Name _____ Date _____ Class _____

# Hess's Law

# Lab 67

## Introduction

Magnesium metal burns with a bright, extremely hot flame to produce magnesium oxide. It would be difficult to measure the heat of reaction, $\Delta H_r$, since the reaction is rapid and occurs at a high temperature. As you learned in Chapter 12, the value of $\Delta H$ for a reaction is the same whether it occurs directly or in a series of steps. This principle, known as Hess's law, allows you to calculate the enthalpy of the magnesium reaction by performing two reactions that are easier to control.

Magnesium oxide, a white powder, reacts (exothermically) with a solution of hydrochloric acid to produce magnesium chloride, liquid water, and heat. Solid magnesium metal reacts with a solution of hydrochloric acid to produce magnesium chloride, hydrogen gas, and (since this reaction is also exothermic) heat. By using the preceding two reactions and knowing the enthalpy for the formation of water ($-285.8$ kilojoules per mole of water) you will be able to calculate the change in enthalpy for the burning of magnesium in oxygen.

In this investigation, you will measure the heat released by these two reactions. From this information and your knowledge of Hess's law, you will calculate the heat of reaction for magnesium burning in air.

## Pre-Lab Discussion

*Read the entire laboratory investigation and the relevant pages of your textbook. Then answer the questions that follow.*

1. What safety procedures need to be observed when working with each of the following compounds?

   a. magnesium oxide _____

   _____

   b. magnesium chloride _____

   _____

   c. hydrochloric acid _____

   _____

2. State Hess's law in your own words. _____

   _____

   _____

Name _____

3. Write the balanced chemical equations for the three reactions described in the Introduction.

_____

_____

_____

4. What is the sign of the change in enthalpy for each of the three reactions used in this investigation? Why? _____

_____

_____

## Problem

What is the enthalpy change associated with the reaction of magnesium with oxygen to produce magnesium oxide?

## Materials

chemical splash goggles
laboratory apron
magnesium oxide (MgO)
laboratory balance
graduated cylinder, 100-mL
hydrochloric acid (HCl), 1.0 *M*
2 plastic foam cups
thermometer
cardboard cover for cup
paper towel
piece of magnesium ribbon

## Safety

Wear your goggles and lab apron at all times during the investigation. Hydrochloric acid is corrosive and should be handled with care. Wash any splashes or spills immediately with water and notify your teacher. Magnesium oxide dust is toxic if inhaled. Do all steps of the Procedure involving MgO under a fume hood. Magnesium chloride is moderately toxic if ingested. Be sure to keep your fingers and hands away from your mouth. Note the caution alert symbols here and with certain steps of the Procedure. Refer to page *xi* for the specific precautions associated with each symbol.

## Procedure

*Part A*

1. Put on your goggles and lab apron. Obtain approx. 1 g of MgO from your teacher. **CAUTION**: *Magnesium oxide is toxic. Avoid inhalation of the dust. Perform all procedural steps involving MgO in a fume hood.* Measure and record the mass of the MgO to the nearest 0.01 g.

2. Using a graduated cylinder, place 100.0 mL of 1.0 *M* HCl into a plastic foam cup. **CAUTION:** *Hydrochloric acid is corrosive. Use care when handling it. Wash spills and splashes immediately with plenty of water and notify your teacher.* Use a thermometer to measure the temperature of the HCl to the nearest 0.2°C, and record this value. Also record the volume. Place the cup inside another cup.

3. Work under a fume hood. Add the MgO to the HCl. Immediately cover the inner cup with a lid and insert a thermometer into the hole in the lid. Swirl the cup gently to mix the contents.
4. Record the highest temperature reached by the MgO/HCl mixture.

5. Dispose of the magnesium chloride solution in your cup as directed by your teacher. Rinse the cups and dry them with a paper towel.

*Part B*

6. Obtain approx. 0.5 g of Mg metal . Measure and record its mass to the nearest 0.01 g.

7. Using a graduated cylinder, place 100.0 mL of 1.0 *M* HCl into a plastic foam cup. **CAUTION:** *Hydrochloric acid is corrosive. Use care when handling it. Wash spills and splashes immediately with plenty of water and notify your teacher.* Measure and record the temperature of the HCl to the nearest 0.2°C. Also record the volume. Place the cup inside another cup.
8. Add the magnesium to the HCl. Immediately cover the inner cup with the lid and insert the thermometer into the hole in the lid. Swirl the cup gently to mix the contents.
9. Record the highest temperature reached by the Mg/HCl mixture.

10. Dispose of the magnesium chloride solution in your cup as directed by your teacher. Clean up your work area and wash your hands before leaving the laboratory.

## Observations

*Part A*

Mass of MgO _____

Volume of HCl _____

Initial temperature of HCl _____

Final temperature of MgO/HCl _____

*Part B*

Mass of Mg _____

Volume of HCl _____

Initial temperature of HCl _____

Final temperature of Mg/HCl _____

Lab 67

Name _____

## Calculations

*Part A*

1. Calculate the number of moles of MgO used.

2. Calculate the mass of the HCl solution. Assume the density of the HCl solution is the same as water (1.0 g/mL).

3. Calculate the change in temperature.

4. Calculate the amount of heat released by the reaction. Ignore the heat capacity of the $MgCl_2$, and assume the specific heat of the HCl solution is the same as water (0.00418 kJ/g•°C).

   $q = mC\Delta T$

5. Calculate the heat of reaction in kilojoules per mole of MgO.

*Part B*

6. Calculate the number of moles of Mg used.

7. Calculate the mass of the HCl solution. Assume the density is the same as water (1.0 g/mL).

8. Calculate the change in temperature.

9. Calculate the amount of heat released by the reaction.

   $q = mC\Delta T =$

10. Calculate the heat of reaction in kilojoules per mole of Mg.

## Critical Thinking: Analysis and Conclusions

1. Write the balanced thermochemical equation for the formation of one mole of liquid water from gaseous hydrogen and oxygen.

   _____

2. Based on your data, write a balanced thermochemical equation for the reaction of one mole of magnesium oxide with hydrochloric acid.

   _____

3. Based on your data, write a balanced thermochemical equation for the reaction of one mole of magnesium with hydrochloric acid.

   _____

4. Combine the three equations from Questions 1–3 so they will add to make a balanced thermochemical equation for the burning of one mole of magnesium in oxygen. You may have to reverse one or more of the equations.

_____

_____

_____

_____

5. Based on your data, calculate the change in enthalpy for the burning of magnesium in oxygen. Use the appropriate sign on your answer.

_____

6. Calculate the percent error for this investigation given the known heat of reaction is $-601.8$ kJ/mol Mg.

## Critical Thinking: Applications

1. Given the following information:

$NH_3(g) + HCl(g) \rightarrow NH_4Cl(s)$ $\quad \Delta H = -176.0$ kJ/mol

$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$ $\quad \Delta H = -92.2$ kJ/mol

$N_2(g) + 4H_2(g) + Cl_2(g) \rightarrow 2NH_4Cl(s)$ $\quad \Delta H = -628.9$ kJ/mol

calculate the $\Delta H$ for the synthesis of hydrogen chloride gas from hydrogen and chlorine gas. The equation is

$$H_2(g) + Cl_2(g) \rightarrow 2HCl(g)$$

Reversing the first two equations and multiplying the first by 2 yields:

_____

_____

_____

_____

_____

_____

2. The Calorie (note the capital C) mentioned in connection with foods is actually a kilocalorie (1000 calories). If 4.18 joules are equal to 1 calorie and a cup of ice cream releases 200 kilocalories, how many cups of ice cream release the same amount of energy as the reaction producing one mole of liquid water from its constituent gases?