

Calorimetry and the Determination of the Enthalpy Change of a Reaction

Experimental Overview

The purpose of this experiment is to determine the enthalpy change, ΔH for an acid-base reaction. Acid-base neutralizations are exothermic. Combining solutions containing an acid and a base results in a rise of solution temperature. The heat given off by the reaction is calculated using the equation

$$q = (\text{grams of solution})(\text{specific heat of solution})(\Delta T)$$

When measuring the heat transfers for exothermic reactions using a calorimeter, most of the heat released is absorbed by the solution. A small amount of this heat will be absorbed by the calorimeter itself. The heat change for the reaction thus becomes

$$q_{\text{rxn}} = -(q_{\text{solution}} + q_{\text{calorimeter}})$$

Typically, the specific heat ($J/^{\circ}\text{C}$) of the calorimeter is determined experimentally, as it will be in this experiment.

Materials Needed

HCl, 2.0 M, 100ml

NaOH, 2.0 M, 100ml

Calorimeter with lid

(1) 250 ml beaker

50 ml or 100 ml graduated cylinder

Digital thermometer

(1) 400 ml beaker

Distilled water

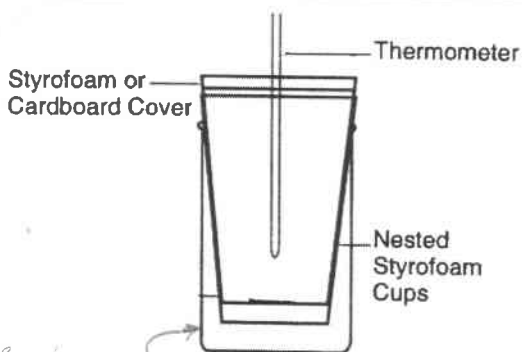
Safety Precautions

HCl solution is toxic by ingestion or inhalation; it is severely corrosive to skin and eyes. The NaOH solution is severely corrosive to skin and eyes. Wear chemical splash goggles. Wash hand thoroughly with soap and water before leaving the lab

Procedures

Part 1. Determine the Heat Capacity of the Calorimeter

1. Set up the calorimeter using a beaker and a Styrofoam cup with a cover having a hole in it to accept a thermometer.



2. Measure 50.0 ml of distilled water in a 50 ml or 100 ml graduated cylinder and transfer the water into the calorimeter.

3. Measure and record the temperature of the water.

- Heat approximately 75 ml of distilled water to about 70°C in a 250 ml beaker.
- Measure 50.0 ml of the 70°C water in a graduated cylinder.
- Measure and record the temperature of the hot water.
- Immediately pour the hot water into the room temperature water in the calorimeter.
- Cover the calorimeter, insert the thermometer (do not let the thermometer probe poke the bottom of the Styrofoam cup!!).
- After 5 seconds, record the temperature.
- Empty the calorimeter and dry the inside of the calorimeter when finished

Part 2. Determine the Heat of a Reaction: $\text{HCl (aq)} + \text{NaOH (aq)} \rightarrow \text{NaCl (aq)} + \text{H}_2\text{O (l)}$

NOTE: Do not heat either the acid or base solutions for this part of the lab. Further, do not let the digital thermometer drop all the way into the acid or base solutions.

- Measure 50.0 ml of a 2.0 M HCl solution in a graduated cylinder and transfer to the calorimeter.
- Record the temperature of the HCl solution.
- Rinse the graduated cylinder with tap and then distilled water (or use a separate graduated cylinder).
- Measure 50.0 ml of a 2.0 M NaOH solution in the graduated cylinder.
- Record the temperature of the NaOH solution.
- Quickly add the 50.0 ml of 2.0 NaOH to the calorimeter, cover, and insert the thermometer. (do not let the thermometer probe poke the bottom of the Styrofoam cup!!).
- Record the temperature after 5 seconds.

Clean up: Flush solutions down the drain with plenty of water. Rinse all glassware with tap water twice. Rinse the *tip* of the thermometer probe with tap water. Return thermometers, Styrofoam cups, and lids to your teacher.

Copy these tables:

Part 1: Determination of Heat Capacity of the Calorimeter

T_i (water room temp)	
T_i (water heated)	
T_i (average)	
T_f (mixed)	
q_{cal} (J)	
C_{cal} (J/°C)	

Part 2: Determination of Heat of Reaction

T_i (NaOH)	
T_i (HCl)	
T_i (average)	
T_f (mixed)	
q_{rxn} (J)	
ΔH_{rxn} (kJ/mol)	

Calculations

Part 1. Determine the Heat Capacity of the Calorimeter

1. Calculate the average initial temperature, T_i (average) of the hot and cold water.
2. The difference between T_i (average) and T_f (mixed) is due to the heat lost by the water and absorbed by the calorimeter. The heat lost by the water q_{water} , is:

$$q_{\text{water}} = (\text{grams of water})(\text{specific heat of water})(\Delta T_{\text{water}})$$

where $\Delta T_{\text{water}} = T_f$ (mixed) – T_i (average), and the specific heat of water is $4.18 \text{ J}/(\text{g} \cdot ^\circ\text{C})$.

The heat gained by the calorimeter, q_{cal} is equal to the heat lost by the water, but *opposite in sign*. Use the above equation to calculate the q_{cal} for the calorimeter.

3. Calculate the heat capacity of the calorimeter, C_{cal} . This is equal to the heat the calorimeter absorbs when 100ml of solution changes 1°C .

$$C_{\text{cal}} = q_{\text{cal}} / (T_{f(\text{mixed})} - T_{i(\text{water room temp})})$$

Part 2. Determine the Heat of a Reaction: $\text{HCl}(\text{aq}) + \text{NaOH}(\text{aq}) \rightarrow \text{NaCl}(\text{aq}) + \text{H}_2\text{O}(\text{l})$

1. Calculate the amount of heat evolved in the reaction, q_{rxn} . If it is assumed that all the heat of reaction is absorbed by the solution and the calorimeter, then:

$$q_{\text{rxn}} = - [(\text{grams of solution})(\text{specific heat of solution})(\Delta T_{\text{solution}}) + (C_{\text{cal}})(\Delta T_{\text{solution}})]$$

where $\Delta T_{\text{solution}} = T_f$ (mixed) – T_i (average). Assume the density of the final solution is 1.03 g/ml . This means that 103 grams of solution was used (50 ml + 50 ml). Also assume that the specific heat of the solution is $4.18 \text{ J}/(\text{g} \cdot ^\circ\text{C})$.

2. Calculate the enthalpy change, ΔH_{rxn} , in terms of kJ/mol , for the reaction. (Hint: you used 0.1 mol of each reaction: (0.050 L)(2.0M)).

Post-Lab Questions

1. What is meant by calorimetry? (look it up)
2. The equation for calculating the heat *evolved* in the reaction is:

$$q_{\text{rxn}} = - [(\text{grams of solution})(\text{specific heat of solution})(\Delta T_{\text{solution}}) + (C_{\text{cal}})(\Delta T_{\text{solution}})]$$

What is the meaning of the negative sign in front of the brackets?

3. The *net* ionic equation for the reaction is $\text{H}^+ + \text{OH}^- \rightarrow \text{H}_2\text{O}$. Using the values for the standard heats of formation in your textbook (appendix 3), calculate ΔH_{rxn} for this reaction (Hess's Law).

Name: _____ Period: _____

Rubric for Grading Lab
Enthalpy Change of a Reaction

Points Earned	Points Possible	
	2	Lab is listed with page number in Table of Contents
		The following are copied neatly and completely and with a heading
	2	Title
	3	Experimental Overview
	2	Materials Needed
	5	Part 1 Data Table: Completely filled out (Heat Capacity of Calorimeter)
	5	Part 2 Data Table: Completely filled out (Heats of Reaction)
		Calculations
	2	Calculation showing T_{average}
	3	Calculations showing heat gained by calorimeter (in joules)
	3	Calculations showing heat capacity of calorimeter ($J/^{\circ}C$)
	3	Calculations showing q_{rxn}
	3	Calculations showing ΔH_{rxn} (kJ/mole)
	6	Acceptable experimental value for ΔH_{rxn}
		Post-Lab Questions
	2	Question 1 answered correctly
	2	Question 2 answered correctly
	4	Question 3 showing Hess's Law calculation for reaction
	3	Question 3 correct value and units
	5	Neatness
	55	Total Points

Grader's Initials: _____