MiraCosta College
Introductory Chemistry Laboratory
Experiment 7

Measuring the Specific Heat of a Metal Element

EXPERIMENTAL TASK

Use a simple calorimeter to measure the specific heat of a metal element.

Objectives

After completing this experiment, the student will be able to:

1. Use a simple calorimeter to conduct an experiment to measure heat transfer.
2. Calculate the specific heat of a solid sample using the calorimeter experiment data.
3. Analyze possible sources of error in a calorimetry experiment.

Additional Reading

- General, Organic and Biological Chemistry, by Timberlake, sections 5.1 – 5.2
- Laboratory Handbook for General Chemistry, by Griswold, et al, section VI.

Background

Temperature and heat are related to each other, but they are still fundamentally different quantities. While both are derived from the energy associated with the motion (kinetic energy) of atoms and molecules, heat is related to the TOTAL kinetic energy of the particles, while temperature is related to the AVERAGE kinetic energy of the particles.

The precise quantitative relationship between temperature and heat is different for different substances, and is called the *specific heat* of the substance (an older term is *heat capacity*).

By definition, the specific heat of a substance is the amount of heat required to raise the temperature of 1 gram of the substance by 1 °C. Each substance has its own specific heat, and this quantity is therefore an "identifying" property—that is, it can be used to help identify a substance, just like the melting point or density.

The amount of heat transferred (Q) into or out of a sample of a substance, such as water, can be determined if the mass (m) of the sample and the substance's specific heat (s) are known, and the sample's change in temperature (ΔT) is measured. That is,

$$Q = m \times s \times \Delta T$$

Equation 1

The heat transfer should have units of either joules (J) or calories (cal), the mass is in grams, and the change in temperature is in °C. Therefore, the specific heat must be in units that, when multiplied by g and by °C, will give either J or cal, so specific heat is generally reported in units of either $\frac{J}{g\bullet{}^\circ C}$ or $\frac{cal}{g\bullet{}^\circ C}$.

In this experiment you will measure the specific heat of a metal element. What variables must be measured in order to calculate specific heat? The answer to this is found in an analysis of the "definition" of specific heat:

$$s = \frac{Q}{m \bullet \Delta T} = \frac{\text{amount of heat transferred from metal to water}}{\text{mass of sample} \bullet \text{ change in temperature for sampl}}$$

Equation 2

This leads to the following experimental steps:

i. The mass of the sample of the metal element is measured.
ii. The sample is heated.
iii. Then the hot metal sample is added to a measured amount of water in the calorimeter.
iv. The metal sample's temperature change (ΔT) is measured during this process, by measuring the temperature of the hot sample just before adding it to the water, and then measuring the temperature of the sample after it has been added to the water.
v. Finally, the amount of heat transferred from the metal sample to the water (Q) is measured (see below).

In order to measure Q, the heat transferred from the metal sample to the water (step v), it is necessary to analyze Equation 1, above, which leads to these steps:

i. The mass of the water in the calorimeter is measured.
ii. ΔT for the water is measured, by measuring the temperature of the water before the metal sample is added to it and after the sample has been added. NOTE: the final temperature of the water will be the same as the final temperature of the metal sample, because they will be mixed together in the calorimeter.
iii. Q (in J) is calculated based on Equation 1, using the specific heat of water, 4.184 $\frac{J}{g \bullet {}^\circ C}$, along with the measured mass and of the water in the calorimeter.

The final result will therefore be the specific heat of the metal element, in $\frac{J}{g \bullet {}^\circ C}$***.***

Pre-lab Questions

1. A student performs an experiment similar to this one, but using a sample of a mineral instead of a metal element. The mineral sample's mass is 5.272 g, and it is heated to a temperature of 98.6 °C before being added to the water. The mass of water in the calorimeter is 18.903 g, and it's temperature before the mineral is added is 21.9°C. After adding the mineral sample to the water, the temperature of both the water and the mineral is 27.3°C.
   A. Use Equation 1 to calculate Q, the heat transferred from the mineral sample to the water, in joules (again, the specific heat of water is 4.184 $\frac{J}{g \bullet {}^\circ C}$.
   B. Use the value of Q calculated in part A and Equation 2 to calculate s, the specific heat of the mineral.

2. Equation 2 uses Q, the heat transferred from the metal sample to the water, to calculate the specific heat of the metal. However, is it reasonable to assume that all of the heat that the metal sample lost was actually transferred to the water? Where else might that heat go?

BEFORE STARTING THE EXPERIMENT

This procedure includes a number of steps that should be performed at the same time that other things are going on, and other steps that must be performed in rapid succession. Be sure you and your partner have read the entire procedure, and that you are sure you know what to do at which time.

Safety

Always keep in mind the rules presented in both the "MCC Laboratory Safety Rules" and the Laboratory Handbook for General Chemistry. It is your responsibility to make sure that you follow all safety rules at all times, and to graciously help everybody else in the laboratory (including the instructor) to do the same.

Handle hot glassware with either crucible tongs or “hot hands,” and keep long hair tied back. Even though no flames are used, this experiment does involve using hot plates that can heat to several hundred degrees Celsius.

EXPERIMENT PROCEDURE

Obtain the following, either from the lab drawer, the reagent cart or cabinets or drawers elsewhere in the laboratory:

Stirring hot plate	Magnetic stir bar	400-mL beaker
Large test tube	2 ringstands	2-prong clamp
Ring	2 Styrofoam cups	Digital thermometer & probe

Place the hot plate on the base of one of the ringstands, making sure the top of the hot plate is level. Place the 400-mL beaker on the center of the surface of the hot plate, and then place the magetic stir bar inside the beaker. Attach the 2-prong clamp to this ring stand, and secure the large test tube in the clamp so that the test tube is inside the 400-mL beaker, and the bottom of the test tube is about 1 cm above the magnetic stir bar.

Attach the ring to the other ringstand, a few centimeters above the base of the ringstand. Make sure the Styrofoam cups are both clean and dry, and put one of the cups inside the other. Place the cups inside the ring that is attached to the ringstand. Adjust the ring so that it holds the cups upright, but allows the cups to rest on the base of the ringstand.

Obtain a sample of one of the metal elements from the reagent cart. Be sure to note the identity of the sample, either as an actual element name or as an "unknown" code. Measure and record the mass of the metal sample, and then place it inside the test tube that is clamped to the ringstand. Add enough tap water to the beaker that is on the hot plate to make the level of water 2 or 3 cm above the level of the metal sample that is inside the test tube. Turn the "HEAT" knob on the hot plate to the highest setting, and the "STIR" knob to about 3 or 4 so that the magnetic stir bar gives gentle but complete stirring.

Connect the thermometer probe to the digital thermometer. Place the probe in the test tube so that the tip of the probe is in contact with the metal sample, and turn on the digital thermometer. Make sure the readout is set to units of °C, not °F.

Measure and record the mass of the "calorimeter"—the 2 Styrofoam cups. Add enough DI water to the calorimeter to give a depth of 1.5 to 2.0 cm. Measure and record the mass of the calorimeter and DI water, then place the calorimeter back inside the ring, making sure the water does not spill! Obtain a 250-mL beaker and fill it about 3/4 full with DI water (this will be used in the next few steps).

Once the water on the hot plate starts to boil, monitor the temperature of the metal sample until it maintains a consistent temperature for a full minute or more. Record this temperature as being the temperature of the metal sample before being added to the water in the calorimeter.

Quickly transfer the thermometer probe to the water in the **250-mL beaker** (this is in order to cool the probe to about room temperature so that it doesn't add a lot of heat to the calorimeter), then remove it and dry the probe with a paper towel, and then place it in the water in the calorimeter. Record the temperature of the water in the calorimeter.

The next few steps must be done very quickly, so be sure everything is ready before proceeding. Remove the clamp holding the test tube from the ringstand, keeping the test tube in the clamp (you will be using this clamp as a handle for the test tube). Dry the outside of the test tube with a paper towel, then gently dump the metal sample into the calorimeter—try not to splash the water in the calorimeter! Use the thermometer probe to gently stir the water, and monitor the temperature of the water carefully. Record the highest temperature reached as the final temperature of both the water and the metal sample.

OK—relax now. Repeat this procedure if so directed by your instructor. Otherwise, remove the metal sample and dry it with a paper towel, then return it to the reagent cart. Dry the cups and return them to the cart. Be sure to return all other equipment to its proper place.

RESULTS

Calculate Q (in J), the heat transferred from the metal to the water, using Equation 1. Then use this value of Q in Equation 2 to calculate the s, the specific heat of the metal sample, in $\frac{J}{g \bullet {}^{\circ}C}$

DISCUSSION

In addition to the usual components of a Discussion, be sure to include a few of the possible sources of error in the experiment, such as errors that may have occurred in measuring the temperatures, or in the heat transfer, etc.