**3.1 Required Lab: Specific Heat of a Metal**

**Objective**

In this experiment you will use calorimetry to determine the specific heat of a metal.

**Introduction**

When a substance is heated, the motion of its individual particles increases, resulting in an increase in temperature. The more heat that is added per gram of substance, the greater the temperature change. The relationship between the heat added, the mass of a substance, and the temperature change it undergoes is known as *specific heat*.

$$Specific Heat Capacity= \frac{Energy change in Joules}{Mass in grams ×Temperature change in °C }$$

 Specific heat is defined as the amount of energy necessary to produce a temperature change of 1°C per gram of substance. The specific heats of different substances vary, and therefore this quantity may be useful in identifying an unknown.

The measurement of heat changes is called *calorimetry*. In this lab, calorimetry will be used to determine the specific heat of an unknown metal. This will be done using a coffee cup calorimeter containing water.

A calorimeter is insulated so as to minimize any loss of energy to the surroundings. Therefore, when a heated piece of metal is placed into the calorimeter, all of the energy should be accounted for. In other words, the energy released from the metal should be gained by the water, with no loss to the surroundings. This is based on the Law of Conservation of Energy, which states that energy is neither created nor destroyed. We will assume no heat loss to the calorimeter.

 Energy released by metal = Energy gained by water

There are five measurements that must be made to determine the specific heat of the unknown metal:

1. Determine the mass of the piece of metal.
2. Heat the metal piece to a known temperature and measure this temperature precisely. This is the initial temperature of the metal.

Hot Plate

1. Determine the mass of the water in a calorimeter.
2. Measure the temperature of the water in the calorimeter. This is the initial temperature of the water.
3. Place the metal piece into the water of the calorimeter and measure the highest temperature reached by the water. This is the final temperature of both the metal and the water. The energy change of water is calculated by rearranging the specific heat equation. The specific heat of water is 4.184 joule/gram°C.

$$Energy change= Mass of water ×Specific heat of water×Temp change of water$$

Since the energy gained by the water equals the energy released by the metal, the specific heat of the metal is calculated as follows: temperature change it undergoes is known as *specific heat*.

$$Specific Heat of metal= \frac{Energy change of metal }{Mass of metal ×Temp change of metal }$$

# Pre Lab Questions (Answer on separate paper. Attached to lab sheets.)

1. If a heated piece of metal is placed into a Styrofoam cup containing water at room temperature, where does the metal’s heat go?

2. A 12.48 g sample of an unknown metal, heated to 99.0 °C was then plunged into 50.0 mL of 25.0 °C water. The temperature of the water rose to 28.1 °C. Assuming no loss of energy to the surroundings:

1. How many joules of energy did the water absorb?
2. How many joules of energy did the metal lose?
3. What is the specific heat of metal?

# *Materials*

 Unknown metal Hot plate

 Test tube 400 mL beaker (Must say Pyrex or Kimax)

 Ring stand and supports Thermometer (or Temp probe)

 Calorimeter (2 Nested Styrofoam cups with lid) Test tube holder

 Water Graduated cylinder

# Procedure

1. Set up a water bath using a 400 mL beaker. Fill the beaker halfway with water. Place the test tube into the water bath. Heat with a hot plate until the water is boiling.
2. Obtain a calorimeter. Weigh it as precisely as possible. Fill the calorimeter with about 40 mL (or enough to cover the metal) of distilled water at room temperature. Reweigh the calorimeter.
3. Weigh the unknown metal as precisely as possible (should be at least 25 g). Note the color of your metal. Attach a string to the metal and lower it into the water bath. Heating for 5 minutes.
4. Measure the temperature of the boiling water. This is assumed to be the initial temperature of the metal piece. It may be necessary to replenish the water in the beaker, as it should not be allowed to boil to dryness. Be sure that the level of the water in the beaker remains higher than the metal piece in the test tube.
5. Measure the temperature of the water in the calorimeter. Immediately remove the test tube from the water bath, using a test-tube holder. Carefully transfer the metal piece into the calorimeter by sliding it out. Use a glass rod to guide it, if necessary. Be careful not to allow any water from the test tube to enter the calorimeter. Do not allow any water from the calorimeter to spatter out.
6. Repeat steps 1-5 two more times cleaning out and drying the calorimeter and metal sample between trials.
7. Using the smallest graduated cylinder that is larger than the metal sample, add a few mL of water to the cylinder so that the water has the ability to cover the metal sample. Record an initial volume to the proper number of significant digits.
8. Add the metal sample by sliding it along the side at an angle to prevent breaking the cylinder. Record the final volume.
9. Repeat steps 7 and 8 two more times pouring all water out of the cylinder and drying the metal sample between trials.
10. Cleanup

## Calculations (attach detailed calculations to your data sheet)

1. Determine the change in temperature for both the metal and the water in the calorimeter. Calculate the specific heat of the metal.
2. Calculate the density of your unknown metal by determining its volume and using the mass you have already determined.
3. Determine the identity of your unknown metal by comparing its specific heat and density with those in the Table 1 below.

# Table 1

**Specific Heat and Density of Selected Metals**

|  |  |  |
| --- | --- | --- |
| **Element** | **Specific Heat (J/g °C)** | **Density (g/mL)** |
| Aluminum | 0.900 | 2.7 |
| Copper | 0.385 | 8.9 |
| Iron | 0.449 | 7.9 |
| Lead | 0.129 | 11.4 |
| Magnesium | 1.05 | 1.7 |
| Tin | 0.228 | 7.3 |
| Zinc | 0.388 | 7.1 |
| Brass | 0.380 | 8.5 |
| Bronze | 0.435 | 7.9 |

 **Name**

**Date Performed: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Lab Partner(s)**

 **Date Submitted:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

**Report: Specific Heat of a Metal**

**Data Table**

|  |  |  |  |
| --- | --- | --- | --- |
| **Quantity** | **Trial 1** | **Trial 2** | **Trial 3** |
| **Mass of calorimeter** |  |  |  |
| **Mass of calorimeter and water** |  |  |  |
| **Mass of water in calorimeter** |  |  |  |
| **Mass of metal** |  |  |  |
| **Temp of boiling water bath (init. T of metal)** |  |  |  |
| **Initial temp of water in calorimeter** |  |  |  |
| **Final highest temp of water in calorimeter (final temp of both)** |  |  |  |
| **Volume of water in cylinder** |  |  |  |
| **Volume of metal + water in cylinder** |  |  |  |

**Qualitative Observations:**

**Calculations Table**

|  |  |  |  |
| --- | --- | --- | --- |
| **Quantity** | **Trial 1** | **Trial 2** | **Trial 3** |
| **Mass of water in calorimeter** |  |  |  |
| **Temp Change of Metal** |  |  |  |
| **Temp Change of Water** |  |  |  |
| **Energy Change for water** |  |  |  |
| **Energy Change for metal** |  |  |  |
| **Specific Heat for metal** |  |  |  |
| **Average Specific heat:** |  |  |  |
| **Volume of metal**  |  |  |  |
| **Density of metal** |  |  |  |
| **Average Density of metal:** |  |  |  |

 **1st guess**  **2nd guess**

**Identity of unknown metal \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

# Questions

1. Explain how you were able to identify the unknown metal. What evidence do you have to support your claim?
2. Which metal would cause the greatest increase in the temperature of the water in the calorimeter: the one with the highest specific heat, or the one with the lowest specific heat? Explain.
3. Relative to metals, how does the specific heat of water compare: higher, or lower? Explain
4. If equal masses of two metals are heated to a temperature of 100 °C, which would cause a more severe burn – the one with the higher specific heat or the one with the lower specific heat? Explain.

1. Which do you think gives you a better indication of the identity of an unknown metal sample, density or specific heat? Why?
2. What are two possible sources of error for method used to measure specific heat?