Name _____ Date _____ Class _____

Entropy and Enthalpy Changes

Lab 68

Introduction

Does your bedroom seem to get messy spontaneously? Have you ever noticed how the walls and roof of a deserted building seem to collapse on their own? Can you explain what happens to the arrangement of water molecules as ice melts?

Each of these questions is related to the concept of entropy. Entropy is a measure of the disorder of a system. Spontaneous processes are those that result in a more disordered arrangement of substances, that is, an increase in entropy. Your room gets messy because it has a natural tendency to do so. (Using entropy as an excuse to not clean your room is not recommended!) Old buildings collapse by themselves and water molecules in an ice crystal leave the crystal structure spontaneously because, in both cases, the entropy increases.

In this investigation, you will apply the principle of entropy to three related, spontaneous reactions. You will dissolve solid sodium hydroxide (NaOH) in water, react NaOH solution with hydrochloric acid (HCl), and react solid NaOH with HCl. You will then decide what change in entropy has occurred in each reaction. You will also measure the enthalpy change associated with each reaction.

Pre-Lab Discussion

Read the entire laboratory investigation and the relevant pages of your textbook. Then answer the questions that follow.

1. What is the definition of a spontaneous reaction?

2. How many chemical reactions will be performed in this investigation? Which of them are spontaneous?

3. Why must you wear gloves when working with NaOH pellets?

4. Characterize the following as increasing entropy or decreasing entropy:
   a. gases forming from liquids
   b. decreasing the temperature
   c. dissolving a solid in water

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5. In what units will the heat of reaction be expressed?

Problem

What is the level of entropy and the thermochemical relationship of three chemical reactions?

Materials

chemical splash goggles
laboratory apron
latex gloves
graduated cylinder, 100-mL
distilled water
2 plastic foam cups
weighing paper
laboratory balance
forceps or scoopula
sodium hydroxide pellets (NaOH)
thermometer
stirring rod
paper towel
hydrochloric acid (HCl), 1.0 *M*
sodium hydroxide (NaOH), 1.0 *M*
hydrochloric acid (HCl), 0.5 *M*

Safety

Wear your goggles and lab apron at all times during the investigation. Sodium hydroxide pellets and solutions are caustic. Gloves should be worn when handling the pellets. Hydrochloric acid is corrosive to skin and clothing. If you spill any acid, immediately wash the area with plenty of cold water and notify your teacher. Note the caution alert symbols here and with certain steps of the Procedure. Refer to page *xi* for the specific precautions associated with each symbol.

Procedure

Part A

1. Put on your goggles and lab apron. Use a graduated cylinder to put 100.0 mL of distilled water in a plastic foam cup. Record this volume.

2. Put on a pair of latex gloves. On a piece of weighing paper, find and record the exact mass of six to seven pellets of solid sodium hydroxide (NaOH). **CAUTION:** *NaOH is caustic. Wear gloves whenever you handle it. Use forceps to handle NaOH pellets.*
3. Place the cup inside another cup. Measure the temperature of the water to the nearest 0.2°C and record this value as the initial temperature (T_i). Pour the NaOH pellets into the cup and begin gently stirring with the stirring rod. Record the highest temperature reached as the final temperature (T_f).
4. Pour the solution down the sink followed by plenty of water. Rinse and dry the cups.

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Part B

5. Place one cup inside the other. Using a graduated cylinder, put 50.0 mL of 1.0 *M* HCl into the inner cup. Rinse the graduated cylinder and put 50.0 mL of 1.0 *M* NaOH into it. Record these volumes. **CAUTION:** *NaOH solutions are caustic and HCl solutions are corrosive. Care should be taken when working with them.*
6. Measure the temperature of each solution. Be sure to rinse and dry the thermometer when changing from one solution to another. The temperatures should be within 0.2°C of each other. If not, notify your teacher. Record the HCl value as the initial temperature (T_i).
7. While gently stirring, add the NaOH to the HCl and measure the highest temperature reached. Record this value as the final temperature (T_f).
8. Pour the solution down the sink followed by plenty of water. Rinse and dry the cups.

Part C

9. Place one cup inside the other. Using a graduated cylinder, put 100.0 ml of 0.5 *M* HCl into the inner cup. Record this volume.

10. Repeat Steps 2 and 3 of Part A, using the 0.5 *M* HCl instead of distilled water.

11. Clean up your work area and wash your hands before leaving the laboratory.

Observations

Part A

volume of H_2O _____

mass of NaOH pellets _____

initial temperature _____

final temperature _____

Part B

volume of HCl solution _____

volume of NaOH solution _____

initial temperature _____

final temperature _____

Part C

volume of HCl solution _____

mass of NaOH pellets _____

initial temperature _____

final temperature _____

Waste Disposal

All substances used in this investigation can be flushed down the sink followed by plenty of water. ■

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Calculations

Part A

1. Calculate the mass of the water in the cup. Assume the density of water is 1.0 g/mL.

2. Calculate the temperature change.

3. Calculate the moles of NaOH.

4. Calculate the heat absorbed by the water as the NaOH dissolved. Use 0.00418 kJ/g•°C as the specific heat of water.

5. Calculate the heat released per mole of NaOH. Label this value as ΔH_A.

Part B

1. Calculate the temperature change, the mass of the liquids in the cup, and the moles of NaOH as you did in the calculations for Part A. Assume the density of the HCl and NaOH solutions are the same as water.

2. Calculate the heat absorbed by the liquids as the HCl and NaOH reacted. Assume the specific heat of the solutions is the same as that of water.

3. Calculate the heat released per mole of NaOH. Label this value as ΔH_B.

Part C

1. Calculate the change in temperature, mass of the HCl, and moles of NaOH as before.

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2. Calculate the heat absorbed by the liquids as the HCl and NaOH reacted. Assume the liquids have the same specific heat as water.

3. Calculate the heat released per mole of NaOH. Label this value as ΔH_C.

Critical Thinking: Analysis and Conclusions

1. Explain what happens to the entropy in each of the three reactions.

2. Write the equations for the reactions in Parts A, B, and C. Include the heat terms as determined in the investigation. How does the sum of A + B compare to the equation for Part C? *(Making comparisons)*

3. Which of these reactions is exothermic? How do you know? *(Interpreting data)*

4. Compare the sum of $\Delta H_A + \Delta H_B$ to ΔH_C. Are they different? Explain the source of any error. *(Making comparisons)*

5. What process is represented by ΔH_A? By ΔH_B? By ΔH_C? *(Making inferences)*

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Critical Thinking: Applications

1. How would changing the amount of NaOH affect the results of this investigation? *(Making predictions)*

2. Solid carbon reacts with oxygen gas to form carbon dioxide gas ($\Delta H = -393.5$ kJ/mol C). Carbon monoxide (CO) gas reacts with oxygen gas to form carbon dioxide gas ($\Delta H = -282.8$ kJ/mol CO). What is the enthalpy change for the reaction of solid carbon with oxygen gas to form carbon monoxide gas? *(Applying concepts)*