1: Thermochemistry (Experiment)

Introduction

This experiment is an introduction to the basic principles of thermochemistry and involves the exchange of energy as heat. The ideas and concepts involved in thermodynamics are in your everyday experiences. For example, on a hot summer day, the hood of a car can get hotter than the sidewalk cement, and when cooking, you have probably noticed that a wooden spoon does not heat as fast as a metal one. After completing this lab, you will better understand the reasons behind these and other thermal phenomena.

Safety Precautions

WEAR SAFETY GOGGLES throughout the entire experiment. To avoid burns, use crucible tongs to pick up hot metal. Never pick up a heated metal with your bare hands. All waste from this experiment can be poured down the drain.

Part I: Determining the Heat Capacity of the Calorimeter

All parts of this experiment require the use of a calorimeter. In this part of the experiment, you will construct an inexpensive but effective coffee-cup calorimeter. For this experiment, we will consider the calorimeter to be a perfect insulator and for it to have no heat capacity.

The heat capacity of a substance is the heat required to raise the temperature of one gram of the substance one degree Celsius or Kelvin. All substances have a characteristic heat capacity. When two substances having different temperatures come into contact, energy in the form of heat is exchanged between them until they reach a common temperature. If they are insulated from their surroundings, the amount of heat lost from the hotter substance equals that gained by the colder one. The heat lost or gained is related to the mass, the heat capacity of the substance, and the temperature change. This relationship is shown below:

$$Q = m \times C_p \times \Delta T \tag{1.1}$$

where Q is the heat, m is the mass, C_p is the heat capacity of that substance, and ΔT is the change in temperature.

Procedure

1. Set up the hot plate and heat 500 mL of deionized water to boiling in a 600 mL beaker.
2. Put two Styrofoam coffee cups in a 250 mL beaker.
3. Place a 4"x 4" piece of cardboard, with the hole in the center, on top of the coffee cups. If the hole is too big, cover it with two pieces of lab tape and punch a hole with your pen or pencil big enough so the temperature probe can fit. Insert a temperature probe through the hole.
4. Take the top Styrofoam cup from the calorimeter and tare it. Weigh out about 100 grams of deionized water into it and record the mass.
5. Place the cup back into the calorimeter set-up and cover with the cardboard top. Using a clamp, gently secure the temperature probe and lower it into the cup so that the tip of the probe is covered with water but is not touching the bottom of the cup. Allow the temperature probe to sit in the water for a few minutes before recording the temperature.
6. Obtain a sample of lead from your TA. The sample should be strung with nylon string. Do not remove the string. Weigh the lead sample on a balance, using weighing paper to protect it from contamination. Record the mass.
7. Suspend the lead metal into the beaker of boiling water by putting a glass stirring rod through the loop of the nylon string and placing the stirring rod across the top of the beaker. Make sure the metal is completely submerged in the boiling water and is not in contact with the sides of the beaker. Suspension of the sample ensures that the metal will have the same equilibrium temperature as the water by preventing direct heating from the hot plate. If the metal is in direct contact with the glass, the glass may shatter.
8. When the water begins to boil, allow the metal to remain in the boiling water for 2-3 minutes. This will ensure the temperature of the metal equilibrates with the temperature of the boiling water.

Question 1.1

Why is the temperature not expected to be exactly 100 °C? Explain.

9. Measure the temperature of the boiling water bath using the **temperature probe**. Start data collection on the LabQuest device. Record the temperature for 1 minute, then cool and dry the temperature probe.
10. When the metal is ready to be transferred, start data collection on the Logger Pro device and measure the temperature of the water in the calorimeter using a temperature probe. Measure the temperature for 1 minute.
11. Finally, begin data collection and then lift the metal from the hot water with the nylon string slightly slanted so water will drip off the metal. Remove the temperature probe and cardboard top from the calorimeter and then quickly drop the metal into the calorimeter and cover with the cardboard with the temperature probe. Make sure the metal is completely covered with water.

Question 1.2

Why do we want the water to drip off the metal before it is placed in the calorimeter?

12. Adjust the temperature probe's height so that it is not touching the lead or the Styrofoam cup, yet the water is covering the entire temperature probe bulb.
13. Gently swirl the calorimeter to distribute the heat throughout the calorimeter. Watch the Logger Pro display closely as the temperature rises. Sometimes it will rise, then fall, and rise again due to the uneven distribution of heat within the calorimeter. Record the temperature for a two-minute time period.
14. Repeat this procedure two more times. Dry the calorimeter and temperature probe between trials.
15. Calculate the heat capacity of your calorimeter. Report the average heat capacity for the calorimeter. Also, calculate the standard deviation, 95% confidence limit, and relative deviation of your data.

Part II: Determining the Heat Capacity of a Metal

In this experiment, you will determine the heat capacity of a metal using the coffee cup calorimeter you constructed in Part I of the experiment.

Procedure

1. Using your calorimeter for which the heat capacity has now been determined, you will analyze an unknown metal sample by essentially repeating the procedure in Part I. The sample will be either **aluminum** or **copper**. (Remember to record the color of your unknown sample.)
2. Calculate the specific heat for your metal for each run. (Remember that the heat lost by the metal is equal to the heat gained by the water in the calorimeter and by the calorimeter itself.) Calculate the average specific heat for your metal as well as the standard derivation, rel. deviation, the 95% confidence limit of your data. Then, using the values given, determine the identity of the metal and then calculate the percent deviation of your calculated specific heat value from the accepted value. (Al = 0.900 J/g·C; Cu = 0.389 J/g·C)

Question 1.3

Do you expect your value for the specific heat to be too high or too low? Explain.

Question 1.4

Although the coffee-cup calorimeter is efficient, it is not perfect. It does absorb some heat. How would this affect your results?

Part III: Calculating the Enthalpy of an Endothermic Reaction

The cold packs in some first-aid kits are made of ammonium nitrate pellets encased in a plastic bag surrounded by water. When the cold-pack is bent, the inner bag is broken, and an endothermic reaction occurs as the ammonium nitrate dissolves in the water. You will be simulating this reaction in this part of the experiment.

Procedure

1. Remove the cardboard top of your calorimeter. Accurately measure about 100 mL of water and place it into the calorimeter. Record the temperature of the water for one minute.
2. Accurately weigh out approximately 20 g of ammonium nitrate and record this mass in your notebook.

3. Add the ammonium nitrate to the water in your calorimeter. Stir the reaction mixture with a stirring rod. Begin data collection and record the temperature for at least two minutes.
4. Determine the accurate temperature change based on your measurements.
5. Using the molecular mass of ammonium nitrate and assuming all the heat is absorbed by the water in the calorimeter (4.184 J/g·C), calculate the enthalpy of the reaction per mole of ammonium nitrate.

Question 1.5

Why does a cold pack "feel" cold?

Part IV: Calculating the Heat of Fusion of Water

Now is your chance to design an experiment. This is an especially important experience since many of you will be pursuing careers in fields that require you to do research. In this part of the experiment, you will design an experiment to determine the heat of fusion of ice. You will probably need your calorimeter, ice, water, and a balance. You may use any of the equipment in your locker. Be sure your method is repeatable. Have fun!

Procedure

1. Design an experiment to determine the heat of fusion of ice.
2. Do the experiment. Write up the procedure.
3. Calculate the heat of fusion from your data, and then calculate the relative error of your value for the heat of fusion relative to the accepted value in your text.

Clean Up

All ammonium nitrate solutions must be disposed of in the CHEM 4B Exp. 1 – Thermochemistry waste container. Be sure to rinse out the calorimeter before returning it.
