Laboratory

10

Heats of Reaction

Objectives

- Determine heat of reaction for the dissolution of solid KOH
- Determine heat of reaction for the reaction of solid KOH with aqueous HCl
- Determine heat of reaction for the reaction of aqueous KOH with aqueous HCl
- Use Hess' Law to compare additive heats of reaction

Equipment and Materials

- Solid KOH
- 1.5 M HCl solution
- Styrofoam cup
- Graduated cylinder
- Glass stirring rod
- Thermistor
- 50 mL beaker
- 250 mL beakers
- Watch glass
- pH paper

Introduction

In this experiment, you will use a Styrofoam cup as a calorimeter to measure the heat released by three different reactions. One of the reactions can be expressed as the combination of the other two reactions. Therefore, the heat of reaction of the one reaction should be equal to the sum of the heats of reaction for the other two. This concept is sometimes referred to as the Hess's Law or additivity of heats of reaction.

PART I: KOH(*s*) → KOH(*aq*)

1. Find and record the mass of a 50 mL beaker that is clean and dry. Weigh out between 2–3 grams of KOH pellets into the beaker. Record the exact mass of the beaker + KOH in your lab notebook

2. Prepare a Microlab experiment to record time and temperature using a thermistor. Prepare the graph with time on the x-axis and temperature on the y-axis.

3. Suspend the thermistor over a Styrofoam cup so that the tip of the thermistor is roughly 1/2 inch from the bottom. Measure out 100.0 mL of water using your graduated cylinder and pour the water in the Styrofoam cup.

4. Begin recording the temperature of the water in the cup and do so for about 2 minutes.

5. Continue to record the temperature and add the solid KOH to the water in the cup and stir continuously. Record temperature data for another 3 minutes.

6. Pour the resulting solution into a clean, dry beaker and cover with a watch glass to prevent any contamination. **DO NOT DISPOSE OF THIS SOLUTION!** You will need it later in the lab. Rinse the Styrofoam cup with deionized water.

7. Export your data to an Excel file that can be shared between lab partners. Be sure to name the file so that you know which part of the experiment the data is from.

PART II: $KOH(s) + HCl(aq) \rightarrow KCl(aq) + H_2O(l)$

1. Find and record the mass of a 50 mL beaker that is clean and dry. Weigh out another 2–3 g sample of solid KOH into the beaker. Record the exact mass of the KOH + beaker.

2. Prepare a new Microlab experiment to record time and temperature as before. Prepare a graph to display time and temperature as in Part I. Set up the thermistor as in Part I, as well.

3. Place ~160 mL of 1.5 M HCl into a 250 mL beaker. Record the actual molarity of the acid in your notebook.

4. Use your graduated cylinder to measure out 100.0 mL of HCl and pour into the Styrofoam cup.

5. Begin recording the temperature of the HCl in the cup and do so for 2 minutes.

6. After 2 minutes, add the solid KOH to the acid and stir continuously. Record temperature data for another 3 minutes.

7. Test the pH of the solution using a piece of pH paper and record the result in your notebook. Think about what this result tells you about a limiting reactant. Dispose of the solution into the waste container; rinse and dry your Styrofoam cup.

8. Export your data to an Excel file that can be shared between lab partners. Be sure to name the file so that you know which part of the experiment the data is from.

PART III: $KOH(aq) + HCl(aq) \rightarrow KCl(aq) + H_2O(l)$

1. Rinse your graduated cylinder with deionized water. Measure out 50.0 mL of the KOH solution from Part I and place into a 50 mL beaker that is clean and dry.

2. Rinse the graduated cylinder again, then measure out 50.0 mL of the 1.5 M HCl solution and pour into the Styrofoam cup.

3. Suspend the thermistor in the beaker with the KOH solution for 2 minutes. Record the initial temperature of the solution.
4. Rinse and dry the thermistor, then prepare a new Microlab experiment to record time and temperature, and set up the thermistor over the Styrofoam cup as in the previous parts.
5. Begin recording the temperature of the HCl in the cup and do so for two minutes.
6. After 2 minutes, add the KOH solution from the beaker into the cup and stir continuously. Continue recording the temperature for another 3 minutes. Test the pH of the resulting solution using pH paper and record the results in your notebook.
7. Export the data to an Excel file as before, and dispose of the solution appropriately.

PART IV: DATA ANALYSIS

1. Use a spreadsheet to create a time vs. temperature graph for each of your three trials.
2. Compare the graphs for the three trials. Discuss and explain the similarities and differences between them.
3. Create a table to include the data and results as shown on the following page. Fill in your data, and collect data from three other lab groups as well.
4. Show a sample calculation for all calculations that need to be done in the table. You can use the following information in the calculations needed to fill in your table:

$$\text{Heat} = C \times m \times \Delta T$$

$C = 4.184\frac{J}{g \cdot {}^{\circ}C}$, m is the mass of water used in your solution (assume 1 g/ml), and ΔT is the change in your solution's temperature.

5. How does your data compare with data from the other groups? Find a mathematical relationship between the amount of KOH used and the amount of heat evolved from the reactions for each of your groups' data.
6. What relationship do you see between the heat values of the different parts (1–3)? What relationship do you see in the chemical reactions of the different parts (1–3)? Does your data support or refute Hess' law?

Part 1

Mass of KOH

Moles of KOH

mL of solution

ΔT

Heat (J)

Heat (J)/mole KOH

Part 2

Mass of KOH

Moles of KOH

Moles of HCl

mL of solution

pH test (acidic or basic)

Limiting reagent

ΔT

Heat (J)

Heat (J)/mole KOH

Part 3

Mass of KOH

Moles of KOH

Moles of HCl

mL of final solution

pH test (acidic or basic)

Limiting reagent

ΔT

Heat (J)

Heat (J)/mole KOH