

## CALORIMETRY

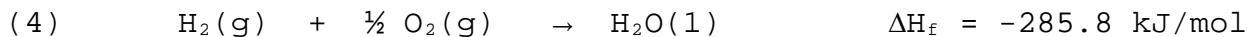
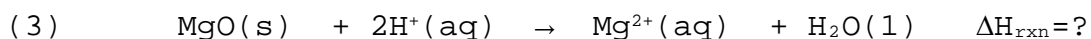
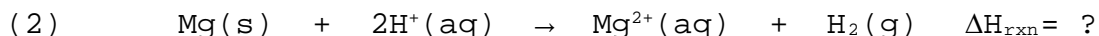
### INTRODUCTION

The heat evolved by a chemical reaction can be determined using a calorimeter. The transfer of heat or flow of heat is expressed as the change in Enthalpy of a reaction,  $\Delta H$ , at constant pressure. In today's laboratory you will be determining the Enthalpy of neutralization as well as the enthalpy of formation of MgO. Styrofoam cups will be used to construct a calorimeter because Styrofoam has good insulating properties.

The enthalpy of neutralization will be determined from the reaction of a strong acid (HCl) and a Strong Base (NaOH).  
The enthalpy of formation of MgO(s):



Will be calculated by experimental, determining the enthalpy changes for the reactions of magnesium metal and magnesium oxide with acid and the known enthalpy of formation of liquid water (-285.8 kJ/mol.) (See equations. 2-4)



The heat  $q$ , absorbed or released will be determined by running the reactions in calorimeters and measuring the temperature change ( $\Delta T$ ) as the reaction proceeds.

(5)  $q$  evolved by the reaction =  $q$  gained by the solution +  $q$  gained by the calorimeter

**\*Note:** the heat gained by the calorimeter  $q_{\text{calorimeter}}$ , is negligible.

$$(6) \quad -q_{\text{rxn}} = [m C_p \Delta T_{\text{soln}}] + [m C_p \Delta T]_{\text{calorimeter}}$$

where  $m$  = mass (in grams) of the solution  
 $C_p$  = heat capacity (in J/g- °C) at constant pressure  
 $\Delta T$  = change in temperature in degrees Celsius

In this experiment we will assume that the heat gained by the calorimeter is negligible and, therefore, the heat evolved by the reaction can be calculated from the temperature change of the solution alone:

$$(7) \quad -q \text{ heat lost by the rxn} = q \text{ heat gained by the H}_2\text{O}$$

Since we are trying to determine the molar enthalpies of Mg and MgO reactions with acid, it is important that Mg and MgO be limiting reagents in their reactions with acid. Then  $q_{\text{rxn}}$  can be converted to molar enthalpy by calculating the moles of metal consumed in the reaction.

$$(8) \quad \Delta H_{\text{rxn}} = \frac{-q_{\text{rxn}}}{(\text{moles of Mg})}$$

$$\Delta H_{\text{xn}} = \frac{-q_{\text{rxn}}}{(\text{moles of MgO})}$$

**SAFETY:**

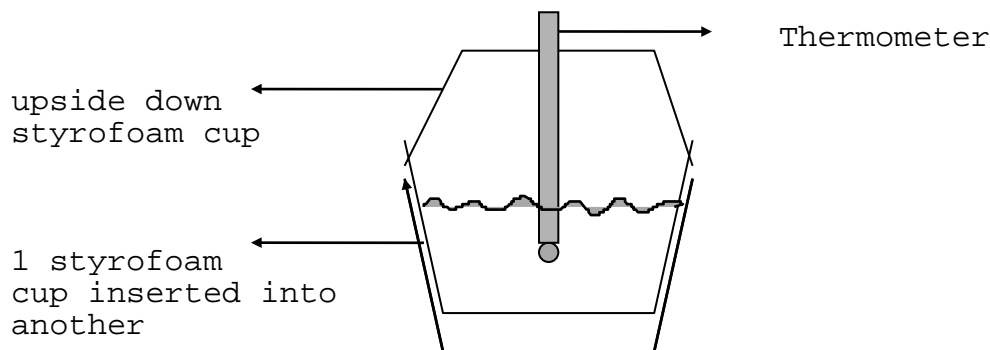
Dilute hydrochloric acid (HCl), nitric acid (HNO<sub>3</sub>) and sodium hydroxide (NaOH) can harm eyes, skin, and clothing. Handle with care. Any acid or base spilled on the skin or splashed into your eyes must be rinsed with a large volume of water.

**DISPOSAL:**

Dispose of the Magnesium reaction mixtures in the waste container: Magnesium mixtures waste

**PROCEDURE**

**A. Construct a calorimeter using 3 Styrofoam cups (located on the side bench) as shown below:**



Check the stockroom.

**B. The Reaction of HCl and NaOH**

1. 100mL graduate cylinder 25.0 ml of 0.5M HCl into the Styrofoam cup. Measure and record its temperature. Add 25.0 ml of 1.0 M NaOH into a clean and dry 150 ml beaker. Measure and record its temperature. The two temperatures should not differ by more than 2 degree Celsius.
2. Carefully add the 1.0 M NaOH solution to the HCl in the Styrofoam cup. Quickly place the lid on the Styrofoam cup. Read the temperature and record the maximum temperature.
3. Repeat the HCl + NaOH procedure for a second trial

**C. Enthalpy of Reaction for Mg(s) + 2H<sup>+</sup>(aq)**

1. Weigh about 0.4g of Mg metal (on weighing paper). Record weight to the nearest milligram.
2. Add 100-mL of 0.5 M(aq)HCl solution to the calorimeter. Record its temperature. Now add the magnesium metal to the calorimeter and stir the solution.
3. Read the temperature and record the maximum temperature.

**D. Enthalpy of Reaction for MgO(s) + 2H<sup>+</sup>(aq)**

1. Repeat the same steps as in procedure C (including re-measuring the temperature of the acid solution).
2. Use about 0.7g of powdered MgO weighed to the nearest milligram (instead of 0.4g of Mg metal). Note: MgO powder is "sticky." To prevent any loss of MgO, add BOTH solid MgO and weighing paper to the calorimeter making sure all the MgO dissolves. Assume the heat capacity ( $C_p$ ) of the paper is negligible.

# Laboratory Book

Title

**Purpose:**

**Equations:**

**Safety:**

**Disposal:**

**Materials and Equipment Table:**

**Procedure:**

**Data:**

Molarity of HCl\_\_\_\_\_

Molarity of NaOH\_\_\_\_\_

## I. Reaction of HCl + NaOH

	Trial 1	Trial 2
Volume of HCl		
Initial temperature of HCl		
Volume of NaOH		
Initial temperature of NaOH		
Maximum temperature		

II.  $\Delta H_f$  for  $MgO$

a. Reaction for  $Mg(s) + 2H^+(aq)$

	Trial 1	Trial 2
Volume of HCl		
Initial temperature of HCl		
Grams of Mg		
Maximum temperature		

b. Reaction for  $MgO(s) + 2H^+(aq)$

	Trial 1	Trial 2
Volume of HCl		
Initial temperature of HCl		
Grams of MgO		
Maximum temperature		

## Calculations:

### I. Reaction of HCl + NaOH

- Average NaOH and HCl initial temperature
- Change in temperature
- Mass of final mixture
- Heat evolved during reaction
- Moles of water formed
- $\Delta H$  of neutralization (Heat evolved per mole of H<sub>2</sub>O, KJ/mol) for each trial
- Average  $\Delta H_{\text{neutralization}}$

### II.

- Use  $\Delta T$  to compute  $q_{\text{rxn}}$  (in kJ/gram) and  $\Delta H_{\text{rxn}}$  (in kJ/mol) for each reaction. Assume the following: the heat gained by the styrofoam calorimeter is negligible and can be excluded from the calculations; the density of the solution is 1.00 g/mL; the heat capacity of the solution is 4.18 J/g-°; and the volume of the solution is 100mL.
- Using  $\Delta H_f$  for water, and Hess' Law, compute  $\Delta H_f$  for MgO.
- Using the  $\Delta H_f$  value for MgO found in the appendix of your textbook as the "true value," calculate the percent error.

## Questions:

- For the following problems, assume that the volume of the final solution is 200.-mL, the density of the solution is 1.00 g/mL and the heat capacity of the solution is the same as water (4.184 J/g- degree Celsius).
  - When 0.800 g of Ca metal is added to 200-mL of 0.500 M HCl(aq) according to the method described in Procedure III a, a temperature increase of 13.0 degree Celsius is observed. What is  $\Delta H_{\text{rxn}}$  at room temperature for the reaction of  $\text{Ca(s)} + 2\text{H}^+(\text{aq})$ ?

- b) When 1.12g of CaO is added to 200-mL of 0.500 M HCl(aq) according to the method described in Procedure *III b*, a temperature increase of 4.62 degree Celsius is observed. What is  $\Delta H_{\text{rxn}}$  at room temperature for the reaction of
- $$\text{CaO}(s) + 2\text{H}^+$$
2. A student carelessly inserts the thermometer while assembling the calorimeter and a large hole is torn in the plastic lid. How will this affect his experimental results?

**Summary:**