Calorimetry and Hess's Law

Experiment 10

This experiment explored the Hess Law and thermodynamics of Calorimetry. Calorimetry is used at a constant pressure during this lab experiment and by using constant pressure, enthalpy can be found. Two Styrofoam cups, inside of each other, are used to hold various solutions. The two cups are used as the Calorimetry system and are able to measure the heat absorbed and released in each experiment. In the first reaction, water at room temperature is placed in the system, while another set of water is heated until boiling appears. The hot water is added to the water in the cups, raising the temperature. This reaction is exothermic, because as the temperature rises, heat and energy are released. In the second reaction, a magnesium metal ribbon is added to a solution of HCl in the Calorimetry system. This reaction is also exothermic, because heat and energy are released. The magnesium metal ribbon reacts with the HCl solution creating magnesium chloride and hydrogen gas. In the third reaction, magnesium oxide powder is placed in a solution HCl. This reaction is endothermic, because as the temperature decreases, heat is absorbed and more energy is created. This experiment is determining the heat of each reaction to find the combustion of magnesium metal. Each reaction performed added onto information needed to find this data.

The results of this experiment were taken by using the LoggerPro software to record time and temperature of each reaction. Once the data was recorded, further calculations were made to determine the heat gained by the calorimeter, calorimeter constant, and enthalpy of reactions.

Part A was very important in this experiment, because this determined the calorimeter constant. To find the constant, max temperature and ΔT_c and ΔT_h water had to be found first. To find max temperature, two slope intercept equations had to be found on the LoggerPro graph. The first equation was the increasing of temperature: y = 2.906t - 266.4. The second equation was the decreasing of temperature y = -0.01142t + 63.85. By using algebra and setting the equations equal to each other (2.906t - 266.4 = -0.01142t + 63.85) max temperature (t) was found at 61.72°C. ΔT_c was found by using max temperature – initial temperature. ΔT_c = 61.72°C – 22.2°C = 39.5°C. ΔT_h was found by using max temperature – hot temperature. ΔT_h = 61.72°C – 144.0°C = -82.3°C. Next heat lost by the hot and cold water were found. $q_{hot\ water}$ = (q_s) (m_{hot}) (ΔT_h) = (4.18 J g^{-1} °C^{-1})(20 g) (-82.3°C) = -6,878.6 J. $q_{cold\ water}$ = (q_s) (m_{cold}) (ΔT_c) = (4.18 J g^{-1} °C^{-}

^{1}) (40 g) (39.5°C) = 6,607.7 J. Using the heat lost by the hot and cold water, the calorimeter constant can be found. $C_c = -(-q_{hot\ water} + q_{cold\ water})$ = -(-6,878.6 J + 6,607.7 J) = 270.06 J. The calorimeter heat gained is found by $q_{cal} = (C_c)(\Delta T_c)$ = (270.06 J) (39.5 °C) = 10,700.0 J °C^{-1}.

Part B was the reaction of Magnesium ribbon and Hydrogen Chloride ($Mg + 2HCl \rightarrow MgCl_2 + H_2$). Enthalpy must be found of this reaction to determine the enthalpy wanted at the end of experiment. $-\Delta H = (m_{acid} + m_{Mg})(q_c)(\Delta T_c) + (C_c)(\Delta T_c)$ = (50 g + 0.32 g) (4.18 J g^{-1} °C^{-1}) (49.6°C – 21.6 °C) + (270.06 J)(49.6°C – 21.6 °C) = -8,183.0 J. Enthalpy is negative because this experiment is exothermic. It releases energy and heat into the surroundings. Also, heat fusion must be found in this reaction. $-\Delta H° = \Delta H_{products} - \Delta H_{reactants}$ = 1 ΔH(Mg)+ 2 ΔH(HCl) - 1 ΔH($MgCl_2$) - 1 ΔH(H_2) = 1(0) + 2(-167.4) – 1(-671.8) – 1(0) = -337.0 kJ mol^{-1}.

Part C was the reaction of Magnesium Oxide and Hydrogen Chloride ($MgO + 2HCl \rightarrow MgCl_2 + H_2O$). Enthalpy must be found of this reaction to determine the enthalpy wanted at the end of experiment. $-\Delta H = (m_{acid} + m_{Mg})(q_c)(\Delta T_c) + (C_c)(\Delta T_c)$ = (50 g + 0.31 g) (4.18 J g^{-1} °C^{-1}) (27 °C - 21.7 °C) + (270.06 J) (27 °C - 21.7 °C) = -2,546.0 J. Enthalpy is negative because this experiment is endothermic. It absorbs energy and heat from the surroundings. Also, heat fusion must be found in this reaction. $\Delta H° = \Delta H_{products} - \Delta H_{reactants}$ = 1 ΔH(MgO)+ 2 ΔH(HCl) - 1 ΔH($MgCl_2$) - 1 ΔH(H_20) = 1(-601.8) + 2(-167.4) – (-671.8) – (-285.8) = 21.00 kJ mol^{-1}.

Reaction 4 is ($H_2 + 1/2O_2 \rightarrow H_2O$) the formation of water in a standard state. The heat formation is given as ΔH° = -285.8 kJ mol^{-1}. During the lab, this experiment was not carried out, but given in the lab notebook to determine the reaction wanted at the end of the experiment. After finding all the previous data, now calculations will be made to find the combustion of Magnesium. Using the equations of all three reactions that occurred, combustion of Magnesium equation can be found

$$\text{Reaction 2:}\quad Mg(s) + 2\,HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$$

$$\text{Reaction 3:}\quad -1\left(MgO(s) + 2\,HCl(aq) \rightarrow MgCl_2(aq) + H_2O(l)\right)$$

$$\text{Reaction 4:}\quad H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(l)$$

$$\text{Wanted Reaction:}\quad Mg(s) + \frac{1}{2}O_2(g) \rightarrow MgO(s)$$

By canceling 2HCl, H_2, $MgCl_2$, and H_2O, the equation left is the combustion of Magnesium. After finding this equation, heat fusion (ΔH°) can be found. $-\Delta H° = \Delta H_{products} - \Delta H_{reactants}$ = 1 ΔH(Mg) + 1/2 ΔH(O_2) – 1(MgO) = 1(0) + 1(0) -1(-601.8) = -601.8 kJ mol^{-1}. This reaction is exothermic, because heat and energy are released when the products are formed at the end of the reaction.

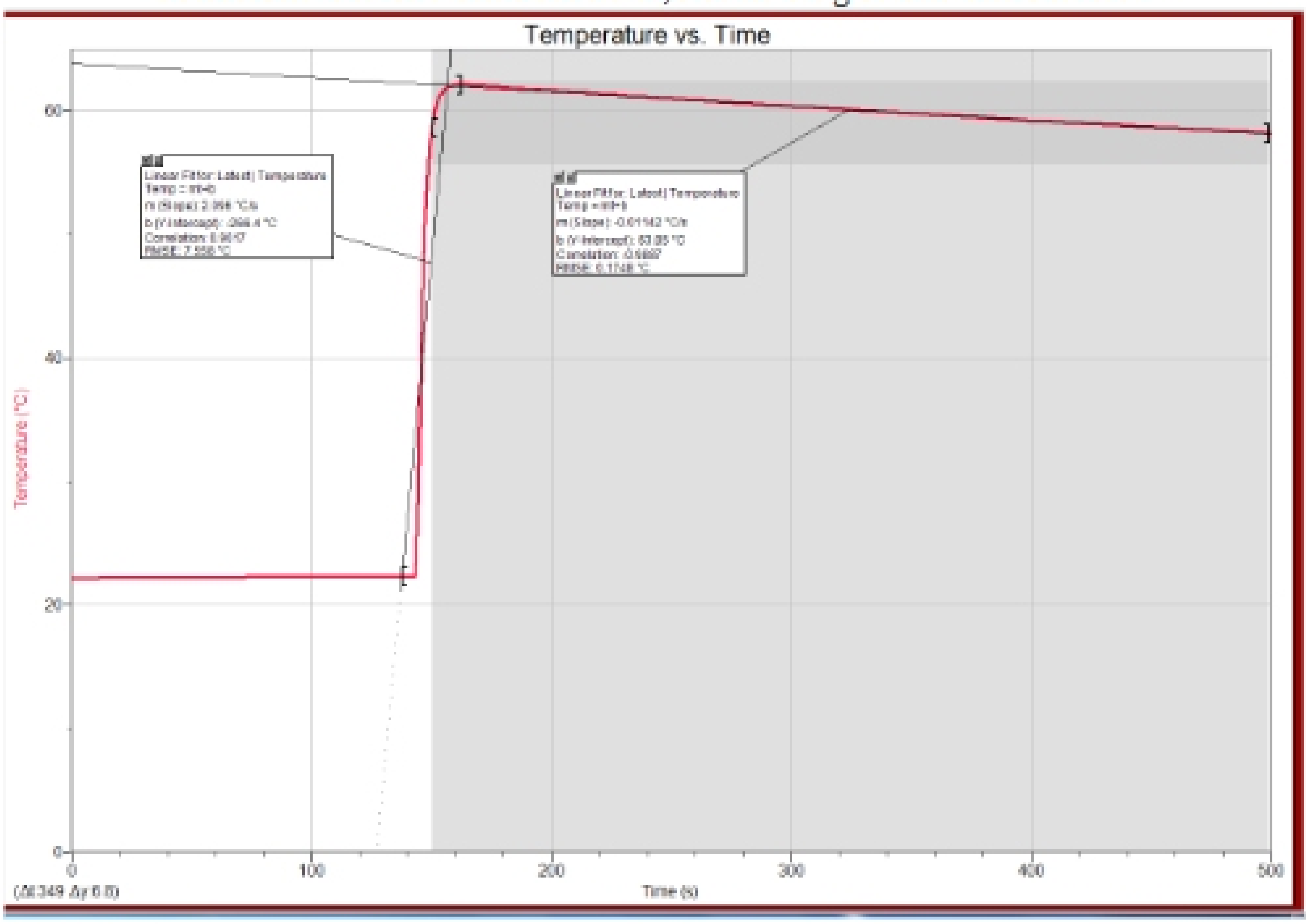
Heat Formation of Each Reaction

Combustion of Mg	Mg with HCl	MgO with HCl	Combustion of H_2O
-601.8 kJ mol^{-1}	-337.0 kJ mol^{-1}	21.00 kJ mol^{-1}	-285.0 kJ mol^{-1}

Part A: Data Collection from Calculations

$\Delta T_{cold\ water}$	$\Delta T_{hot\ water}$	T_{max}	$q_{hot\ water}$	$q_{cold\ water}$	C_c	q_{cal}
39.5°C	-82.3°C	61.72°C	-6,878.6 J	6607.7 J	270.06 J	10,700.0 J °C^{-1}

Part A: Reaction of Water with Water, Determining Calorimeter Constant



These results show that this reaction is exothermic, releasing energy and heat. The calorimeter constant would be affected if cold water was added to hot water, unlike this reaction. The hot water in the system would be cooled by the water added, meaning more energy would be required and heat would be absorbed from the surroundings. The calculations made for the calorimeter are fairly confident. There is always room for error, but confidence is present in calculating all of the data.

Part B: Data Collection from Calculations

Mass of HCl	Mass of Mg	T_{max}	ΔT_c	C_c