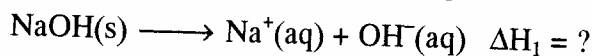


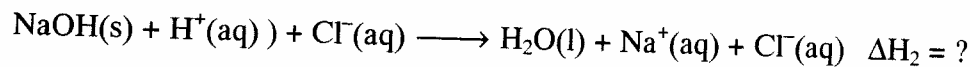
Additivity of Heats of Reaction: Hess's Law

In this experiment, you will use a Styrofoam-cup calorimeter to measure the heat released by three reactions. One of the reactions is the same as the combination of the other two reactions. Therefore, according to Hess's law, 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 *additivity of heats of reaction*. The primary objective of this experiment is to confirm this law. The reactions we will use in this experiment are:

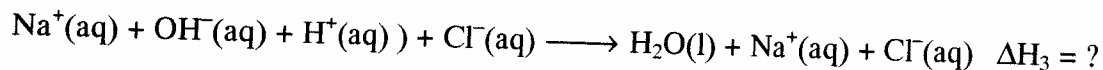
- (1) Solid sodium hydroxide dissolves in water to form an aqueous solution of ions.



- (2) Solid sodium hydroxide reacts with aqueous hydrochloric acid to form water and an aqueous solution of sodium chloride.



- (3) Solutions of aqueous sodium hydroxide and hydrochloric acid react to form water and aqueous sodium chloride.



OBJECTIVES

In this experiment, you will

- Combine equations for two reactions to obtain the equation for a third reaction.
- Use a calorimeter to measure the temperature change in each of three reactions.
- Calculate the heat of reaction, ΔH , for the three reactions.
- Use the results to confirm Hess's law.

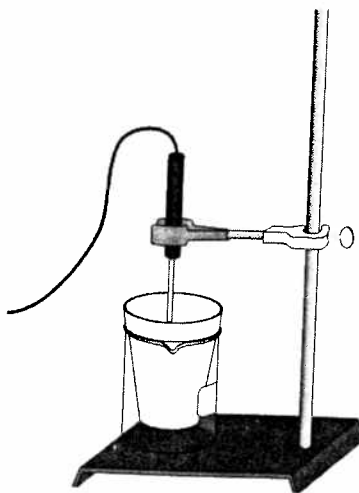


Figure 1

Experiment 18

You will use a Styrofoam cup in a beaker as a calorimeter, as shown in Figure 1. For purposes of this experiment, you may assume that the heat loss to the calorimeter and the surrounding air is negligible. Even if heat is lost to either of these, it is a fairly constant factor in each part of the experiment, and has little effect on the final results.

PRE-LAB EXERCISE

In the space below, combine two of the above equations algebraically to obtain the third equation. Indicate the number of each reaction on the shorter lines.

_____	_____
_____	_____
_____	_____



MATERIALS

computer
Vernier computer interface
LoggerPro
Temperature Probe
50 mL of 1.0 M NaOH
50 mL of 1.0 M HCl
100 mL of 0.50 M HCl


100 mL of water
4.00 g of solid NaOH
ring stand
utility clamp
stirring rod
Styrofoam cup
250 mL beaker

PROCEDURE

Reaction 1

1. Obtain and wear goggles.
2. Connect the probe to the computer interface. Prepare the computer for data collection by opening the file "18 Hess's Law" from the *Chemistry with Computers* folder.
3. Place a Styrofoam cup into a 250 mL beaker as shown in Figure 1. Measure out 100.0 mL of water into the Styrofoam cup. Lower the Temperature Probe into the solution.
4. Use a utility clamp to suspend a Temperature Probe from a ring stand as shown in Figure 1.
5. Weigh out about 2 grams of solid sodium hydroxide, NaOH, and record the mass to the nearest 0.01 g. Since sodium hydroxide readily picks up moisture from the air, it is necessary to weigh it and proceed to the next step without delay. **CAUTION: Handle the NaOH and resulting solution with care.**
6. Click on  Collect to begin data collection and obtain the initial temperature, t_1 . It may take several seconds for the Temperature Probe to equilibrate at the temperature of the solution. After three or four readings at the same temperature have been obtained, add the solid NaOH to the Styrofoam cup. Using the stirring rod, stir continuously for the remainder of the 200 seconds or until the temperature maximizes. As soon as the temperature has begun to drop after reaching a maximum, you may terminate the trial by clicking  Stop.

Additivity of Heats of Reaction: Hess's Law

7. Examine the initial readings in the table to determine the initial temperature, t_1 . To determine the final temperature, t_2 , click the Statistics button, . The maximum temperature is listed in the statistics box on the graph. Record t_1 and t_2 in your data table.
8. Rinse and dry the Temperature Probe, Styrofoam cup, and stirring rod. Dispose of the solution as directed by your instructor.

Reaction 2

9. Repeat Steps 3-8 using 100.0 mL of 0.50 M hydrochloric acid, HCl, instead of water.
CAUTION: *Handle the HCl solution and NaOH solid with care.*

Reaction 3

10. Repeat Steps 3-8, initially measuring out 50.0 mL of 1.0 M HCl (instead of water) into the Styrofoam calorimeter. In Step 5, instead of solid NaOH, measure 50.0 mL of 1.0 M NaOH solution into a graduated cylinder. After t_1 has been determined for the 1.0 M HCl, add the 1.0 M NaOH solution to the Styrofoam cup. **CAUTION:** *Handle the HCl and NaOH solutions with care.*