Hess's Law Labs

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Introduction - In order to calculate the enthalpy change for the combustion of magnesium oxide ($Mg_{(s)}+1/2O_{2(g)}$----> $MgO_{(s)}$), we used a coffee cup calorimeter to calculate the enthalpies of of two separate reactions. The two reactions we conducted were $Mg_{(s)} + 2H^{+}_{(aq)} \rightarrow Mg^{2+}_{(aq)} + H_{2(g)}$, and $H_2O_{(l)} + Mg^{2+}_{(aq)} \rightarrow MgO_{(s)} + 2H^{+}_{(aq)}$. After we found the enthalpies for these two equations, we were able to combine them, along with the known enthalpy of the formation of water, using Hess's Law (the enthalpy of a reaction that takes place in several steps can be calculated by combining the enthalpies of the intermediary steps conducted at the same temperature), in order to find the enthalpy for the combustion of magnesium oxide. We predicted that the enthalpy change would be negative (exothermic) based our previous knowledge of combustion as a reaction that releases energy.

Experimental Question - What is the enthalpy change associated with the reaction of magnesium with oxygen to produce magnesium oxide? Can Hess's law be used to calculate this?

A Testable Prediction - We predict that the enthalpy change would be negative since we knew the reaction was exothermic and that it would be possible to use Hess's law to find the enthalpy change.

Data Analysis

Raw Data Tables:
Part 1: Reacting a 10.0 cm magnesium ribbon with 100 mL of hydrochloric acid in a coffee cup calorimeter.

	Magnesium Ribbon length (cm)	Amount of 1M HCl added (mL)	Initial Temperature in Celsius	Final Temperature in Celsius
Trial 1	10.0 cm	100 mL	22.1°C	31.8 °C
Trial 2	10.0 cm	100 mL	22.1 °C	30. 4 °C
Trial 3	10.0 cm	100 mL	21.7 °C	31.7 °C

Part 2: Reacting magnesium oxide with 100 mL of hydrochloric acid in a coffee cup calorimeter.

	Mass of Magnesium Oxide (g)	Amount of 1M HCl added (mL)	Initial Temperature in Celsius	Final Temperature in Celsius
Trial 1	1.030 g MgO	100 mL	22.1 °C	29.5 °C
Trial 2	1.040 g MgO	100 mL	22.1 °C	30.2 °C

Calculation of data

Part 1, using Trial 3:

to find the enthalpy of $Mg_{(s)} + 2H^{+}_{(aq)} \rightarrow Mg^{2+}_{(aq)} + H_{2\,(g)}$

$\Delta T = T_{final} - T_{initial}$

$\Delta T = 31.7\ °C - 21.7\ °C = 10\ °C$

90.8 cm = 1.832 g

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10.0 cm = x

90.8x = 18.32

x = 0.202 g Mg

0.202/24.31 g/mol = 0.008309 mol Mg

$q = mc\Delta T$

q = 100 g HCl x 4.18 J/g·°C x 10 °C

q = 4180 J 4.180 kJ

$\Delta H = -q$

$\Delta H = -4.180$ kJ

-4.180/0.008309= -503.07 kJ/mol

Part 2, using Trial 2:

to find the enthalpy of $MgO_{(s)} + 2H^{+}_{(aq)} \rightarrow H_2O_{(l)} + Mg^{2+}_{(aq)}$

$\Delta T = T_{final} - T_{initial}$

$\Delta T = 30.2\ °C - 22.1\ °C = 8.1\ °C$

1.040 g MgO/ 40.31 = 0.0258 mol MgO

$q = mc\Delta T$

q = 100 g HCl x 4.184 J/g·°C x 8.1 °C

q = 3389.04 J or 3.38904 kJ

$\Delta H = -q$

$\Delta H = -3.389$ kJ

-3.389/ 0.0258 mol = -131.36 kJ/mol

to find the enthalpy of $Mg + 1/2O_2 \rightarrow MgO$
using these equations and their enthalpies:

Enthalpy: -503.07 kJ/mol $Mg_{(s)} + 2H^+_{(aq)} \rightarrow Mg^{2+}_{(aq)} + H_{2\,(g)}$

Enthalpy: +131.36 kJ/mol $H_2O_{\,(l)} + Mg^{2+}_{(aq)} \rightarrow MgO_{(s)} + 2H^+_{(aq)}$

Enthalpy: -258.8 kJ/mol $H_2 + 1/2O_2 \rightarrow H_2O$

Enthalpy: -630.51 kJ/mol $Mg + 1/2O_2 \rightarrow MgO$

by combining the 3 reactions above, and therefore their enthalpies, we can determine the enthalpy of the equation of the combustion of Mg ($Mg + 1/2O_2 \rightarrow MgO$) is -630.51 kJ/mol

-503.07 + 131.36 + -258.8 = -630.51 kJ/mol

Error Analysis

A. The theoretical enthalpy value for the combustion of magnesium in the reaction $Mg + 1/2O_2 \rightarrow MgO$ is -607.10 kJ/mol. Our value, -630.51 kJ/mol was very close. Differences in these values could have been from incorrect lab protocol, which will be discussed in Part C of Error Analysis.

B. The standard enthalpy for the reaction $Mg + 1/2O_2 \rightarrow MgO$ is -607.1 kJ/mol. Finding the percent error:

$$\text{Percent Error} = \frac{(-630.51 - -607.10)}{-607.10} \times 100 = 3.86\ \%$$

C. Possible sources of error could have occurred from improper lab technique. First off, when measuring the magnesium oxide powder into the weighing boat, the scale fluctuating slightly, possibly giving us a moderately incorrect weight of the powder. This could have inflated or deflated the enthalpy calculated. Also, when moving the magnesium oxide powder from the weighing boat to the styrofoam cup, a small amount of powder slipped onto the lab station table. This could have decreased the mass of the amount of magnesium oxide for the reaction, thus inflating the enthalpy change. Lastly, when pouring the 100 mL of HCl into the coffee cup, a small amount missed the cup. This decreases the amount of acid added, resulting in an inflation of the enthalpy value found.

Conclusion

In conclusion, the data supported our hypothesis. Our enthalpy value was negative, and thus the reaction was exothermic. Hess's law could be used to calculate the heat of combustion of magnesium. Compared to the expected value of magnesium's heat of combustion, we were very close. There was a small percent error of 3.86% and that was due to incorrect lab procedures. It's quite possible that in a perfect world, if no errors occurred, it would possible to calculate the almost exact heat of combustion for magnesium performing the same reactions.

Discussion of theory

1) We calculated the change in enthalpy using the specific heat capacity formula. We had used it before but we learned a lot by using it in a real life setting. At first, when calculating enthalpy, we made the mistake of putting in the grams of Magnesium and Magnesium Oxide for m (in the equation $q = mc\Delta T$). We were getting enthalpies close to zero. We had to go back to the equation and use the amount of HCl for m (in the equation $q = mc\Delta T$) to get the correct enthalpy and making this mistake at first in this experiment permanently taught us that lesson.

2) This experiment taught us how to use Hess's law to calculate the energy change in a reaction through experimentation. We learned how to use the sum of the individual reactions in our reaction to calculate it's change in energy with experimental data.

3) In this lab we also learned how to convert and alternate units. We learned how to convert kilojoules to joules and also that a temperature change in Kelvin is equal temperature change in Celsius.