercury (D = 13.6 g/mL)

5. Define the meaning of specific heat capacity.

6. Calculate the heat absorbed, in Joules, when 32-grams of aluminum are heated from 28°C to 85°C using Equation 1.

7. List all of the equipment, including sizes, you will be using in this experiment.

8. Using algebra, rearrange Equation 3 (*found on pg 3-1)* to solve for C_{metal} . The equation you obtain will be the equation you will be using in lab.

9. A hot metal with mass 16.33 grams is transferred from boiling water (98.7 ^{o}C) to a coffee cup calorimeter containing 31.34 grams of water initially at 21.6 ^{o}C. If the temperature of the water in the cups increases to 23.9 ^{o}C , what is the specific heat capacity of the metal?