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Investigating Factors That Affect ΔT, q_{rxn}, and ΔH for Neutralization Reactions

Problem: Determine the temperature change, heat of reaction, and enthalpy change for a series of acid-base neutralization reactions.

Pre-Laboratory Assignment

1. a. Write the net ionic equation for the reaction of hydrochloric acid and aqueous sodium hydroxide.

   b. Using standard enthalpy of formation values found in Appendix J of your textbook, calculate ΔH for this reaction.

2. While assembling the equipment and reagents for this investigation, suppose you spilled 50.0 mL of 1.00 M hydrochloric acid on your uniform. How would you handle the incident?

3. a. When 50.0 mL of 1.00 M hydrochloric acid and 50.0 mL of 1.00 M sodium hydroxide react, the temperature rises 6.7^{o}C. Use the total solution volume, density of water, and specific heat of water to calculate the heat absorbed by the solution, q_{soln}, during this reaction.

   b. Calculate the amount of heat released, q_{rxn}, by this acid-base reaction.

   c. Calculate the moles of hydrogen ion and hydroxide ion initially present, and the moles of water produced in this reaction.

   d. Calculate the ΔH (in kJ/mol) for the reaction forming 1 mole of water.

   e. How does your calculated ΔH compare to the ΔH you calculated in Pre-Laboratory Assignment 1b.

4. If a reaction between 50.0 mL of 1.00 M hydrochloric acid and 50.0 mL of 1.00 M sodium hydroxide causes a 6.7^{o}C increase in temperature, predict how these variations would affect the temperature change.

   a. using 100.0 mL of 1.00 M hydrochloric acid and 100.0 mL of 1.00 M sodium hydroxide

   b. using 50.0 mL of 2.00 M hydrochloric acid and 50.0 mL of 2.00 M sodium hydroxide

   c. using 25.0 mL of 1.00 M hydrochloric acid and 75.0 mL of 1.00 M sodium hydroxide

   d. using 25.0 mL of 1.00 M sulfuric acid and 75.0 mL of 1.00 M sodium hydroxide

Experiment Procedures

1. Construct a polystyrene-cup calorimeter.

2. Construct a data table for this experiment.

3. Perform these experiments. Begin each one by placing the acid in the calorimeter and monitoring its temperature for 1 min, in order to ensure a stable initial temperature. Record this initial temperature. Add the base to the calorimeter, and quickly stir the solution. Monitor the temperature of the reaction solution for at least 1 min, and record its maximum temperature. Dispose of the reaction solution by pouring down the drain. Rinse the calorimeter and thermometer with distilled water, then dry them.

Caution: Hydrochloric acid, sulfuric acid, and sodium hydroxide are corrosive and toxic.

Experiment 1: 50.0 mL 1.00 M hydrochloric acid and 50.0 mL 1.00 M sodium hydroxide.

Experiment 2: 100.0 mL 1.00 M hydrochloric acid and 100.0 mL 1.00 M sodium hydroxide.

Experiment 3: 50.0 mL 2.00 M hydrochloric acid and 50.0 mL 2.00 M sodium hydroxide.

Experiment 4: 25.0 mL 1.00 M hydrochloric acid and 75.0 mL 1.00 M sodium hydroxide.

Experiment 5: 25.0 mL 1.00 M sulfuric acid and 75.0 mL 1.00 M sodium hydroxide.

3. Calculate the ΔT for each experiment and record on your data table. Compare your ΔT values to those of the person next to you. If any ΔT values differ by more than $\pm 0.50^{o}$C, repeat that experiment together.

Experiment Data and Observations

Post-Laboratory Questions

1. Calculate these for each of your five experiments.

   a. number of moles of H^+ initially present
   b. number of moles of OH^- initially present
   c. number of moles of H_2O produced
   d. temperature change
   e. heat released during the reaction
   f. enthalpy for the reaction forming 1 mole of water

   Record your answers here:

experiment number	**initial mol H^+, mol**	**Initial mol OH^-, mol**	**mol H_2O produced, mol**	**ΔT, °C**	**q_{rxn}, J**	**ΔH_{rxn}, kJ/mol**

2. In Pre-Laboratory Assignment 4**,** you made temperature change predictions for four variations of Experiment 1. Does your experimental data support your predictions? For each incorrect prediction, describe the error in your initial reasoning.

3. a. Does doubling the volumes of acid and base in a neutralization reaction double the amount of heat released? Explain.

   b. Does doubling the concentrations (but not the volumes) of acid and base in a neutralization reaction double the amount of heat released? Explain.

   c. How would you use the results of your Experiments 1–3 to explain the difference between temperature and heat?

4. a. Experiments 1 and 4 each have a total reaction solution volume of 100.0 mL and use 1.00 M hydrochloric acid and 1.00 M sodium hydroxide. How do you account for their different ΔT and q_{rxn}?

   b. Experiments 4 and 5 each use 25.0 mL of a 1.00 M strong acid and 75.0 mL of 1.00 M sodium hydroxide. How do you account for their different ΔT and q_{nrxn}?

5. Which factors: volume, concentration, monoprotic vs. diprotic acid, affect the value of ΔH_{rxn}? Explain each one.

6. Based on a total reaction volume of 100.0 mL, what volumes of 1.00 M sulfuric acid and 1.00 M sodium hydroxide will produce the greatest amount of heat?