Lab #11: Heats of Reaction and Hess's Law
Lab Exercise
Chemistry II
10 points
<u>USE BLUE/BLACK INK</u>!!!!

Name: ______________________________
Partner: ______________________________
Date: __________________ Hour: ________

Goal:

The goal of this lab is to determine the heat of reaction of burning magnesium by using Hess's Law.

Introduction/Background:

The reaction of magnesium metal with air in a Bunsen burner flame provides a dazzling demonstration of a combustion reaction. Magnesium burns with an intense flame that produces a blinding white light. This reaction was utilized in the early days of photography as a source of "flash powder" and later in flash bulbs. It is still used today in flares and fireworks.

Magnesium reacts with the oxygen gas in the air to form magnesium oxide in an exothermic synthesis reaction. A great deal of heat and light is produced; the temperature of a flame can reach as high as 2400 °C. The amount of heat energy produced in this reaction cannot be measured directly in a high school lab. It is possible, however, to determine the amount of heat produced by an indirect method using Hess's Law.

The heat (or enthalpy change) for a chemical reaction is called the heat of reaction (ΔH_{rxn}). The enthalpy change–defined as the difference in enthalpy between the products and reactants–is equal to the amount of heat transferred at constant pressure and does not depend on how the transformation occurs. This definition of enthalpy makes it possible to determine the heats of reaction for reactions that cannot be measured directly. According to Hess's Law, if the same overall reaction is achieved in a series of steps, rather than one step, the enthalpy change for the overall reaction is equal to the sum of the enthalpy changes for each step in the reaction series. There are two basic rules for calculating the enthalpy change for a reaction using Hess's Law:

1) Equations may be "multiplied" by multiplying each stoichiometric coefficient in the balanced chemical equation by the same factor. The heat of reaction is proportional to the amount of reactant. Thus, if an equation is multiplied by a factor of two to increase the number of moles of product produced, then the heat of reaction must also be multiplied by a factor of two.
2) Equations may be "subtracted" by reversing the reactants and products in the balanced chemical equation. The heat of reaction for the reverse reaction is equal in magnitude by opposite in sign to that of the forward reaction.

In this experiment, three equations will be combined to form the overall reaction of the combustion of magnesium:

A) the single displacement reaction of magnesium with hydrochloric acid
B) the double displacement reaction of magnesium oxide and hydrochloric acid
C) the synthesis of liquid water from hydrogen gas and oxygen gas

Research questions: (If more room is needed to answer a question, additional pages may be attached.)

1) Write and balance the equation for the single displacement reaction of hydrochloric acid reacting with magnesium:

2) Write and balance the equation for the double displacement reaction of magnesium oxide and hydrochloric acid:

3) Write and balance the equation for the synthesis of liquid water from hydrogen gas and oxygen gas:

4) Write and balance the equation for the synthesis of magnesium oxide from its elements:

5) Arrange the equations you wrote in questions 1-3 in such a way as they add up to the equation you wrote in question 4:

6) What is the definition of the heat of formation of a compound?

7) Use your textbook Appendix Table A-6 (or the *CRC Handbook*) to determine the heat of formation of liquid water from its respective elements in their standard states at 25 °C.

8) State Hess's Law:

9) How can Hess's Law be used in this lab to determine the heat of reaction of burning magnesium without actually burning any magnesium?

Materials:

60 mL 1 M hydrochloric acid	7 cm magnesium ribbon
1 ruler	1 100 mL beaker
1 permanent marker	1 25 mL graduated cylinder
0.40 g magnesium oxide	1 pair of scissors
1 test tube brush	1 small massing boat
1 balance	1 microscoop
1 microcalorimeter	1 stirring rod
1 digital thermometer	1 pair of forceps
1 piece of massing paper	1 ringstand
1 test tube clamp	1 10 mL beaker

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Hazards:

The student safety contract applies. _______________

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Procedure Part 1–Reaction of Magnesium and Hydrochloric Acid:

1) Mass the magnesium
    a) physically and chemically clean and dry the scissors and forceps
    b) obtain a 7-cm piece of magnesium ribbon using the forceps
    c) cut the magnesium ribbon into two UNEQUAL pieces using the forceps
    d) measure the two pieces of magnesium ribbon
    e) separately mass both strips of magnesium ribbon using the massing paper
2) Obtain the hydrochloric acid
    a) physically and chemically clean, dry, and label the 100 mL beaker
    b) obtain about 60 mL of hydrochloric acid in the 100 mL beaker
3) Mass a clean, dry microcalorimeter
4) Mass the hydrochloric acid
    a) physically and chemically clean and dry the 25 mL graduated cylinder
    b) measure out 15 mL of hydrochloric acid in the 25 mL graduated cylinder
    c) pour the acid into the microcalorimeter
    d) mass the calorimeter with the acid in it
5) Set up the calorimeter
    a) clamp thermometer to ringstand
    b) lower thermometer into microcalorimeter so it is not touching the bottom or the sides
6) Take the initial temperature of the hydrochloric acid in the microcalorimeter
7) Perform the reaction of Mg and HCl
    a) add the smaller piece of magnesium to the microcalorimeter
    b) stir the solution with a stirring rod until the magnesium has completely reacted and the temperature of the solution remains constant
8) Record the final temperature of the solution
9) Dispose of the microcalorimeter's contents in the waste container
10) Rinse out and dry the microcalorimeter
11) Repeat steps 3-10 for the reaction of the second (larger) piece of magnesium

Procedure Part 2–Reaction of Magnesium Oxide and Hydrochloric Acid:

1) Obtain the magnesium oxide
    a) physically clean, chemically clean, dry, and label the 10 mL beaker
    b) obtain a very small amount of magnesium oxide powder in the 10 mL beaker
2) Mass a clean, dry microcalorimeter
3) Mass the hydrochloric acid
    a) physically and chemically clean and dry the 25 mL graduated cylinder

b) measure out 15 mL of hydrochloric acid in the 25 mL graduated cylinder
c) pour the acid into the microcalorimeter
d) mass the calorimeter with the acid in it

4) Set up the calorimeter
   a) clamp thermometer to ringstand
   b) lower thermometer into microcalorimeter so it is not touching the bottom or the sides
5) Take the initial temperature of the hydrochloric acid in the microcalorimeter
6) Mass the magnesium oxide
   a) tare a small massing boat
   b) add 0.20 g of magnesium oxide to the massing boat
7) Perform the reaction of MgO and HCl
   a) add the 0.20 g of magnesium oxide to the microcalorimeter
   b) stir the reaction until the temperature stays constant for several five-second intervals
   c) record the final temperature of the solution
8) Dispose of the microcalorimeter's contents in the waste container
9) Rinse out and dry the microcalorimeter
10) Repeat steps 2-8 for a second trial of the magnesium oxide reaction
11) Clean up!

Data:

Balance # ______

	Reaction of Mg + HCl		**Reaction of MgO + HCl**	
	Trial 1	Trial 2	Trial 1	Trial 2
mass of calorimeter (g)				
mass of calorimeter + HCl (g)				
mass of solid (Mg or MgO) (g)				
initial temperature (°C)				
final temperature (°C)				

RECORD ADDITIONAL DATA ON A SEPARATE SHEET

Post-lab calculations (show work here or on a separate sheet and attach; no need for a conclusion):

1) Calculate the mass of the hydrochloric acid used in each trial

2) Calculate the total mass of the reactants for each trial

3) Calculate the change in temperature (final-initial) for each trial

4) Calculate the heat absorbed by the solution in the microcalorimeter using the the formula

$$q = m \cdot \Delta t \cdot C_p$$

Assume the mass is the total mass of the reactants and the specific heat capacity of the solution is the same as that of water.

5) Calculate the moles of magnesium and magnesium oxide in each trial.

6) Calculate the heat absorbed by the solution in kilojoules per mole for each trial

7) Average the two trials of the Mg + HCl.

8) Average the two trials of the MgO + HCl.

9) Use Hess's Law and your answers from questions 7 and 8 (and research questions 1-5) to calculate the heat of reaction for the burning of magnesium in oxygen.

10) Look of the heat of formation of magnesium oxide in the *CRC Handbook*.

11) Calculate your percent error (using your answers from questions 9 and 10).

Lab handout based on the experiment "Heat of Reaction and Hess's Law" in Flinn ChemTopic Labs (Volume 10), edited by I. Cesa (Flinn Scientific, Batavia, IL, 2002)