

35

HEATS OF REACTION

Text Reference

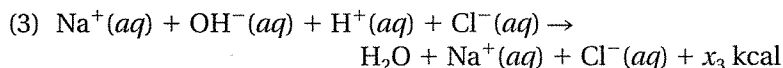
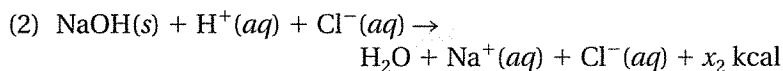
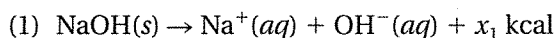
Sections 17.2 and 17.4

PURPOSE

To measure the heats of reaction for three related exothermic reactions and to verify Hess's law of heat summation.

BACKGROUND

Energy changes occur in all chemical reactions; energy is either absorbed or released. If energy is released in the form of heat, the reaction is called *exothermic*. If energy is absorbed, the reaction is called *endothermic*. In this experiment, you will measure the amounts of heat released in these three related exothermic reactions:



After determining the heats of reaction, you will analyze your data and verify the additive nature of heats of reaction.

MATERIALS (PER PAIR)

safety goggles and apron
plastic-foam cup
100-mL graduated cylinder
400-mL beaker
thermometer
50-mL beaker
centigram balance
spatula

wire stirrer
distilled water
sodium hydroxide pellets,
NaOH
0.5M hydrochloric acid,
HCl
1.0M hydrochloric acid, HCl
1.0M sodium hydroxide,
NaOH

SAFETY FIRST!

In this lab, observe all precautions, especially the ones listed below. If you see a safety icon beside a step in the Procedure, refer to the list below for its meaning.



Caution: Wear your safety goggles. (All steps.)



Caution: 0.5M and 1.0M hydrochloric acid are eye and skin irritants. (Steps 4, 7.)

Caution: Sodium hydroxide is a very corrosive material that can cause severe skin burns and permanent eye damage. Under no circumstances, handle solid sodium hydroxide with your fingers. Sodium hydroxide pellets absorb water from the air and can eventually be mistaken for a puddle of water. Never leave the sodium hydroxide container uncovered; never leave pellets on the balance or on the laboratory bench. (Steps 2, 5, 7.)



Caution: If you should break a thermometer, immediately report the incident to your teacher. Never use a thermometer as a stirrer. (Steps 3, 8.)



Note: Return or dispose of all materials according to the instructions of your teacher. (Steps 3, 6, 9.)

PROCEDURE

As you perform the experiment, record your data in Data Table 1.

Procedure note: After each reaction, dispose of the solution as directed by your teacher and rinse the cup and thermometer with water.

Reaction 1



1. Measure 100 mL of distilled water into a plastic-foam cup. Place the cup inside a 400-mL beaker for support. This assembly, together with a thermometer, will serve as your calorimeter.



2. Measure and record the mass of a 50-mL beaker to the nearest 0.01 g. **CAUTION:** *NaOH is extremely corrosive.* Using a spatula, add as close to 2.00 g as possible of sodium hydroxide pellets to the beaker. Measure and record the combined mass of the beaker and sodium hydroxide to the nearest 0.01 g. (Do this operation as quickly as possible to avoid error due to absorption of water by the NaOH.)



3. Measure and record the temperature of the water in the foam cup to the nearest 0.5°C. Add the NaOH pellets to the water in the calorimeter. Stir the mixture gently with a wire stirrer until all the solid has dissolved. **CAUTION:** *Hold the thermometer with your hand at all times.* Record the highest temperature reached during the reaction.



Reaction 2



4. **CAUTION:** *Low-concentration hydrochloric acid can irritate your skin.* Measure 100 mL of 0.5M HCl into the plastic-foam cup and place the cup inside a 400-mL beaker.



5. Using a spatula, measure out 2.00 g of solid NaOH pellets. **CAUTION:** *NaOH is extremely corrosive.*



6. Measure and record the temperature of the HCl solution in the foam cup. Add the NaOH pellets to the acid solution and stir *gently* until the solid is dissolved. Measure and record the highest temperature reached by the solution during the reaction.

Reaction 3



7. Place the plastic-foam cup inside a 400-mL beaker. Measure 50 mL of 1.0M HCl into the cup. Rinse the graduated cylinder and fill with 50 mL of 1.0M NaOH.



8. Measure and record the temperature of the HCl solution (in the cup) and the NaOH solution (in the cylinder) to the nearest 0.5°C. Rinse the thermometer between measurements.



9. Pour the NaOH solution into the foam cup. Stirring the mixture gently, measure and record the highest temperature reached.

OBSERVATIONS

DATA TABLE 1: EXPERIMENTAL DATA				
Parameter	Reaction 1	Reaction 2	Parameter	Reaction 3
mass (beaker)			initial temperature (HCl solution)	
mass (beaker + NaOH)			initial temperature (NaOH solution)	
mass (NaOH)			average initial temperature	
initial temperature			final temperature	
final temperature				

ANALYSES AND CONCLUSIONS

1. Determine the change in temperature, ΔT , for each reaction. Record your results in Data Table 2.
2. Calculate the mass of the reaction mixture in each reaction. (To do this, first determine the total volume of the solution. Then calculate the mass of the solution, based on the assumption that the density of the solution is the same as that of pure water, 1.0 g/mL.) Record your results in Data Table 2.
3. Calculate the total heat released in each reaction, assuming that the specific heat of the solution is the same as that of pure water, 1.0 cal/(g°C). Remember:

$$\text{heat of reaction} = \text{mass} \times \text{specific heat} \times \Delta T$$

Record your results in Data Table 2.

4. Calculate the number of moles of NaOH used in reactions 1 and 2, and record the results in Data Table 2.
5. In reaction 3, the number of moles of NaOH can be calculated from the concentration of the solution (1.0M, or 1.0 mole of NaOH per liter of solution) and the volume used. The calculation is shown below.

$$50.0 \text{ mL NaOH} \times \frac{1 \text{ mol NaOH}}{1000 \text{ mL NaOH}} = 0.050 \text{ mol NaOH}$$

Enter this result in Data Table 2.

6. Calculate the energy released per mole of NaOH for each reaction and enter your results in Data Table 2.

DATA TABLE 2: RESULTS OF CALCULATIONS					
Reaction Number	Mass of Reaction Mixture	ΔT	Total Heat Released	mol NaOH Consumed	Heat Released per mol NaOH
1					
2					
3					

7. Show that the equations for reactions 1 and 3, which are given in the Background section, add up to give the equation for reaction 2. Include the energy released per mole of NaOH in each equation.

8. Examine all the class data. Does the sum of the energy released per mole of NaOH for reactions 1 and 3 equal the energy released per mole of NaOH in reaction 2? What factors might account for any difference?

9. Calculate the percent difference between the heat given off in reaction 2 and the sum of the heats given off in reactions 1 and 3. Assume that the heat given off in reaction 2 is correct.

$$\text{percent difference (in evolved heat)} = \frac{|(\text{heat}_1 + \text{heat}_3) - \text{heat}_2|}{\text{heat}_2} \times 100\%$$

10. Would changing the amount of NaOH used in reaction 1 affect the value obtained for the energy given off per mole of NaOH? Explain.

11. State in your own words what is meant by the additive nature of heats of reaction.

Name _____ Date _____ Class _____

12. Taking into account your answer to problem 4, explain why you were asked to use exactly 2.00 g of NaOH in reactions 1 and 2, and an equivalent number of moles of NaOH in reaction 3.

GOING FURTHER

Develop a Hypothesis

Suppose nitric acid (HNO_3) was substituted for HCl in reactions 2 and 3. Propose a hypothesis about how the heat change for reaction 2 would be affected.

Design an Experiment

Propose an experiment to test your hypothesis. If resources are available and you have your teacher's permission, perform the experiment.
