

Specific Heat Set

Experiment Guide



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Designed by



Manufactured by



Introduction

Overview

This set contains five metal specimens, each with a mass of approximately 80 grams. These specimens are intended for lab exercises to find the specific heat of a material. They may also be used for other purposes, such as density determination.

Included is a lab exercise that guides students through a typical method for determining the specific heat of an unknown sample. Likely sources of inaccuracy in the lab stem from inadequate mixing of the water around the sample as the heat is transferred, as well as incorrect placement of the thermometer within the insulated container while measuring (if too near the metal sample, inaccuracy will result). Some teachers may prefer to supply only the first page of the experiment (containing the basic theory), thus allowing for a more challenging laboratory experience.

Included Equipment

Material	Specific Heat (J/g°C)	Specific Heat (cal/g°C)
Zinc	0.387	0.0925
Aluminum	0.900	0.215
Stainless Steel	0.500	0.119
Copper	0.386	0.0923
Brass	0.380	0.0920

Note: Older versions of this set include stamped letters on top of each sample (A = Zinc, B = Aluminum, C = Steel, D = Copper, E = Brass). The stamps were discontinued to avoid confusion with common element names and symbols and to allow teachers to designate samples as desired. The following diagram is provided to visually identify the samples.



Additional Equipment Needed

- 1 Metric scale or balance
- 1 Thermometer or temperature sensor
- 1 Insulated container and lid, such as a foam calorimetry cup or 3 stacked foam drink cups
- 1 Heat-resistant container, such as a beaker or cooking pot
- 1 Heat source, such as electric hot plate
- 1 Stirring rod
- 1 Piece of string, heavy thread, or fine wire

Safety

Please teach and expect safe behavior in your classroom and lab. Safety considerations call for supervision of students at all times: safety eyewear, no horseplay, immediate reporting to the instructor of accidents or breakage, among others.

This product is intended for use by students age 13 years and older, under competent adult supervision.

Of particular concern with this experiment is that students will be exposed to both hot plates and boiling water. Extreme care should be taken to prevent students from getting burned.

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Experiment

Finding the Specific Heat of a Material

Introduction

When heat flows into or out of an object, the object's temperature gradually changes (except during a phase change such as melting or boiling). There are several variables involved during this heat transfer:

Temperature Change — a larger change in temperature suggests a larger heat flow

Mass — a temperature change in an object of greater mass transfers more heat than the same change in an object of lesser mass

Specific Heat — a basic thermal property of the material

These variables are related by the following equation:

$$Q = m C \Delta T$$

Where:

Q is the amount of heat transferred

m is the mass of the object

C is the specific heat (a constant that depends on the object's material)

ΔT is the temperature change

Experiment Overview

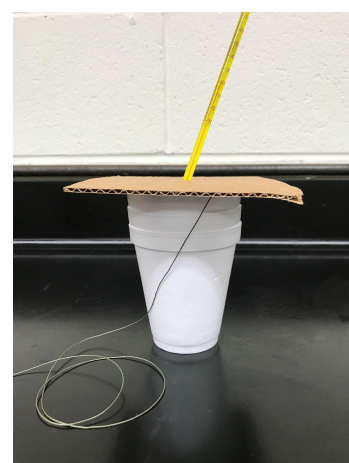
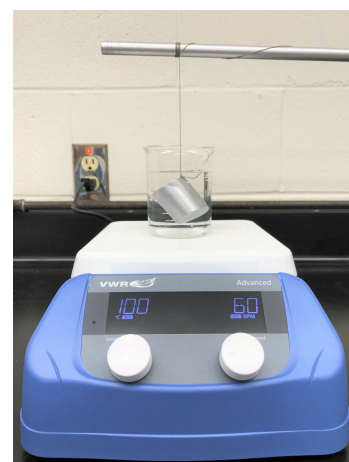
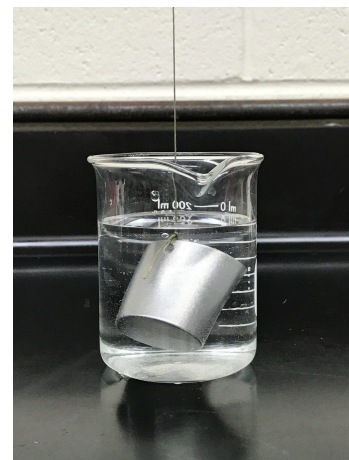
In this experiment, you will heat a metal sample in boiling water (100°C). The object will then be quickly moved to an insulated cup of water with a known initial temperature. When the hot metal is placed in the cool water, heat energy will transfer from the metal to the water. The amount of heat gained by the water, Q_{water} , is the same amount of heat lost by the metal, Q_{metal} . Knowing this relation, as well as the masses, temperatures, and the specific heat of water (1 calorie/g°C or 4.186 J/g°C), you will be able to calculate the specific heat of the metal.

Equipment

- 1 Metal sample
- 1 Metric scale or balance
- 1 Thermometer or temperature sensor
- 1 Insulated container and lid, such as a foam calorimetry cup or 3 stacked foam drink cups
- 1 Heat-resistant container, such as a beaker or cooking pot
- 1 Heat source, such as electric hot plate
- 1 Stirring rod
- 1 Piece of string, heavy thread, or fine wire

Procedure

1. Obtain a metal sample and identify it here as instructed by your teacher: _____
2. Measure the mass, m_{metal} , of the sample and record it in Table 1 on the next page.
3. Tie a string through the hole in the metal sample so that it can be suspended in the boiling water. Leave at least a half meter of string connected to the sample.
4. Prepare the hot water:
 - a. Hang the metal sample in a heat-resistant container (such as a beaker as shown). The sample should be close to the bottom but not touching.
 - b. Fill the container with enough hot tap water to completely cover the sample, then remove the sample to use in the following steps.
 - c. Boil the container of water on a hot plate in a safe location, free of obstructions and the possibility of getting bumped.
 - d. While the water begins heating, continue with the following next steps.
5. Prepare the cold water:
 - a. Obtain an insulated container, such as a foam calorimetry cup or three stacked foam drink cups. You will also need an insulated lid with a hole for the thermometer.
 - b. Measure the mass, m_{cup} , of the **empty insulated cup** and record it in Table 1 on the next page.
 - c. Place the metal sample in the insulated cup with the string hanging out.
 - d. Fill the container with the coldest available tap water, just enough to completely cover the sample.
 - e. Remove the sample, weigh the cup and water, and record the combined mass, $m_{\text{cup + water}}$, in Table 1.
 - f. Find the mass of the water by subtracting the mass of the cup, m_{cup} , from the combined mass of the cup and water, $m_{\text{cup + water}}$. Record the mass of the water, m_{water} , in Table 1.
6. Hang the metal sample in the container of hot water so that it is completely submerged in the water but not touching the sides or bottom of the container. (If it touches, the container may heat the sample above the boiling point of water). The string can be tied above the container, as shown, but make sure you are able to remove it quickly when transferring it to the cold water.
7. Once the water has come to a boil, leave the metal sample in the boiling water for **at least 2 minutes**. Meanwhile, continue with the following step.



8. Measure the temperature of the **cold water** in the insulated cup with a thermometer, then replace the lid. Record the initial water temperature, T_{water} , in Table 2.
9. Once the sample has been in the boiling water for **at least 2 minutes**, turn off the hot plate and quickly transfer the sample to the cold water in the cup. Immediately replace the cup's lid, insert the thermometer, and begin gently stirring the water. Make sure the thermometer only touches the water, not the metal sample.
10. Monitor the temperature of the water in the cup while gently swishing the cup on the table or stirring with a rod. The temperature should increase until it reaches a maximum equilibrium temperature. Record this final maximum temperature, T_{final} , in Table 2.

After reaching this temperature, the water will begin to cool off via heat loss to the environment, so it is important to record the final maximum temperature **before** it begins dropping.

Table 1: Mass Data

Item	Mass (g)
Metal Sample, m_{metal}	
Empty Cup, m_{cup}	
Cup and Water, $m_{\text{cup} + \text{water}}$	
Water, m_{water}	

Table 2: Temperature Data

Item	Temperature (°C)
Boiling Water	100 °C
Metal Sample, T_{metal}	100 °C
Cold Water, T_{water}	
Final Temperature, T_{final}	

Analysis

1. Calculate the temperature change of the water, ΔT_{water} . This is the difference between the initial cold water temperature and the final equilibrium temperature of the water and metal in the cup ($\Delta T_{\text{water}} = T_{\text{final}} - T_{\text{water}}$). Use the temperatures from Table 2 on the previous page. Show your work here. Remember to include units ($^{\circ}\text{C}$).

$$\Delta T_{\text{water}} = T_{\text{final}} - T_{\text{water}} = \underline{\hspace{2cm}} - \underline{\hspace{2cm}} = \underline{\hspace{2cm}}$$

2. Use the heat equation to calculate the amount of heat transferred from the metal to the water:

$$Q_{\text{water}} = \Delta T_{\text{water}} m_{\text{water}} C_{\text{water}}$$

Where:

ΔT_{water} = temperature change of water

m_{water} = mass of the water

C_{water} = specific heat of water (1 cal/g $^{\circ}\text{C}$ or 4.186 J/g $^{\circ}\text{C}$)

Show your work here: (remember to include units)

$$Q_{\text{water}} = \Delta T_{\text{water}} \times m_{\text{water}} \times C_{\text{water}} = \underline{\hspace{2cm}} \times \underline{\hspace{2cm}} \times \underline{\hspace{2cm}}$$

$$Q_{\text{water}} = \underline{\hspace{2cm}}$$

3. Calculate the temperature change of the metal, ΔT_{metal} . This is the difference between the initial hot metal temperature and the final equilibrium temperature of the water and metal in the cup ($\Delta T_{\text{metal}} = T_{\text{metal}} - T_{\text{final}}$). Use the temperatures from Table 2 on the previous page. Remember to include units ($^{\circ}\text{C}$).

$$\Delta T_{\text{metal}} = T_{\text{metal}} - T_{\text{final}} = \underline{\hspace{2cm}} - \underline{\hspace{2cm}} = \underline{\hspace{2cm}}$$

4. Calculate the specific heat of the metal sample, C_{metal} .

Given that the amount of heat gained by the water must have been the same as the amount of heat lost by the metal, we can assume that $Q_{\text{water}} = Q_{\text{metal}}$. Therefore:

$$Q_{\text{water}} = Q_{\text{metal}} = m_{\text{metal}} C_{\text{metal}} \Delta T_{\text{metal}}$$

Solving for C_{metal} ,

$$C_{\text{metal}} = Q_{\text{metal}} / (m_{\text{metal}} \Delta T_{\text{metal}})$$

Show your work here: (remember to include units)

$$C_{\text{metal}} = Q_{\text{metal}} / (m_{\text{metal}} \times \Delta T_{\text{metal}}) = \underline{\hspace{2cm}} / (\underline{\hspace{2cm}} \times \underline{\hspace{2cm}})$$

$$C_{\text{metal}} = \underline{\hspace{2cm}}$$

Notes



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