

# **Thermochemistry**

## Chem 111 Laboratory Experiment

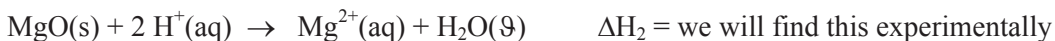
### **Part I.**

#### **Introduction**

The purpose of Part 1 of this experiment is to determine the enthalpy of formation of a compound, magnesium oxide, MgO. The formation reaction is,



To determine this, we will perform two reactions and measure their enthalpy change using calorimetry.

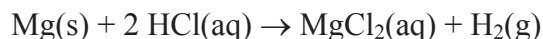


Once the three values,  $\Delta H_1$ ,  $\Delta H_2$  and  $\Delta H_3$ , are obtained, Hess's Law can be used to combine those values such that the desired heat of formation can be calculated.

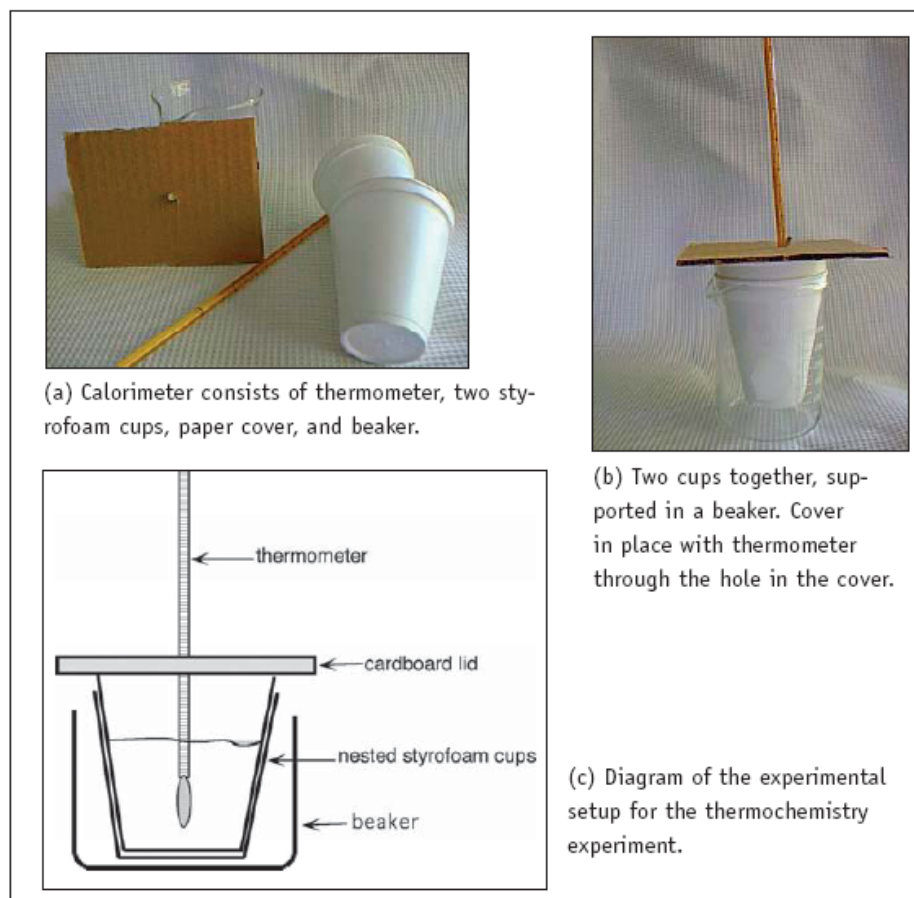
#### **EXPERIMENTAL PROCEDURE**

##### **PART Ia. Determining $\Delta H_1$ and the Relation Between the Quantity of Material Reacting and the Heat Transferred**

In this portion of the experiment we want to explore the relationship between the quantity of magnesium metal reacting with hydrochloric acid and the heat evolved by the reaction.



- (a) Set up your coffee-cup calorimeter and support it in a ring stand or beaker as illustrated by your instructor and in the Figure.
- (b) Weigh out, to the nearest 0.001 g, three different portions of magnesium metal, say about 0.2 g, about 0.4 g, and about 0.5 g. Record the masses in the data table on the report form.
- (c) Place one of the magnesium samples in a clean, dry coffee-cup calorimeter.



**Figure** Equipment and setup for the thermochemistry experiment.

- (d) Using a graduated cylinder, measure out as accurately as possible 100.mL of 1.0 M HCl. Measure the temperature of the HCl solution and record this initial temperature on the report form. Replace the thermometer in the calorimeter setup.
- (e) Add the HCl solution to the calorimeter and swirl gently but steadily. At 30 second intervals record the temperature (to the nearest 0.5 °C) until the temperature has held constant or decreased for three consecutive readings.
- (f) Repeat the steps above with another sample of Mg. Do all three samples, making sure the calorimeter is clean and dry each time.
- (g) In each case, determine  $\Delta T$ , the change in temperature between the temperature of the HCl solution before adding it to the magnesium and the maximum temperature of the reacting system. If you were to plot the temperature of the reacting system versus time, you would see something like that illustrated here.

## **PART Ib: Determining $\Delta H_2$ : Heat of Reaction of Magnesium Oxide with Hydrochloric Acid**

- (a) Set up the calorimeter as in PART I. Make sure it is clean and dry.
- (b) Weigh out about 0.7 g of MgO to the nearest 0.001 g and place the powder in the calorimeter.
- (c) Repeat steps (d) and (e) as in PART I above with another sample of magnesium oxide.

### **Calculations and Report**

In each reaction, we will assume that the calorimeter absorbs no heat. Therefore, the amount of heat energy released is determined by the temperature rise of the solution. Each solution is dilute, so we will assume that they have a specific heat capacity of 4.18 J/g $\cdot$ °C and a density of 1.00 g/mL.

Use the equation,

$$\# J = \text{Specific heat capacity} \times \text{mass (g)} \times \Delta T$$

to determine the quantity of heat released. Then, using this and the number of moles of compound reacting, determine the value of  $\Delta H$  for each reaction.

$$\Delta H = \frac{\# J}{\# \text{ moles}}$$

Remember that if heat is released, then  $\Delta H$  must be a negative value.

**Report** the value of  $\Delta H$  for each reaction.

Use the three reactions performed in Part 1 to verify if the amount of heat released is proportional to the number of moles of compound reacting. **Report** on whether this is true.

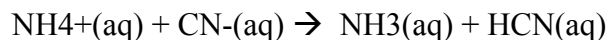
Use the  $\Delta H$  values determined experimentally as well as that for formation of H<sub>2</sub>O liquid to calculate the value of  $\Delta H$  of formation for MgO(s). To do so, you must find a way of combining the three reactions for which you know  $\Delta H$  so that they add up to give the reaction of interest. Remember that you can reverse reactions (and then must switch the sign of  $\Delta H$ ) or multiply reactions by a constant (and then must multiply the  $\Delta H$  by that same constant). Report how you do this calculation and the final value of the heat of formation of MgO(s).

## Part II.

Exploring the heat of neutralization of acids and bases.

### Introduction

All acid-base reactions involve the same basic step: the transfer of an  $H^+$  ion (which is just a proton) from the acid to the base. An example is the reaction between  $NH_4^+$  and  $CN^-$  ions.



In this case the ammonium ion,  $NH_4^+$ , is the acid and cyanide ion ( $CN^-$ ) is the base.

In this experiment you will perform reactions between the following two acids and bases:

#### Acids

hydrochloric (HCl)

Acetic ( $CH_3CO_2H$ )

#### Bases

ammonia ( $NH_3$ )

sodium hydroxide (NaOH)

You will react each acid with each base, so you will perform four reactions.

### Procedure

Similarly to Part I, pour 25 mL of the acid (measured with a graduated cylinder) into the Styrofoam cup and measure its temperature. Add 25 mL of the base solution, place the lid with thermometer on top, stir, and measure the temperature change.

### Calculations

Calculate the enthalpy change for each reaction in terms of kJ/mol.

### Report

Report the four enthalpy changes you determine and explain the trends you see in terms of the strengths of the acids and bases used.