Heat of Neutralization

Cautions HCl and NaOH are corrosive and toxic

Purpose The purpose of this experiment is to determine the heat of neutralization for a reaction between a strong acid and a strong base.

Introduction

Chemical and physical changes are often accompanied by energy transfer. For example, when gasoline is combusted in a car engine, the engine block becomes hot and the car's pistons move. This example demonstrates two ways heat can be transferred in a chemical process: through heat (the temperature change) or through work (mechanical motion). Most chemical reactions run in a laboratory do not produce a significant amount of work; therefore it can be assumed that all energy gained or lost is in the form of heat.

Chemical processes are qualitatively classified based on whether heat is absorbed or released as the change occurs. Processes that *require* heat to occur, such as melting ice into liquid water, are **endothermic** processes. Processes that *release* heat as they occur, like the combustion of gasoline, are **exothermic** processes.

This experiment focuses on heat changes observed during chemical or physical processes. These heat changes can be determined based on temperature changes. Changes in heat that accompany chemical processes can be measured quantitatively using a calorimeter, which is a closed system within which the process can occur. In addition to the reactants that will undergo a chemical change, a reference substance must also be present to accept or donate the heat being evolved or consumed in the process. Since the system is closed, any measured temperature change is due only to the chemical or physical change occurring within and any heat lost or gained by the process is equal to the heat gained or lost by the reference material, that is:

$$q_{process} = -q_{reference} \quad \textbf{(1)}$$

Two properties of the reference substance must be known, its quantity in grams (or moles) and its specific heat, which is the quantity of heat required to increase one gram of substance by $1^{o}C$. The mathematical relationship between heat and temperature is:

$$q = ms(T_f - T_i) = ms\Delta T \quad \textbf{(2)}$$

where q is the heat transferred, m is the quantity of reference substance, s is the specific heat of the reference substance (in units matching m), and T_f and T_i are the final and initial temperatures of the contents of the calorimeter.

In today's lab, the heat change that occurs during a reaction between a strong acid and a strong base will be determined. The reaction is exothermic in nature, and produces water and a neutral salt. The specific value that will be determined is called the 'heat of neutralization", ΔH_n, and is the heat evolved when 1 mol of acid reacts with 1 mole of base. Nested styrofoam coffee cups will be used as the calorimeter, and approximate densities and specific heats of the various solutions will be used to determine quantities. It will be assumed there are no significant heat losses through the coffee cups or thermometer.

Heat of Neutralization

Procedure

1. Obtain two clean 100 mL graduated cylinders. Using a wax pencil, label the first cylinder "A" (for acid) and the second cylinder "B" (for base).
2. Using cylinder "A" measure 40.0 mL of the 3.00 M HCl solution provided. Make sure to record this solution's exact concentration on your data sheets.
3. Using cylinder "B" measure 41.0 mL of the 3.00 M NaOH solution provided. Again, make sure this solution's exact concentration is recorded.
4. Obtain two Styrofoam cups, a lid, and two thermometers in split rubber stoppers. Secure each thermometer in a clamp on a ring stand. Label one Styrofoam cup "A" and the second cup "B".
5. Pour the acid solution from cylinder "A" into the cup labeled "A". Place one thermometer in this solution to measure its temperature. Pour the base solution from cylinder "B" into the cup labeled "B". Place the other thermometer in this solution to measure its temperature. Do not record any data in the grey cells.
6. Measure the temperature of the acid and base solutions every 30 seconds for 3 minutes. If the temperature of either solution is changing continue taking measurements of the two solutions until they have reached a constant temperature. Record these values in the proper spaces on your data sheet.
7. Quickly and carefully, while stirring, pour the base solution into acid solution. Note the time on your data sheet when mixing occurred.
8. Continue to stir the solution while taking time-temperature readings every 30 seconds for 12 minutes.
9. When data collection is complete, the solution may be poured down the drain with an excess of water.
10. Repeat the complete procedure two more times for a total of three trials. Make sure to rinse and dry the cups between trials.

Waste Disposal

Pour all solutions down the sink with an excess of water.

Clean-Up

Wash all glassware with soap then rinse 3 times with tap water, and once with deionized water.

Calculations*: Show all work for calculations on Page 7.*

- Prepare a graph of temperature vs. time for each of your trials. See Figure 1 below for an example.
- Using your graph, draw a best-fit line through all data points prior to mixing, and read this temperature value. This temperature is the initial temperature of the reactants. See Figure 2.
- Using your graph, determine the maximum temperature of the reactants. This value must be extrapolated. First draw a vertical line at the time of mixing. Then, draw a best-fit line through all data points after the time of mixing. The temperature where the best-fit line crosses the vertical mixing line is the maximum temperature of the mixture. See Figure 2.
- Calculate the heat transferred using the average initial temperature of reactants, the maximum temperature of the mixture, and the mass and specific heat of the solution. Assume a density of 1.040 g/mL and a specific heat of 4.017 J/g ^{o}C for the reaction mixture.

Heat of Neutralization

- Calculate the number of moles of the limiting reagent using its concentration and volume. Use this value and the heat transferred to calculate the Heat (or enthalpy) of neutralization for the reaction of 1 mole of HCl with 1 mole of NaOH.

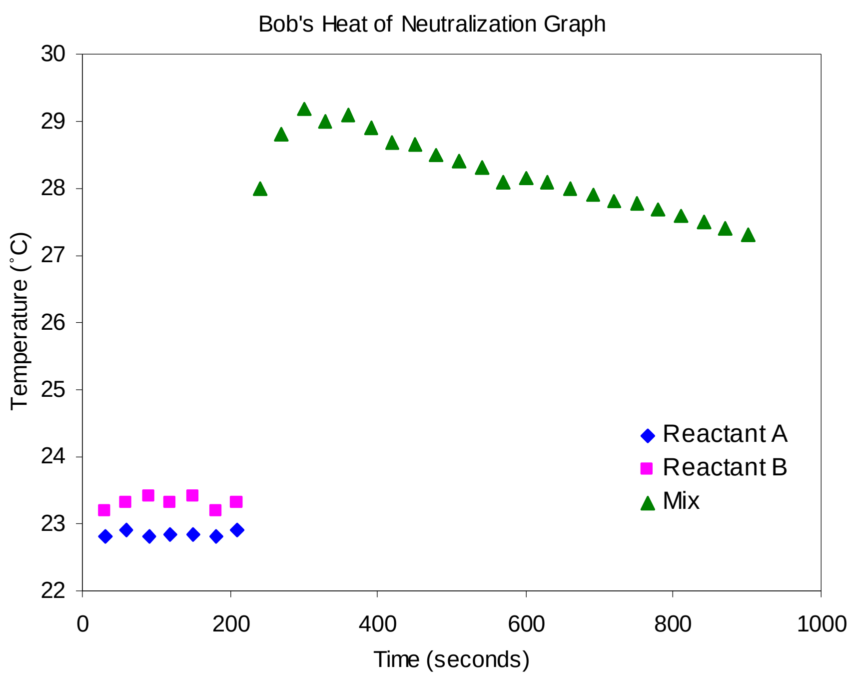

Figure 1: Sample time vs. temperature graph

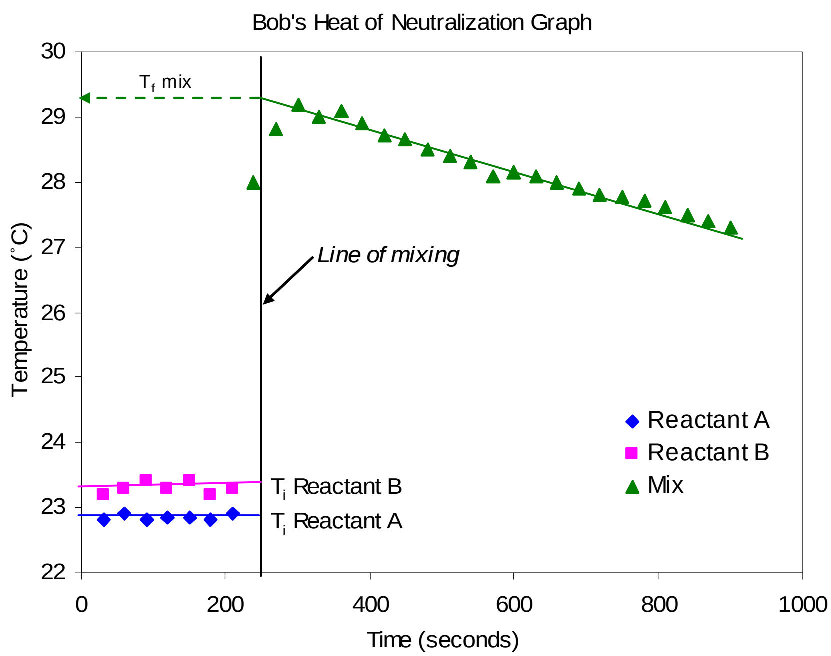

Figure 2: Labeled Sample time vs. temperature graph

Heat of Neutralization

Calculations:

Heat of Neutralization

Data Sheet

Name: ___________________________________ **Lab Partner:** _______________________________

Trial 1				
Clock Time	**TIME (s)**	**Temperature of Acid**	**Temperature of Base**	**Temperature of Mixture**
MIX				

Trial 2				
Clock Time	**TIME (s)**	**Temperature of Acid**	**Temperature of Base**	**Temperature of Mixture**
MIX				

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Trial 3				
Clock Time	TIME (s)	Temperature of Acid	Temperature of Base	Temperature of Mixture
MIX				

Heat of Neutralization

Molarity of HCl used			
Molarity of NaOH used			
	TRIAL 1	**TRIAL 2**	**TRIAL 3**
Volume of HCl			
Volume of NaOH			
Moles of HCl			
Moles of NaOH			
Limiting Reagent			
Initial Temperature of HCl (T_i) *(extrapolated from graph)*			
Initial Temperature of NaOH (T_i) *(extrapolated from graph)*			
Average Temperature of Reactants			
Final Temperature (T_f) *(extrapolated from graph)*			
Temperature Change			
Heat Transferred (kJ)			
Heat of Neutralization (kJ/mol)			
Average Heat of Neutralization			
Literature Value			
Percent Error			

Heat of Neutralization

Post-lab Assignment

Name: ______________________________

1. Calculate the percent error in your ΔH_n calculation using the reference value you found in your pre-lab.

2. Was your calculated value higher or lower than expected?

3. Provide some sources of the error in your measurement based on your answer to Question 2.

4. What changes can be made to the procedure to improve the results? Suggest at least two possible changes.

Heat of Neutralization

Pre-lab Assignment

Name: ________________________________

1. Write the balanced molecular, total ionic and net ionic equation for the neutralization reaction between hydrochloric acid and sodium hydroxide.

2. Using a reference source, find the heat of reaction for the neutralization reaction between hydrochloric acid and sodium hydroxide. Cite your source. Also enter this value in its appropriate space on your data sheets.

3. A student followed the procedure in this experiment, using 50.00 mL of 1.00 M HCl and 51.00 mL of 1.00 M NaOH both solutions having an initial temperature of 25.5 ^{o}C. After mixing, a maximum temperature of 32.2 ^{o}C is measured. For this problem, assume the density of the solution is 1.03 g/mL and its specific heat is 4.18 J/g ^{o}C. Calculate the enthalpy change for the neutralization reaction. Calculate the experimental error compared to the accepted your value in question 2.