A HESS' LAW INVESTIGATION

The CCLI Initiative

Computers in Chemistry Laboratory Instruction

LEARNING OBJECTIVES

The objectives of this experiment are to . . .

- measure the heats of reaction for two chemical reactions.

- use Hess's Law, in conjunction with the above measurements, to calculate the heat of reaction for the combustion of magnesium metal.

BACKGROUND

The heat of reaction (ΔH) is defined as the heat lost or gained as a reaction proceeds from reactants to products. It is often given as part of a thermochemical equation, such as that shown for the combustion of hydrogen in equation 1:

$$2 H_2 (g) + O_2 (g) \rightarrow 2 H_2O (l) \qquad \Delta H = -572 \text{ kJ} \qquad (1)$$
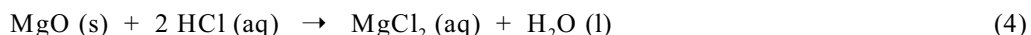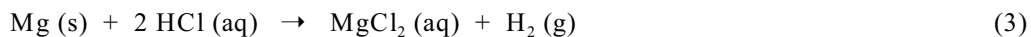
The negative sign indicates that this reaction is exothermic. Thus, when two moles of hydrogen gas and one mole of oxygen gas combine to form two moles of liquid water, 572 kJ of heat energy is released. Conditions of constant atmospheric pressure (the reaction vessel is an open container) and near room temperature ($25\,^{\circ}C$) are assumed in the above value, although heats of reaction do not vary appreciably with temperature.

A calorimeter is a device for measuring the heat of reaction. For reactions involving aqueous solutions, a simple Styrofoam coffee cup works well. One carries out the reaction in the cup and measures the temperature change (Δt). Assuming adiabatic conditions (no heat loss), the reaction heat all goes into warming the solution *and* cup. This heat quantity can be calculated as shown in equation 2:

$$\text{Heat} = (\text{specific heat of solution}) \times (\text{grams solution}) \times (\Delta T) + (\text{heat capacity of cup}) \times (\Delta T). \quad (2)$$

The solution has specific heat equal to 3.86 J/g $^{\circ}C$ and density of 1.00 g/mL. The estimated cup heat capacity is 3.0×10^1 J/$^{\circ}C$. The final heat of reaction calculation requires a stoichiometric conversion from grams of limiting reactant to moles as expressed in the balanced equation.

In this experiment you will measure ΔH values for the reactions in equations 3 and 4:

$$Mg\,(s) \;+\; 2\,HCl\,(aq) \;\rightarrow\; MgCl_2\,(aq) \;+\; H_2\,(g) \qquad\qquad (3)$$

$$MgO\,(s) \;+\; 2\,HCl\,(aq) \;\rightarrow\; MgCl_2\,(aq) \;+\; H_2O\,(l) \qquad\qquad (4)$$

Using the thermochemical equations for these two reactions along with that previously given for the hydrogen/oxygen reaction (equation 1), you will then calculate the ΔH value for the combustion of magnesium:

$$2\,Mg\,(s) \;+\; O_2\,(g) \;\rightarrow\; 2\,MgO\,(s) \qquad\qquad \Delta H \;=\; ? \qquad\qquad (5)$$

This calculation is done by applying Hess' Law as described in your text book.

Temperature measurement in this experiment is made with an IC temperature probe. The spreadsheet program will be used to graph the temperature *vs.* time data for the two reactions. From these plots, Δt values will be determined.

SAFETY PRECAUTIONS

As usual, any skin contacted with chemicals should be washed immediately. Safety goggles must be worn at all times in the lab.

BEFORE PERFORMING THIS EXPERIMENT . . .

...you will need a *MicroLAB* program capable of measuring and displaying temperature and time. This is available under the **Time and Temperature** tab. Choose the one your instructor indicates.

EXPERIMENTAL PROCEDURE

Temperature probe calibration and experiment program

Calibrate your temperature probe at a minimum of three points using an ice/water mixture for the lower temperature calibration and mixtures of ice or tap water and hot tap water for the upper temperature calibrations.

Running the experiment

Obtain two Styrofoam cups (one nested in the other for extra insulation), a Styrofoam lid, a thermistor, a magnetic stir bar, and a supporting beaker. Fit the temperature probe through the Styrofoam lid to a length such that its tip goes deep into the cup but misses the stir bar. Use a rubber band to prevent the temperature probe from slipping lower.

The Mg/HCl reaction

1. Obtain 100 mL of 1.00 *M* HCl in a graduated cylinder. Pour the HCl into the cup, add the stir bar, position the cups and supporting jar on the magnetic stirrer provided at your work station, and adjust the stirring rate to a vigorous rate, but without splashing. Finally, insert the thermistor and allow several minutes for temperature equilibration.
2. Weigh approximately 0.25 grams of magnesium turnings on an analytical balance. Tare a piece of weighing paper on the balance pan for supporting the magnesium and record the magnesium weight to at least 0.001 g.

3. Start the experiment program. Remember that you will be performing two experiments and thus creating two data files. Be sure to give them different, distinguishable file names. As the experiment starts, you should see successive, constant temperature readings of near room temperature. Allow these readings to continue for at least one minute to establish an accurate initial temperature baseline value.

4. Quickly add the magnesium turnings and reposition the temperature probe and lid assembly. As the reaction occurs, you should observe the temperature climb. Continue taking data until a final, constant temperature plateau or a defined downward slope is well established. The experiment can be stopped at that point.

The MgO/HCl reaction

The second experiment is conducted in a manner identical to that described above except that MgO is used instead of Mg metal and the weighed amount is different. Use a tared weighing boat on an analytical balance to weigh approximately one gram of MgO powder. Again record to the nearest 0.001 g. When you transfer the powder to the calorimeter, take care to transfer it as completely as possible, leaving little or no residue on the weighing paper or adhering to the inside of the Styrofoam cup. Re-weigh the weighing boat to determine the amount of MgO remaining, and subtract that from the original weight.

DATA ANALYSIS

1. Reload your data file for the reaction of Mg with HCl into the *MicroLAB* program.

2. From your plot of temperature *vs.* time, determine the initial and final temperatures and calculate the heat of reaction per mole of magnesium reacted. If a slight downward or upward trend appears on the initial or final temperature plateau, use the maximum value achieved. Record these temperatures (to the nearest 0.1 °C) in your report. Repeat this procedure for the three remaining data files. (Your instructor may want to teach you how to do a graphical method that will produce more accurate values for ΔT. If so, this can be accomplished using the *MicroLAB* analysis tools, then use this data for the calculations.)

3. Obtain printouts of both your data and graph.

4. Repeat steps 1-3 for the reaction of MgO with HCl.

5. Use Hess's Law to calculate ΔH for the combustion of magnesium, as discussed at the top of page 2.