20 Specific Heat of an Unknown Metal

Purpose

Measure the specific heat of a metal object and identity the metal based on its specific heat.

Background

The amount of thermal energy that an object must absorb to change its temperature by one degree is called its heat capacity. The amount of thermal energy that a single gram of a specific material must absorb in order to change its temperature by one degree is the material's *specific heat capacity*, or *specific heat*. The specific heat of water is a standard to which specific heats of other substances are compared.

When thermal energy flows into or out of an object, its temperature changes. The amount of change depends on the mass of the object, the material from which the object is made, and the temperature of the environment. The specific heat of the material can be found using a known quantity of water and a calorimeter. The calorimeter is relatively well insulated so very little thermal energy will come from or go into the surrounding air. Assume that thermal energy is conserved inside the calorimeter. This means that whatever thermal energy is gained or lost by an object put into the calorimeter is equal to the thermal energy gained or lost by the water in the calorimeter. The equation describes that the change in thermal energy, ΔQ, depends on the mass, m, the specific heat, c, and the change in temperature, ΔT.

$$\Delta Q = mc\Delta T$$

When an unknown metal object is put into water in a calorimeter, the change in thermal energy of the object equals the change of thermal energy of the water.

$$m_{object}c_{object}\Delta T_{object} = m_{water}c_{water}\Delta T_{water}$$

The initial temperatures of the object and water will be different, but the final temperature-called the equilibrium temperature-will be the same.

Materials

Equipment	
• PASPORT Xplorer GLX	• Balance
• Fast-Response Temperature Probe (included with GLX)	• Graduated Cylinder, 50-mL
• Basic Calorimetry Set (1 metal object and 2 calorimeter cups)	• Stir rod

Consumables	
• Braided Physics String, 20 cm	• Water, 300 mL
• Towel	• Ice (cube or crushed), 100 mL

Safety Precautions

- Follow all directions for proper use of the equipment.

Procedure

Use a Fast-Response Temperature Probe to measure the change in temperature of a known mass of water at room temperature when a metal object of known mass and known initial temperature is put into the water. Use the Xplorer to record and display the data.

Equipment Setup

1) Measure and record the mass of one of the metal objects from the PASCO Basic Calorimetry Set.

2) Put ice and water into one calorimeter cup to make an ice water bath. Tie a piece of string to the metal object and lower the object into the ice bath.

3) Leave the metal object in the ice water for 10 minutes. Add more ice as the ice begins to melt.

4) Prepare a known quantity of water that is at room temperature (about 20-25 ºC). Measure and record the mass of the second calorimeter cup. Add about 200 mL of water to the calorimeter. Measure and record the total mass of the cup plus the water.

Fig. 1: Equipment setup

5) Put the end of the Fast-Response Temperature Probe into the room temperature water. Add a stir rod to the water

Xplorer GLX Setup

1) Plug a Fast-Response Temperature Probe into the first temperature port on the left side of the Xplorer GLX and then turn on the GLX (⏻).

   A graph of Temperature (ºC) versus Time (s) will open

Record Data

1) Press ▶ on the GLX to measure the signal from the Temperature Probe.

   The temperature appears in the graph display.

2) After 1 minute, lift the cold metal object out of the ice water bath and quickly dry any droplets of water still on the object.

3) Suspend the object in the room temperature water in the calorimeter. It should be completely covered by water but not touch the bottom of the calorimeter.

4) Stir the water gently as you continue to record temperature data.

5) Wait until the graph of temperature stops changing (the object and the water are in thermal equilibrium), and then press ▶ to stop data recording.

6) Remove the Temperature Probe and the metal object from the calorimeter. Clean up the equipment as instructed.

Analyze

Record results in your lab notebook/data table as you complete your analysis.

1) Use the graph of temperature versus time to find the initial temperature of the water and the equilibrium temperature, or final temperature, of the water and the metal object after the object warms up and the water cools down.

2) Press F3 to open the Tools menu. Select Smart Tool. Use the right-left arrow buttons to move the cursor to the part of the graph that shows the initial temperature of the water. Record the value.

3) Repeat the process to find the final temperature (equilibrium temperature) of the water and the metal object.

4) Use your data to calculate the specific heat of the metal object.

5) Use your calculated value of the specific heat to identify the type of metal.

Data Table)

Measurement	Value
Mass of object	kg
Mass of cup	kg
Mass of cup plus water	kg
Mass of water	kg
Initial Temperature of Metal	°C
Initial Temperature of Water	°C
Final Temperature of Water	°C

Calculations

Calculate the specific heat of the unknown metal. The specific heat of water, c_{water} is 4186 J/kg°C. Remember that the final temperature of the water-the equilibrium temperature-is also the final temperature of the metal object. Assume that the initial temperature of the metal object is 0ºC (the temperature of the ice-water bath)

$$m_{object} c_{object} \Delta T_{object} = m_{water} c_{water} \Delta T_{water}$$

$$m_{object} c_{object} \left(T_{final} - T_{initial}\right)_{object} = m_{water} c_{water} \left(T_{initial} - T_{final}\right)_{water}$$

Solve for the specific heat of the object, c_{object}.

Result	Value
Specific Heat of Metal	J/kg°C

The table shows some specific heats of common metals:

Metal	Specific Heat (J/kg°C)	Metal	Specific Heat (J/kg°C)
aluminum	901	iron	449
brass	380	lead	128
copper	386	silver	234
gold	129	steel	450

Analysis and Synthesis Questions

1) Describe, in words, what happened to the temperature on the graph.

2) What kind of metal is the object?

3) Compare the value you obtained with your data (measured) to the value in the list (accepted). What is the percent difference between your measured value and the accepted value?

4) What are some possible sources of error