A Laboratory Experiment Investigating Hess's Law

Introduction:

Magnesium metal burns with a bright, extremely hot flame to produce magnesium oxide. It would be difficult to measure the heat of reaction, ΔH, since the reaction is rapid and occurs at a high temperature. As you learned in studying thermochemistry, the value of ΔH 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, water, and (since this reaction is also exothermic) heat.

Magnesium metal reacts with hydrochloric acid (exothermically) to produce $MgCl_2$ (aq), H_2 gas, and (once again) 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 the air.

Pre-Lab Questions:

1. In your own words, state the basis of Hess's law

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

3. What are the signs of the changes in enthalpy for each of the three reactions used in this investigation?

The Problem to Solve:

What is the enthalpy change associated with the reaction of magnesium and oxygen, producing magnesium oxide.

Materials:

Chemical splash goggles	2 plastic foam cups
Laboratory apron	thermometer
Magnesium oxide (MgO)	cover for cup
Laboratory balances (3 decimal places)	paper towel
Graduated cylinder, 100-mL (accuracy?)	piece of magnesium ribbon
Hydrochloric acid (HCl), 1.00M	

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 Mg) under a fume hood. Magnesium chloride is moderately toxic if ingested. Be sure to keep your fingers and hands away from your mouth.

Procedure

Part A

1. Put on your goggles and lab apron. Obtain a sample of MgO that has a mass between 1.000 and 1.500g. 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 0.001 g.
2. Using a graduated cylinder, place nearly 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 $NaHCO_3$ and notify your teacher.* Use a thermometer to measure the temperature of the HCl to the nearest 0.1^{o}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 a piece of magnesium ribbon approximately 5.0-cm long. Measure and record its mass to the nearest 0.001 g.
7. Using a graduated cylinder, place close to 100.0 mL of 1.0M HCl into a plastic foam cup. CAUTION: *Hydrochloric acid is corrosive. Use care when handling it. Wash spills and splashes immediately with plenty of $NaHCO_3$ water and notify your teacher.* Measure and record the temperature of the HCl to the nearest 0.1°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.

Data Table: (should include the following)
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

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 (0.004184 kJ/g°C).
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
10. Calculate the heat of the reaction in kilojoules per mole of Mg.

Calculations (continued)

11. Display the three balanced equations needed to solve this lab.
12. Show your Hess' Law calculation for the change in enthalpy for the burning of magnesium in oxygen. Use the appropriate sign on your answer. You may have to reverse one or more of the equations.
13. Calculate the percent error for this investigation given the known heat of reaction is –601.8 kJ/mol Mg. *(Interpreting data)*

Critical Thinking: Applications (These are post-lab questions!)

1. Given the following information:
   $NH_3(g) + HCl(g) \rightarrow NH_4Cl(s)$ ΔH= -176.0 kJ/mol
   $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$ ΔH= - 92.2 kJ/mol
   $N_2(g) + 4H_2(g) + Cl_2(g) \rightarrow 2NH_4Cl(s)$ ΔH= - 628.9 kJ/ mol

   Calculate the ΔH for the synthesis of hydrogen chloride gas from hydrogen and chlorine gas. The equation is
   $H_2(g) + Cl_2(g) \rightarrow 2HCl(g)$ *(Applying concepts)*
2. The Calorie (note the capital C) mentioned in connection with foods is actually a kilocalorie (1000 calories). If 4.184 joules are equal to 1 calorie and a cup of ice cream contains 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? *(Applying concepts)*