Experiment III

Energy Changes in Chemical Reactions

Introduction

Thermochemistry is a branch of chemistry that studies heat changes in a chemical reaction. Heat changes involved in a reaction can be measured by simplify some of the reaction system and reaction surrounding parameters. In this experiment, the heat changes are studied in a constant pressures and only involves solid- and liquid-phase substances (volume changes can be neglected). Therefore, the work relating to the reaction system ($w = \boldsymbol{P}\ \Delta\boldsymbol{V}$), can be ignored. Based on the first law of thermodynamics, the internal energy changes, $\boldsymbol{\Delta E}$, which accompanies the reaction in this kind of experimental conditions is same as the reaction enthalpy changes, $\boldsymbol{\Delta H_{rx}}$. Besides the law of Conservation of Energy, the Principles of Black – the released heat equals to the absorbed heat – can also be used to solve problems in this experiment. Through simplification of various reaction parameters, heat changes resulted from a chemical reaction in a calorimeter can easily determined by measuring the temperature changes within a reaction mixture.

In this experiment, we will determine the released of heat that comes from acid-base neutralization reaction between hydrochloric acid (HCl) and sodium hydroxide (NaOH) in two different conditions:

$$HCl_{(aq)} + NaOH_{(aq)} \rightarrow NaCl_{(aq)} + H_2O_{(l)} \qquad \Delta H_{rx1} = ?$$

$$HCl_{(aq)} + NaOH_{(s)} \rightarrow NaCl_{(aq)} + H_2O_{(l)} \qquad \Delta H_{rx2} = ?$$

The enthalpy of solution reaction of sodium hydroxide, $NaOH_{(s)}$, in the water will also be determined in this experiment,

$$NaOH_{(s)} \rightarrow NaOH_{(aq)} \qquad \Delta H_{rx3} = ?$$

Determination of heat changes in those three reactions can be calculated using the Hess's Law. Hess's Law states that *the enthalpy changes of a whole process is the sum of the enthalpy changes of each reaction stage* or in other words, the enthalpy of a chemical reaction is independent of the path taken from the initial to the final state. Note that when we sum up the third reaction with the first reaction, we will get the second reaction. In consequence, when the concentration of NaOH and HCl solution is controlled to be equally large in all of the three reactions, it can be stated that:

$$\Delta H_{rx1} + \Delta H_{rx3} = \Delta H_{rx2}$$

To determine the value of ΔH_{rx1}, ΔH_{rx2}, and ΔH_{rx3}, in this experiment we will use a simple calorimeter made of styrofoam cup. The styrofoam cup is closed using a punched-stryrofoam-cap with a thermometer and stirrer rod into the styrofoam cup. Styrofoam is a good insulator, although some heat would be absorbed by the styrofoam and some would be released to the surrounding, its value is quite small compared to the amount of heat absorbed by the solution inside the calorimeter. Consequently, in this experiment, we assume that there is no heat absorbed by styrofoam cup, styrofoam cap, thermometer, stirrer rod, and the surrounding of the styrofoam cup. The other types of calorimeter can also be used to determine the amount of the reaction heat involved in acid-base neutralization reaction.

(EXPLANATION OF THE CALCULATION WILL BE GIVEN BY THE ASSISTANT DURING THE EXPERIMENT)

Chemicals and Equipment

The chemicals required in this experiment are listed below:

HCl 2M, NaOH 2M, solid NaOH, Demineralized water. **Watch Out! Solid NaOH are hygroscopic and can cause skin irritation**

The equipment needed in this experiment are listed below:

Simple calorimeter, stopwatch, rod stirrer, analytical balance, test tubes, Erlenmeyer flask, 50 ml measuring cup, 50 mL/100 mL beaker glass, thermometer.

Procedures

Determining Calorimeter's Constant

a. Heat at least 30 mL of tap water in a beaker glass on a hotplate until it reaches ±60^{o}C.
b. Add 25 mL of cold tap water into the calorimeter, then measure its temperature.
c. Take 25 mL hot water, then measure its temperature after it has been poured.
d. Cool the thermometer by dipping it into cold water.
e. Mix the hot water with the cold one within the calorimeter, then close the lid. At the same time, start measuring elapsed time using stopwatch.
f. Shake the calorimeter gently, careful not to spill its content. Measure the temperature of the water inside every 10 seconds for 90 seconds, then continue taking note at 30 seconds interval for a total of 5 minutes.
g. Determine the maximum temperature obtained, then calculate calorimeter's constant using the following equation:

$$q_{released} = q_{absorbed}$$
$$m_h \times c_w \times (T_h - T) = m_l \times c_w \times (T - T_l) + C \times (T - T_l)$$

m_h = mass of hot water
m_d = mass of cold water
T_h = temperature of hot water
T_d = temperature of cold water
T = maximum temperature measured
c_w = specific heat of liquid water

PART A

Section A.1: Determination of the Heat of Neutralization Reaction: $HCl_{(aq)}$ + $NaOH_{(aq)}$

a. Prepare a styrofoam cup that will be used as calorimeter.
b. Pour 25 mL of 2M HCl into the calorimeter and close the calorimeter using the calorimeter cap that has been mounted with thermometer.
c. Take 25 mL of 2M NaOH solution and put the NaOH solution into a 50 mL beaker glass.
d. Measure the temperature of each of the solution.
e. Turn on the stopwatch. At t = 0 seconds, transfer the NaOH solution into the calorimeter containing 25 ml of HCl 2M immediately, then close the calorimeter immediately (thermometer has been mounted through the cap).
f. Stir the HCl and NaOH mixture, until it is well-mixed.
g. Measure the temperature of the solution at t = 30 seconds.
h. Stir the mixture and measure the temperature of the solution in the calorimeter every 30 seconds, until maximum temperature is obtained and the temperature is relatively constant or decreases slowly and then relatively constant.
i. Calculate the moles of each reagent (HCl and NaOH) and the products.
j. Calculate the heat of the neutralization reaction per mole for the occured reaction.

Section A.2: Determination of the Heat of Neutralization Reaction: $HCl_{(aq)}$ + $NaOH_{(s)}$

a. Mix 30 mL of 2M HCl with 20 mL of demineralized water in calorimeter. Measure and record the temperature of the solution.
b. Weigh 6.00 g of solid NaOH.
c. Turn on the stopwatch. At t = 0 seconds, immediately pour the solid NaOH into the calorimeter using a spatula. **Watch Out! Solid NaOH are hygroscopic and can cause skin irritation.**
d. Stir the mixture until it is well-mixed.
e. Measure the temperature of the solution at t = 30 seconds.
f. Stir the mixture and measure the temperature of the solution in the calorimeter every 30 seconds, until maximum temperature is obtained and the temperature is relatively constant or decreases slowly and then relatively constant.

g. Calculate the moles of each reagent (HCl and NaOH) and identify which reagent that acts as the limiting reagent.
h. Calculate the moles of the obtained product.
i. Calculate the heat of the neutralization reaction per mole for the occured reaction.

Section A.3: Determination of the Heat of Solution: $NaOH_{(s)} \rightarrow NaOH_{(aq)}$

a. Prepare 50 mL of demineralized water inside a calorimeter. Measure and record the temperature.
b. Weigh 6.00 g of solid NaOH.
c. Turn on the stopwatch. At t = 0 seconds, immediately transfer the solid NaOH into the calorimeter.
d. Stir the mixture until it is well-mixed.
e. Measure the temperature of the solution at t = 30 seconds.
f. Stir the mixture and measure the temperature of the solution in the calorimeter every 30 seconds, until maximum temperature is obtained and the temperature is relatively constant or decreases slowly and then relatively constant.
g. Calculate the heat of solution per mole of solid NaOH in water. Use the calculation in section (A.1) and (A.2) to calculate the heat of solution (use Hess's Law).

PART B. Energy Changes in Chemical Reactions: exothermic and endothermic reactions

a. Coat the bottom (outer part) of a test tube using silicon grease and stick a few grains of solid iodine (I_2) on it.
b. Put some solid $CuSO_4$ into the test tube.
c. Place the test tube in an erlenmeyer flask.
d. Add a few drops of water into the test tube until all of the $CuSO_4$ become soaked. Immediately close the test tube with a cork/rubber cap. Observe and record the phenomenon!

DATA PROCESSING

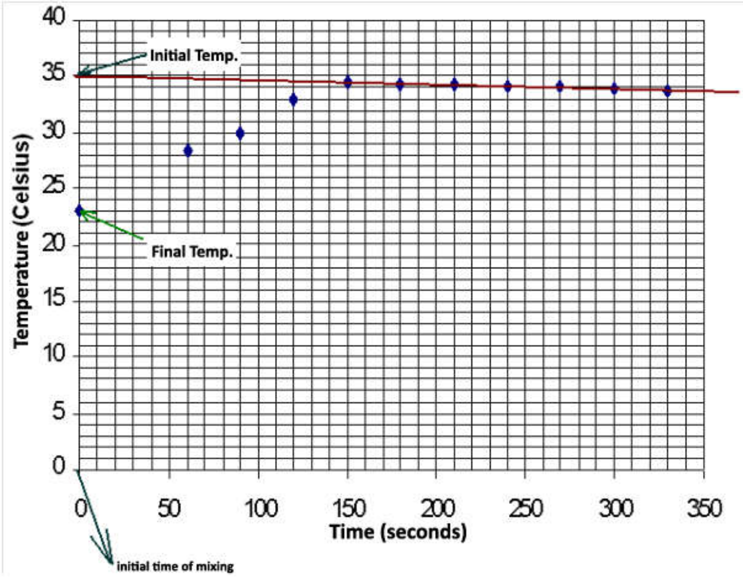
Part A.

Follow these steps to process the acquired data for section A.1-A.3:

a. Plot the T (temperature, ° C) changes to t (time, seconds) for each reaction (A.1-A.3).
b. Indicate the initial temperature and the final temperature for each of the above reactions, as shown in Figure 4.1.
c. Calculate the difference in temperature (ΔT) for each of the above reaction.
d. Calculate the heat absorbed by the calorimeter, q_1.
e. Calculate the heat absorbed by the solution, q_2.

f. Calculate the heat produced in the reaction, q_3 ($q_3 = q_1 + q_2$).

g. Calculate the reaction enthalpy per mole, ΔH (ΔH = q_3 / mol substances involved in the reaction).



Please bring them together:

- Lab Journal
- Long sleeve lab coat
- Graphical paper
- Goggle
- Calculator
- Ruler
- A rag/ tissue