Andrews University
PHYSICS ENTERPRISES

Specific Heat Set

Experiment Guide

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Designed by

TRANSPARENT DEVICES LLC
FOR SCIENCE EDUCATION

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PHYSICS ENTERPRISES

Introduction

Overview

This set contains five metal specimens, each with a mass of approximately 80 grams and stamped with a letter A-E to identify the type of material. 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 Styrofoam® 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

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

Additional Equipment Needed

- 1 Metric scale or balance
- 1 Thermometer or temperature sensor
- 1 Calorimetry cup with lid or
  3 Styrofoam® coffee cups with an insulating cover (foam, wood, etc.)
- 1 Heat source, such as electric hot plate
- 1 Heat resistant container, such as cooking pot or beaker
- 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

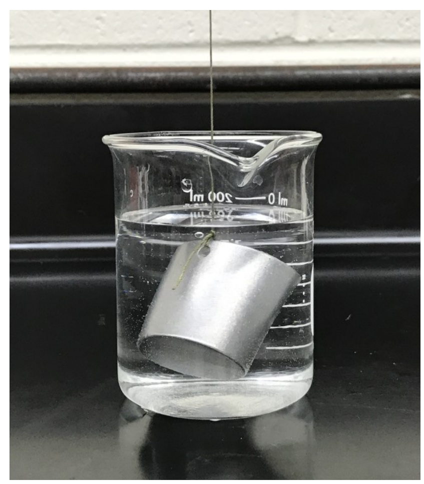
In this experiment, you will heat a metal sample in boiling water (100°C). The object will then be quickly moved to an insulated cup of water with a known initial temperature. When the hot metal is placed in the cool water, heat energy will transfer from the metal to the water. The amount of heat gained 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 Calorimetry cup with lid or
  3 Styrofoam® coffee cups with an insulating cover (foam, wood, etc.)
- 1 Heat source, such as electric hot plate
- 1 Heat resistant container, such as cooking pot or beaker
- 1 Stirring rod
- 1 Piece of string, heavy thread, or fine wire

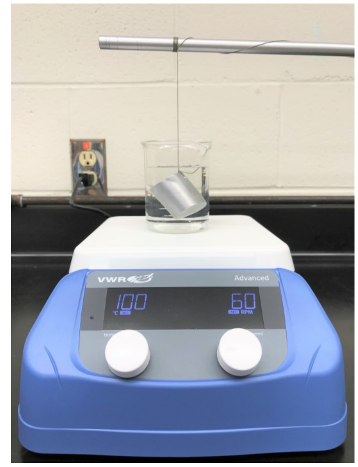
Procedure

1. Obtain a metal sample from your instructor and record the letter stamped on it: _________
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 about a half meter of string connected to the sample so you can tie it.



4. Obtain a hot plate and a heat resistant container. Hang the metal sample in the container such that it is close to the bottom but not touching. Fill the container with enough hot tap water to completely cover the sample, then remove it from the water.
5. Place the container on the hot plate, and be sure it is in a safe location, free of obstructions and the possibility of getting bumped. Turn on the hot plate and set it to its highest setting. While the water and sample are heating, continue with the next steps.
6. Obtain a Styrofoam® calorimetry cup (or three stacked Styrofoam® coffee cups) with a lid containing a hole for a thermometer.
7. Measure the mass of the empty cup and record it in Table 1 on the next page.
8. Place the metal sample in the cup with the string hanging out. Using the coolest available tap water, cover the sample with the minimum amount of water required to completely submerge it.
9. Remove the sample and weigh the cup with the water. Record the mass in Table 1 on the next page.

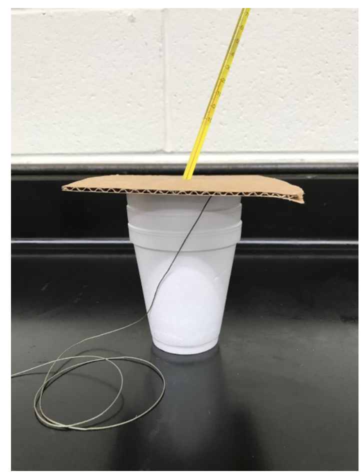
10. Find the mass of the water by subtracting the mass of the cup from the mass of the cup with water. Record the mass of the water, m_{water}, in Table 1 below.



11. 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 to something suspended above the container, as shown, but make sure you are able to remove it quickly when transferring it to the cool water.

12. Once the water has come to a boil, leave the metal sample in the boiling water for <u>at least 2 minutes</u>. Meanwhile, complete step 13.

13. Measure the temperature of the cool water in the Styrofoam® cup with a thermometer; then replace the lid. Record the initial water temperature, T_{water}, in Table 2 below.



14. Once the sample has been in the boiling water for <u>at least 2 minutes</u>, turn off the burner and quickly transfer the sample to the cool water in the cup. Immediately replace the cup's lid and put the thermometer in the hole. Make sure the thermometer never touches the metal sample.

15. 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 below.

    After reaching this temperature, the water may 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	
Cup with Water	
Water, m_{water}	

Table 2: Temperature Data

Item	Temperature (°C)
Boiling Water	100 °C
Metal Sample, T_{metal}	100 °C
Cool 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 cool water temperature and the final equilibrium temperature of the water and metal in the cup ($\Delta T_{water} = T_{final} - T_{water}$). Use the temperatures from Table 2 on the previous page. Remember to include units (°C).

   ΔT_{water} = ________________ - ________________ = ________________

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

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

   Where:

   ΔT_{water} = temperature change of water
   m_{water} = mass of the water
   C_{water} = specific heat of water (1 cal/g °C or 4.186 J/g°C)

   Show your work here: (remember to include units)

   $Q_{water} = \Delta T_{water} \times m_{water} \times C_{water}$ = ________________ x ________________ x ________________

   Q_{water} = ________________

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 ($\Delta T_{metal} = T_{metal} - T_{final}$). Use the temperatures from Table 2 on the previous page. Remember to include units (°C).

   ΔT_{metal} = ________________ - ________________ = ________________

1. 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 $Q_{water} = Q_{metal}$. Therefore:

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

   Solving for C_{metal},

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

   Show your work here: (remember to include units)

   $C_{metal} = Q_{metal} / (m_{metal} \times \Delta T_{metal})$ = ________________ /(________________ x ________________)

   C_{metal} = ________________

Notes

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