Introduction to Thermodynamics in the Laboratory: Calorimetry

Objective: To learn more about thermodynamics through the use of a calorimeter to measure the specific heat of an unknown metal, the heat of solution of an unknown solid and the heat of neutralization of the reaction between hydrochloric acid and sodium hydroxide.

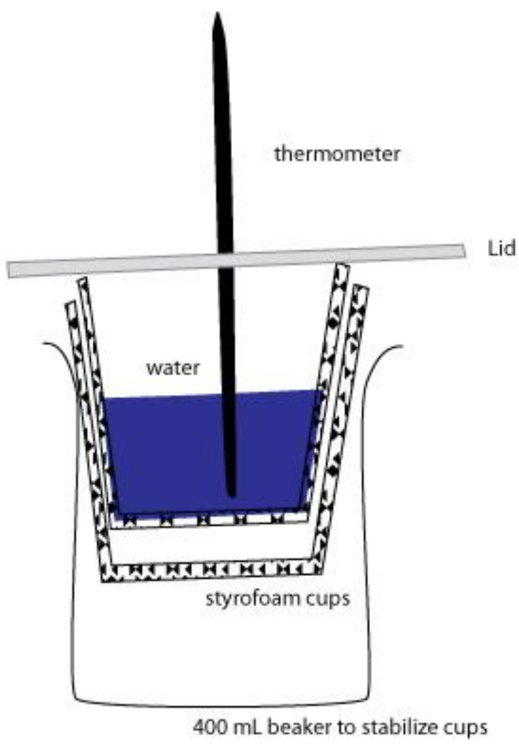
Materials: Coffee cup calorimeter, thermometer, stirring rod, unknown metal shot, unknown solids, 1.00 M HCl and 1.00 M NaOH.

Part One: Specific Heat

Heat Transfer is described by the following equation:

$$\text{mass}_1 \text{ X } \Delta T_1 \text{ X } S.H._1 = \text{mass}_2 \text{ X } \Delta T_2 \text{ X } S.H._2$$

What is not shown in this equation is heat, q. It is implied. Heat lost by one material is equal to heat gained by another. This equation may be rearranged to solve for the specific heat of an unknown substance. Rearrange this equation to solve for $S.H._2$ and use this to solve for the specific heat of an unknown metal.



A coffee cup calorimeter is made out of two nested styrofoam coffee cups and a lid. The lid contains holes big enough to insert a thermometer and a stirring rod. In this experiment we will weight an empty big test tube then fill it half full with a sample of an unknown metal and weigh it again. We will heat this unknown metal by placing the big test tube into a boiling water bath (a beaker filled with boiling water). The metal will stay dry inside the tube but through a process of heat transfer it will become as hot as the boiling water that surrounds it. Once it is heated to this known hot temperature it will be poured into a known mass of water (about 50mL) that is at room temperature inside the coffee cup calorimeter. The temperature and mass of the water must be recorded before the metal is added. Once the metal is added to the water and the mixture is stirred the temperature of the water will rise as the metal cools. We will assume that no heat is lost to the surroundings. (Is this assumption true?). The final temperature of the mixture that is recorded will allow us to find ΔT for both the water and the metal. We will use the value of 4.184 J/g° as the specific heat of water. This provides us with all the data we need to determine the specific heat of an unknown metal. This procedure should be repeated and the results of the two trials averaged.

Once you report your results and your % difference between your values you will be given the identity of your metal. You can then determine the % error from the accepted value for the specific heat of the metal.

Part Two: Heat of Solution

In this part of the experiment place about 50 mL of water at room temperature into the calorimeter (weigh the calorimeter empty and with the water in it so you can calculate the mass of the water). Measure the temperature of the water and record it. Using the analytical balance weight the container of unknown solid, add about half of it to the water and stir continuously. Record the temperature every ten seconds as the solid dissolves until it is completely dissolved and a maximum or minimum temperature is achieved. Weigh the container again so you will know the exact mass of the solid you added to the water. Repeat this procedure with the remaining half of the unknown solid. Calculate qH_2O which equals mass X ΔT X S.H. of the water. qH_2O is equal to $-\Delta H$ of the solution. Is this solution reaction endothermic or exothermic? How do you know. Calculate the ΔH per gram of solid sample for each trial. Determine the average and the range and report this to the instructor. Your instructor will give you the identity of your unknown. Calculate ΔH per mole of compound.

Part Two: Heat of Neutralization

Rinse the calorimeter with distilled water. Using a graduated cylinder, measure out 25 mL of 2.00 M HCl and put this into the calorimeter. Rinse the graduated cylinder and measure out 25 mL of 2.00 M NaOH into a clean, dry 50mL-beaker. Measure the temperature of the acid and the base and record this data. **NOTE: Rinse the thermometer between solutions so the acid and base do not mix yet.** With the thermometer in the calorimeter pour the base into the acid, stir and measure the change in temperature. Use 1.02 g/mL as an average density for the acid and the base so you can calculate the mass of the acid and base solutions. Use 4.184 J/go as the specific heat of the solutions since they are mostly water. Find q for this neutralization reaction. ΔH is equal to -q. Repeat this procedure to obtain data for a second trial. Record your results in your laboratory notebook. You do not need to report this value to the instructor.

How to Calculate Percent Difference where x1 and x2 are two different trials:

$$\%\ \text{Diff} = \left| \frac{x_1 - x_2}{(x_1 + x_2)/2} \right| \times 100$$

How to Calculate Percent Error

$$\%\ \text{Error} = \frac{|\text{Experimental} - \text{Theoretical}|}{\text{Theoretical}} \times 100$$

Set Up for Introduction to Thermodynamics in the Laboratory: Calorimetry

Supplies

20 7 oz styrofoam cups inside of 9oz styrofoam cups with covers that include holes for thermometer and stirring rod. (coffee cup calorimeters)

20 glass stirring rods with loops at the bottom for better stirring action

20 thermometers

Reagents

4 200 mL 2M HCl

4 200 mL 2M NaOH

Unknowns

Unknown metal shot: (set out bottles)
lead
tin
aluminum
zinc
nickel

Unknown solid salt: (one vial for each student)
12 grams of the following salts:
ammonium nitrate
calcium chloride
potassium nitrate
sodium nitrate
sodium carbonate