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Experiment #2 – Hess's Law: Heat of Formation of MgO

Hess's Law states that when a reaction is carried out in a series of steps, ΔH for the overall reaction will equal the sum of the enthalpy changes in the individual steps.
It is possible to calculate enthalpy of a reaction in both the lab setting, and by using Appendix values. Enthalpy is an extensive property, so the amount is important. If a series of reactions are used to create an overall reaction, the enthalpy values can be added to solve for the overall enthalpy of a reaction.

$$\Delta H_{rxn} = \Delta H_a + \Delta H_b + \Delta H_c \qquad (1)$$

In this experiment, the enthalpy of each reaction step will be measured using a calorimeter. The heat released by the reaction will be absorbed by the calorimeter such that:

$$\Delta H_{rxn} = \frac{-Q_{cal}}{\text{moles of solid}} \qquad (2)$$

The heat absorbed by the calorimeter (Q_{cal}) can be found using the equation:

$$Q_{cal} = ms\Delta T \qquad (3)$$

As an alternative to a lab determination of enthalpy values, any reaction may be broken down to formation reactions from elements. Appendix values may be looked up to solve for the enthalpy of reaction under standard conditions.

$$\Delta H_{rxn}^\circ = \Sigma\, nH_f^\circ \text{ (products)} - nH_f^\circ \text{ (reactants)} \qquad (4)$$

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Part A Procedure

Assemble a calorimeter consisting of two polystyrene coffee cups nested together, weigh and record the mass of the dry calorimeter, and place in a 400 mL beaker to stabilize. Obtain a 10 cm piece of Mg, then clean, weigh, and record its mass. Place about 50 mL of 3.0 M HCl in the calorimeter and determine its temperature to the nearest 0.01 °C. Add the Mg metal to the HCl solution and quickly cover the calorimeter. While constantly swirling the solution, determine and record the maximum temperature (0.01 °C) achieved. When complete, weigh and record the mass of the calorimeter and final solution. Calculate ΔH per mole of Mg for the reaction. *Repeat the experiment until two ΔH values agree to within 5% of each other.*

Part B Procedure

Use the same calorimeter from Part A and its original empty mass. Pour about 50 mL of 6.0 M HCl in the calorimeter, measure, and record its temperature to the nearest 0.01 °C. Place approximately 1 gram of MgO in a weighing dish and record its exact mass. Add the MgO to the HCl solution in the calorimeter and follow the procedure from Part A to determine the final temperature of the solution. After the MgO is added to the calorimeter, obtain the mass of the empty weighing dish in order to determine the amount of MgO added to the calorimeter. Weigh and record the mass of the calorimeter and final solution. Calculate ΔH per mole of MgO for the reaction. *Repeat the experiment until two ΔH values fall within 5% of each other*.

Note*: Specific heat of the hydrochloric acid solution in both Part A and Part B is 3.70 J / g °C. *This is not water.

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Data for Part A: Clearly show calculations on another space, (s) = 3.70 J / g °C

Mass of Mg	_____		_____
Mass of Empty Calorimeter + Lid	_____	=	_____
Mass of Calorimeter + Lid + Final Solution	_____		_____
Initial Temperature of HCl Solution	_____		_____
Final Temperature of Solution	_____		_____
Mass of Final Solution	_____		_____
ΔT of Solution	_____		_____
ΔH for reaction **Part A**, kJ/mole Mg	_____		_____

Average ΔH_A _____ kJ / mol Mg

Data for Part B: Clearly show calculations on another space, (s) = 3.70 J / g °C

Mass of Empty Calorimeter + Lid	_____	=	_____
Mass of Calorimeter + Lid + Final Solution	_____		_____
Mass of Weighing Dish	_____		_____
Mass of Weighing Dish + MgO	_____		_____
Initial Temperature of HCl	_____		_____
Final Temperature of Solution	_____		_____
ΔT of Solution	_____		_____
Mass of MgO	_____		_____
Mass of Final Solution	_____		_____
ΔH for reaction **Part B**, kJ / mole MgO	_____		_____

Average ΔH_B _____ kJ / mol MgO

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Data Analysis and Calculations

Use Hess's Law and the following information to determine the heat of formation of MgO:

A. $Mg(s) + 2\ HCl\ (aq) \rightarrow H_2(g) + MgCl_2(aq)$ (**Part A**) $\Delta H_A =$ _____

B. $MgO(s) + 2\ HCl\ (aq) \rightarrow H_2O(l) + MgCl_2(aq)$ (**Part B**) $\Delta H_B =$ _____

C. Write the formation equation for liquid water

$\Delta H_f° =$ _____
Use appendix for value

D. Write the formation equation for MgO(s)

E. Use Hess's Law and the above information to calculate the heat of formation for MgO(s). Show all your work.

F. Look up the literature value of $\Delta H_f°$ for MgO and calculate the % error.

Theoretical $\Delta H_f°$ MgO _____ kJ / mol % error _____