Experimental Applications of Hess's Law
Student Handout

Purpose:

The purpose of this lab is to use Hess's law to determine the heat of reaction for reactions whose energy cannot be easily measured directly.

Background:

There are many reactions for which the heat of reaction cannot be easily measured experimentally. Some of these are dangerous to perform in the lab. Others generate so much heat that simple calorimeters cannot be used. In such cases, it is practical to examine a series of reactions whose net effect is the desired reaction, but whose heats of reaction are more easily measured. Once that has been done, the required heat of reaction can be calculated using Hess's Law.

In the first investigation, the combustion of magnesium is examined.
The burning of magnesium can be represented by the equation:

$$Mg_{(s)} + \tfrac{1}{2} O_{2(g)} \rightarrow MgO_{(s)}$$

The above equation can be obtained by manipulating the three reactions shown below:

1. $MgO_{(s)} + 2\,HCl_{(aq)} \rightarrow MgCl_{2(aq)} + H_2O_{(l)}$
2. $Mg_{(s)} + 2\,HCl_{(aq)} \rightarrow MgCl_{2(aq)} + H_{2(g)}$
3. $H_{2(g)} + \tfrac{1}{2} O_{2(g)} \rightarrow H_2O_{(l)}$

In the second investigation, the heat of formation of solid calcium hydroxide is examined.
The equation for the reaction is:

$$Ca_{(s)} + O_{2(g)} + H_{2(g)} \rightarrow Ca(OH)_{2(s)}$$

The above equation can be obtained by combining the following two reactions:

4. $Ca_{(s)} + 2\,H_2O_{(l)} \rightarrow Ca(OH)_{2(s)} + H_{2(g)}$
5. $H_{2(g)} + \tfrac{1}{2} O_{2(g)} \rightarrow H_2O_{(l)}$

Magnesium and acid reactions, and the calcium and water reaction are measured experimentally. ***Standard Heats of Formation*** values are used for the formation of water.

This lab uses the assumption that a dilute aqueous solution has the same density and specific heat capacity as water.

Materials:

Materials per group:

Equipment	Chemicals	
styrofoam cups, 250 mL, 2	distilled water	100 mL
cardboard lid for cups, 1	hydrochloric acid, $HCl_{(aq)}$ (1.0 mol/L)	200 mL
thermometer, alcohol, 1	magnesium oxide, $MgO_{(s)}$	1 g
graduated cylinder, 100 mL, 1	magnesium metal, ribbon, $Mg_{(s)}$	0.5 g
glass stirring rod, 1	calcium metal, $Ca_{(s)}$	0.5 g
Standard Heats of Formation Table - see 4U Chemistry Reference Sheets section of D2L labs		

Safety Precautions:

- Review ALL safety cautions and precautions, including those on any applicable SDS and/or workplace labels, for this lab with your teacher. Be sure you clearly understand these before proceeding with the lab procedure.
- Review all other applicable safety procedures pertaining to this lab with your teacher. Be sure you clearly understand these before proceeding with the lab procedure.
- PPE: chemical splash goggles, nitrile gloves, lab apron
- Hydrochloric acid is an irritant. Avoid direct contact.
- The calcium hydroxide solution produced is a strong base. Wash skin with cool water in the event of contact.
- Calcium metal reacts vigorously with water and the product is a strong base. Be extremely careful that pieces of calcium metal on the desk do not become wet.
- Students must NOT taste any samples!
- Follow the proper waste disposal methods, as instructed by your teacher.

Procedure:

The Heat of Combustion of Magnesium:

1. Read through the procedure and create a neat data table to record your results.
2. Clear the desk and put on PPE.
3. Nest the 2 styrofoam cups together to create a rudimentary calorimeter. Use the cardboard square as a lid to insulate the calorimeter. Use one hole for the thermometer and one hole to allow reaction gases to escape.
4. Place 100 mL of 1.0 mol/L hydrochloric acid into the nested styrofoam cups calorimeter. Record the temperature of the solution.
5. Accurately find (to the nearest 0.01 g) and record the mass of about 1 g of solid magnesium oxide.
6. Add the solid magnesium oxide to the acid solution in the cup. Stir the mixture gently with the thermometer and record the highest temperature reached.
7. Discard the solution as instructed by the teacher and rinse the cup thoroughly with water.
8. Place 100 mL of 1.0 mol/L hydrochloric acid solution into the styrofoam cup. Record the temperature of the solution.
9. Accurately find (to the nearest 0.01 g) and record the mass of about 0.5 g of magnesium ribbon.
10. Add the magnesium ribbon to the acid solution. Stir the mixture gently with the thermometer and record the highest temperature reached.
11. Discard the solution as instructed by the teacher and rinse the cup thoroughly with water.

The Heat of Formation of solid Calcium Hydroxide:

1. Clear the desk and put on PPE.
2. Place 100 mL of water into the styrofoam cup. Record the temperature of the water.
3. Accurately find (to the nearest 0.01 g) and record the mass of about 0.5 g of calcium metal. CAUTION: Do not allow any of the pieces of calcium metal to become wet.
4. Add the calcium to the water.
5. Stir the mixture and record the highest temperature reached.
6. Dispose of waste and clean up, as instructed by the teacher.

Data:

Record required measurements in the prepared data table.

Analysis:

The Heat of Combustion of Magnesium:

1. **Two** reactions were carried out for this section.
   From the data, calculate the following for **EACH** reaction.
   a. The temperature change of the solution in each case.
   b. The heat absorbed by the solution in each case.
   c. The number of moles magnesium oxide and magnesium used.
   d. The heat of reaction in kJ/mol for magnesium oxide reacting with hydrochloric acid.
   e. The heat of reaction in kJ/mol for magnesium reacting with hydrochloric acid.

   Summarize the results in a neat summary table.

2. Show how equations 1, 2 and 3 in the "background" can be combined to give the equation for the combustion of magnesium. (In other words... apply Hess's Law to reach the "destination" equation!)

3. Use the experimental heats of reaction for the two reactions in the experiment, along with a value for the heat of formation for liquid water, to calculate the molar heat of combustion for magnesium. (In other words... apply Hess's Law to find the heat of the reaction!)

4. Compare the calculated value with that found in tables for the standard heat of formation of magnesium oxide. Calculate the percentage error between the accepted and experimental values for the combustion of magnesium oxide. Note: This value also represents the standard heat of formation for magnesium oxide.

The Heat of Formation of Solid Calcium Hydroxide:

1. **One** reaction was carried out for this section.
   From the data for the reaction, calculate the following:
   a. The temperature change of the solution.
   b. The heat absorbed by the solution.
   c. The number of moles calcium used.
   d. The heat of reaction in kJ/mol for calcium reacted with water.
   e. Summarize the results in a neat summary table.

2. Show how equations 4 and 5 in the "background" can be combined to give the equation for the formation of calcium hydroxide. (In other words... apply Hess's Law to reach the "destination" equation!)

3. Use the experimental heats of reaction for the reaction in the experiment, along with a value for the heat of formation for liquid water, to calculate the molar heat of formation for calcium hydroxide. (In other words... apply Hess's Law to find the heat of reaction!)

4. Compare the calculated value with that found in tables for the standard heat of formation of calcium hydroxide. Calculate the percentage error between the accepted and experimental values for the molar heat of formation of calcium hydroxide.