

Title: Enthalpy of Various Reactions

Introduction:

A calorimeter is a device that measures the amount of heat lost or gained by a substance or reaction. There are two types of calorimeters: a bomb calorimeter which is constant volume and the constant pressure calorimeter, which is quite simpler. The second type of calorimeter is the one that is used in this experiment. It is made of two nested Styrofoam cups with a lid and a hole in the lid to place the thermometer in. The function of the nested cups is to prevent heat loss from the system. If the substance or solution is losing heat then it is called an exothermic reaction and is assigned a negative sign. If; however, it is absorbing heat, then the reaction is endothermic and it is assigned a positive sign.

Specific heat is used to calculate thermal energy. It is the amount of energy needed to raise the temperature of one gram of a substance by one degree Celsius. This property is important because it determines how substances react to their environments. An example of this is water. Since the specific heat of water is high, the system of water requires a great deal of energy to change its temperature and thus water plays a role in temperature regulation of its surroundings.

Enthalpy (H) is a value used to calculate the potential of a thermodynamic system to produce work. Since the total enthalpy of a system cannot be found, the change in enthalpy is calculated instead. In a closed system, much like the calorimeter, the change in enthalpy (ΔH) is equal to the amount of heat absorbed or released. Depending on whether the reaction is endothermic or exothermic, the value of ΔH also receives a positive or negative sign to denote whether heat is being lost or gained.

Sources:

- <http://chemistry.about.com/od/thermodynamics/a/coffee-cup-bomb-calorimetry.htm>
- <http://hyperphysics.phy-astr.gsu.edu/hbase/thermo/spht.html>
- <http://en.wikipedia.org/wiki/Enthalpy>
- Lab Manual

Procedures: As described in the lab manual

Observations/Results:

- For the metal:
 - The metal was zinc. It was cut into thin, flat, rectangular pieces.
 - Since it is a metal it is shiny and has a silvery color.
 - Before the metal and water were combined, the temperature of the water increased slightly.
 - However, when the metal and water were combined, a more notable difference in temperature appeared; the calorimeter felt warmer and the reading on the thermometer went up.
- For the acids (HCl, HNO₃) and base (NaOH):
 - The acids and base were all colorless liquids.
 - HCl had a really strong odor and it seemed to produce steam or smoke.
 - HNO₃ had barely any noticeable odor compared to HCl
 - Before the NaOH and the acid were combined the temperature of calorimeter rose slightly however it was close to room temperature
 - After mixing the temperature rose (the calorimeter heated up)
 - Then decreased as the calorimeter cooled gradually
- For the salt:
 - The salt was a white, odourless crystal-like powder
 - Before the salt was added to the water the calorimeter felt cool (around room temperature)
 - After the salt was added the temperature decreased continuously. The calorimeter did not get warmer.

Tables of Data:**Table 1-Specific Heat Capacity of a Metal**

	Trial 1	Trial 2
Metal	Zinc	Zinc
Mass of metal (g)	10.0489 g	9.3852 g
Mass of calorimeter lids(g)	2.8486 g	2.8658 g
Mass of coffee cups (g)	3.65255 g	4.1689 g
Mass of Calorimeter(g)	6.5012 g	7.0347 g
Volume of water (mL)	20.30 mL	19.80 mL
Mass of Calorimeter and water(g)	26.7313 g	25.3746 g
Initial Temperature ° C	23.60° C	24.50° C
Temperature after 60 s	24.60° C	24.60° C
Temperature after 90 s	24.70° C	24.70° C
Time (s)	120s	120s
Temperature of boiling water ° C	101.3° C	101.4° C
Time (s)	130s	130s
Temperature after 10 s (140)	28.50° C	28.20° C
Temperature after 20 s (150)	28.40° C	28.20° C
Temperature after 30 s (160)	28.50° C	28.20° C
Temperature after 40 s (170)	28.50° C	28.30° C
Temperature after 50 s (180)	27.80° C	28.20° C
Temperature after 60 s (190)	27.70° C	28.20° C
Temperature after 70 s (200)	27.80° C	28.20° C
Temperature after 80 s (210)	27.80° C	28.10° C
Temperature after 90 s (220)	27.80° C	28.20° C
Temperature after 100 s (230)	27.80° C	28.20° C
Temperature after 110 s (240)	27.80° C	28.20° C
Temperature after 120 s (250)	27.70° C	28.20° C
Temperature after 140 s (270)	27.70° C	28.20° C
Temperature after 160 s (290)	27.70° C	28.20° C
Temperature after 180 s (310)	27.70° C	28.10° C
Temperature after 200 s (330)	27.80° C	28.20° C
Temperature after 220 s (350)	27.70° C	28.10° C
Temperature after 240 s (370)	27.70° C	28.20° C
Time (s)	370 s	370 s

Table 2- Enthalpy of Neutralization (HCl)

	Trial 1	Trial 2
Concentration of HCl(M)	1.1 M	1.1 M
Volume of HCl (mL)	50.20 mL	50.12 mL
Temperature of HCl ° C	24.20 ° C	24.60° C
Concentration of NaOH (M)	1.0 M	1.0 M
Volume of NaOH (mL)	50.12 mL	50.14 mL
Volume of water (mL)	20.40 mL	20.13 mL
Initial temperature of NaOH° C	23.90° C	24.00° C
Temperature after 60 s	23.90° C	23.90° C
Temperature after 120 s	23.90° C	23.90° C
Time (s)	120	120
Time (s)	130	130
Temperature after 10 s (140)	29.70° C	29.90° C
Temperature after 20 s (150)	30.60° C	30.50° C
Temperature after 30 s (160)	30.80° C	30.70° C
Temperature after 40 s (170)	30.80° C	30.60° C
Temperature after 50 s (180)	30.80° C	30.60° C
Temperature after 60 s (190)	30.80° C	30.60° C
Temperature after 70 s (200)	30.80° C	30.50° C
Temperature after 80 s (210)	30.80° C	30.50° C
Temperature after 90 s (220)	30.70° C	30.50° C
Temperature after 100 s (230)	30.70° C	30.50° C
Temperature after 110 s (240)	30.70° C	30.50° C
Temperature after 120 s (250)	30.70° C	30.50° C
Temperature after 140 s (270)	30.70° C	30.50° C
Temperature after 160 s (290)	30.70° C	30.50° C
Temperature after 180 s (310)	30.70° C	30.50° C
Temperature after 200 s (330)	30.70° C	30.40° C
Temperature after 220 s (350)	30.70° C	30.40° C
Temperature after 240 s (370)	30.70° C	30.50° C
Time (s)	370	370
Mass of calorimeter, lids, and solution (g)	113.8169 g	118.2226 g

Table 3- Enthalpy of Neutralization (HNO₃) Received from:

	Trial 1	Trial 2
Concentration of HNO₃(M)	1.1 M	1.1 M
Volume of HNO₃ (mL)	50.00 mL	50.00 mL
Concentration of NaOH (M)	1.0 M	1.0 M
Volume of NaOH (mL)	50.00 mL	50.00 mL
Initial temperature of NaOH° C	22.30° C	22.20° C
Temperature after 30 s	22.30° C	22.20° C
Temperature after 60 s	22.30° C	22.20° C
Temperature after 90 s	22.30° C	22.20° C
Temperature after 120 s	22.30° C	22.20° C
Temperature after 150 s	29.50° C	29.20° C
Temperature after 160 s	29.50° C	29.20° C
Temperature after 170 s	29.50° C	29.10° C
Temperature after 180 s	29.50° C	29.10° C
Temperature after 190 s	29.50° C	29.10° C
Temperature after 200 s	29.40° C	29.10° C
Temperature after 210 s	29.40° C	29.10° C
Temperature after 220 s	29.40° C	29.10° C
Temperature after 230 s	29.40° C	29.10° C
Temperature after 240 s	29.40° C	29.00° C
Temperature after 250 s	29.40° C	29.00° C
Temperature after 260 s	29.40° C	29.00° C
Temperature after 270 s	29.40° C	29.00° C
Temperature after 300 s	29.40° C	29.00° C
Temperature after 330 s	29.30° C	28.90° C
Temperature after 360 s	29.20° C	29.00° C
Temperature after 420 s	29.20° C	28.90° C
Temperature after 450 s	29.10° C	28.80° C
Mass of calorimeter, lids, and solution (g)	109.6330 g	109.4509 g

Table 4- Enthalpy of Dissolution of a Salt

Data	Trial 1	Trial 2
Assigned Salt	C	C
Mass of Salt (g)	5.0760 g	5.0458 g
Mass of Calorimeter (g)	7.1001 g	7.1592 g
Mass of Calorimeter + Water (g)	26.3852 g	27.1401 g
Volume of Water (mL)	19.2851 g	19.9809 g
Initial Temperature (°C)	24.70 °C	24.60 °C
Temperature after 60s (°C)	25.10 °C	24.70 °C
Temperature after 120s (°C)	25.00 °C	24.70 °C
Time (s)	120 s	120 s
Time (s)	130 s	130 s
Temperature after 10s (°C) (140)	24.10 °C	24.30 °C
Temperature after 20s (°C) (150)	21.40 °C	21.90 °C
Temperature after 30s (°C) (160)	21.20 °C	21.20 °C
Temperature after 40s (°C) (170)	21.00 °C	20.00 °C
Temperature after 50s (°C) (180)	20.10 °C	20.00 °C
Temperature after 60s (°C) (190)	20.20 °C	19.20 °C
Temperature after 70s (°C) (200)	20.00 °C	19.10 °C
Temperature after 80s (°C) (210)	20.00 °C	19.10 °C
Temperature after 90s (°C) (220)	20.10 °C	19.40 °C
Temperature after 100s (°C) (230)	19.90 °C	19.50 °C
Temperature after 110s (°C) (240)	20.00 °C	19.50 °C
Temperature after 120s (°C) (250)	19.90 °C	19.90 °C
Temperature after 140s (°C) (270)	20.10 °C	19.90 °C
Temperature after 160s (°C) (290)	20.10 °C	20.10 °C
Temperature after 180s (°C) (310)	20.00 °C	20.40 °C
Temperature after 200s (°C) (330)	19.90 °C	20.50 °C
Temperature after 220s (°C) (350)	19.90 °C	20.40 °C
Temperature after 240s (°C) (370)	19.90 °C	20.40 °C
Time (s)	370s	370 s

Calculations:

Part 1 - Enthalpy of a Metal:

Part 1 Calculations

Value	Trial #1	Trial #2
ΔT_{water}	2.95 °C	3.35 °C
E_{water}	250 J	284 J
ΔT_{metal}	-73.60 °C	-73.2 °C
c_{metal}	0.339 J/g°C	0.413 J/g°C
MM_{met}	73.7 g/mol	60.5 g/mol
%error	12.7%	-7.47%

- $\Delta T_{\text{water}} = T_2 - T_1$
 $\Delta T_{\text{water}} = 27.80^\circ\text{C} - 24.85^\circ\text{C}$
 $\Delta T_{\text{water}} = 2.95^\circ\text{C}$
- $E_{\text{water}} = m_{\text{water}} \times c_{\text{water}} \times \Delta T_{\text{water}}$
 $E_{\text{water}} = (20.30 \text{ g}) \times (4.18 \text{ J/g}^\circ\text{C}) \times (2.95^\circ\text{C})$
 $E_{\text{water}} = 250 \text{ J}$
- $\Delta T_{\text{metal}} = T_2 - T_1$
 $\Delta T_{\text{metal}} = 27.80^\circ\text{C} - 101.30^\circ\text{C}$
 $\Delta T_{\text{metal}} = -73.50^\circ\text{C}$
- $-E_{\text{metal}} = E_{\text{water}}$
 $-c_{\text{metal}} \times m_{\text{metal}} \times \Delta T_{\text{metal}} = c_{\text{water}} \times m_{\text{water}} \times \Delta T_{\text{water}}$
 $-c_{\text{metal}} \times (10.0489 \text{ g}) \times (-73.50^\circ\text{C}) = (4.18 \text{ J/g}^\circ\text{C}) \times (20.30 \text{ g}) \times (2.95^\circ\text{C})$
 $c_{\text{metal}} = 0.339 \text{ J/g}^\circ\text{C}$
- $c_{\text{metal}} \times MM_{\text{metal}} \approx 25 \text{ J/mol}^\circ\text{C}$
 $0.339 \text{ J/g}^\circ\text{C} \times MM_{\text{metal}} \approx 25 \text{ J/mol}^\circ\text{C}$
 $MM_{\text{met}} \approx 73.7 \text{ g/mol}$
- $\%_{\text{error}} = (MM_{\text{actual}} - MM_{\text{theoretical}}) \div MM_{\text{theoretical}} \times 100\%$

$$\%_{\text{error}} = (73.7 \text{ g/mol} - 65.384 \text{ g/mol}) \div 65.384 \text{ g/mol} \times 100\%$$

$$\%_{\text{error}} = 12.7\%$$

Part 2 - Enthalpy of Neutralization:

Part 2 Calculations

NaOH and HCL

Value	Trial #1	Trial #2
$\Delta T_{\text{solution}}$	6.80 °C	6.60 °C
V_{solution}	100.3mL	100.3mL
m_{measured}	107.2257 g	111.7497 g
Q_N	$-2.85 \times 10^3 \text{ J}$	$-2.77 \times 10^3 \text{ J}$
n_{NaOH}	0.05012 mol	0.05014 mol
$n_{\text{H}_2\text{O}}$	0.05012 mol	0.05014 mol
ΔH_N	-56.9 kJ/mol	-55.2 kJ/mol
$\%_{\text{error}}$	1.89%	4.83%

NaOH and HNO₃

Value	Trial #1	Trial #2
$\Delta T_{\text{solution}}$	7.10 °C	6.90 °C
V_{solution}	100mL	100mL
m_{measured}	103.0418 g	102.8897 g
Q_N	$-2.97 \times 10^3 \text{ J}$	$-2.88 \times 10^3 \text{ J}$
n_{NaOH}	0.05000 mol	0.05000 mol
$n_{\text{H}_2\text{O}}$	0.05000 mol	0.05000 mol
ΔH_N	-59.4 kJ/mol	-57.6 kJ/mol
$\%_{\text{error}}$	-14.2%	-10.8%

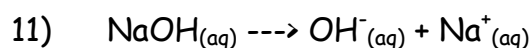
7) $\Delta T_{\text{solution}} = T_2 - T_1$
 $\Delta T_{\text{solution}} = 30.70^\circ\text{C} - 23.90^\circ\text{C}$
 $\Delta T_{\text{solution}} = 6.80^\circ\text{C}$

8) $V_{\text{solution}} = V_{\text{HCl}} + V_{\text{NaOH}}$
 $V_{\text{solution}} = 50.20\text{mL} + 50.12\text{mL}$

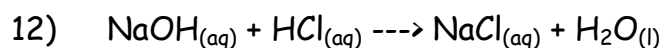
$$V_{\text{solution}} = 100.3\text{mL}$$

$$\begin{aligned} 9) \quad m_{\text{solution}} &= V_{\text{solution}} \times d_{\text{solution}} & m_{\text{measured}} &= m_{\text{total}} - m_{\text{calorimeter}} \\ m_{\text{solution}} &= 100.3\text{mL} \times 1\text{g/mL} & m_{\text{measured}} &= 113.8169\text{g} - 6.5912\text{g} \\ m_{\text{solution}} &= 100.3\text{g} & m_{\text{measured}} &= 107.2257\text{g} \end{aligned}$$

$$\begin{aligned} 10) \quad Q_N &= -E_{\text{H}_2\text{O}} \\ Q_N &= -(m_{\text{solution}} \times c_{\text{water}} \times \Delta T_{\text{solution}}) \\ Q_N &= -(100.3\text{g}) \times (4.18\text{J/g}^\circ\text{C}) \times (6.80^\circ\text{C}) \\ Q_N &= -2.85 \times 10^3\text{J} \end{aligned}$$



$$\begin{aligned} n_{\text{NaOH}} &= C_{\text{NaOH}} \div V_{\text{NaOH}} & n_{\text{OH}} &= n_{\text{NaOH}} \\ n_{\text{NaOH}} &= 1.0\text{mol/L} \times 0.05012\text{L} & n_{\text{OH}} &= 0.05012\text{mol} \\ n_{\text{NaOH}} &= 0.05012\text{mol} \end{aligned}$$



$$\begin{aligned} n_{\text{H}_2\text{O}} &= n_{\text{NaOH}} \\ n_{\text{H}_2\text{O}} &= 0.05012\text{mol} \end{aligned}$$

$$\begin{aligned} 13) \quad \Delta H_N &= E_{\text{released}} \div n_{\text{HOH}} \\ \Delta H_N &= -2.85 \times 10^3\text{J} \div 0.05012\text{mol} \\ \Delta H_N &= -5.69 \times 10^4\text{J/mol} \\ \Delta H_N &= -56.9\text{kJ/mol} \end{aligned}$$

$$15) \quad \%_{\text{error}} = (\Delta H_{\text{N theoretical}} - \Delta H_{\text{N actual}}) \div \Delta H_{\text{N theoretical}} \times 100\%$$

$$\%_{\text{error}} = (-58.0\text{kJ/mol} - (-56.9\text{kJ/mol})) \div (-58.0\text{kJ/mol}) \times 100\%$$

$$\%_{\text{error}} = 1.89\%$$

NaOH and HNO₃

$$\begin{aligned} 7) \quad \Delta T_{\text{solution}} &= T_2 - T_1 \\ \Delta T_{\text{solution}} &= 29.40 - 22.30 \\ \Delta T_{\text{solution}} &= 7.10^\circ\text{C} \end{aligned}$$

$$8) \quad V_{\text{solution}} = V_{\text{HNO}_3} + V_{\text{NaOH}}$$

$$V_{\text{solution}} = 50.00\text{mL} + 50.00\text{mL}$$

$$V_{\text{solution}} = 100\text{mL}$$

$$9) \quad m_{\text{solution}} = V_{\text{solution}} \times d_{\text{solution}} \qquad m_{\text{measured}} = m_{\text{total}} - m_{\text{calorimeter}}$$

$$m_{\text{solution}} = 100\text{mL} \times 1 \text{ g/mL} \qquad m_{\text{measured}} = 109.6330 \text{ g} - 6.5912\text{g}$$

$$m_{\text{solution}} = 100 \text{ g} \qquad m_{\text{measured}} = 103.0418 \text{ g}$$

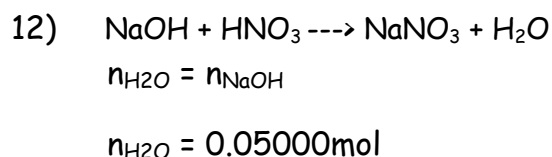
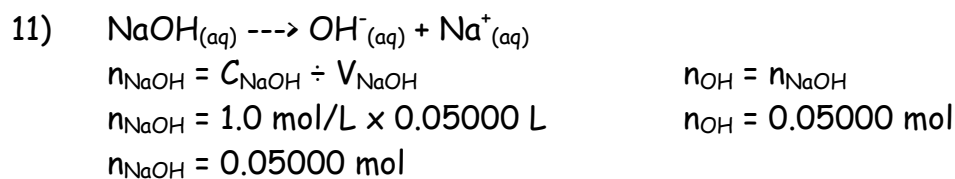
The measured mass is more accurate because the density of the final solution is an approximation using the graduated cylinder. M_{measured} uses the analytical balance which has a lower margin of error compared to the graduated cylinder.

$$10) \quad Q_N = -E_{\text{H}_2\text{O}}$$

$$Q_N = -(m_{\text{solution}} \times c_{\text{water}} \times \Delta T_{\text{solution}})$$

$$Q_N = -(100 \text{ g}) \times (4.18 \text{ J/g}^\circ\text{C}) \times (7.10^\circ\text{C})$$

$$Q_N = -2.97 \times 10^3 \text{ J}$$



$$13) \quad \Delta H_N = E_{\text{released}} \div n_{\text{HOH}}$$

$$\Delta H_N = -2.97 \times 10^3 \text{ J} \div 0.05000\text{mol}$$

$$\Delta H_N = -59.4 \text{ kJ/mol}$$

14) The heats of neutralization per mol of water for the two strong acids (HCl and HNO₃) are supposed to be equal however for HNO₃ it is -59.4 kJ/mol and for HCl it is -56.9 kJ/mol.

$$15) \quad \%_{\text{error}} = (-52.0 \text{ kJ/mol} - (-59.4 \text{ kJ/mol})) \div (-52.0 \text{ kJ/mol}) \times 100\%$$

$$= -14.2 \%$$

Literature Value of Enthalpy of Neutralization of NaOH & HCl: -58.0 kJ/mol

Source: <http://www2.ucdsb.on.ca/tiss/stretton/CHEM2/enthal06.htm>

Literature Value of Enthalpy of Neutralization of NaOH & HNO₃: -52.0 kJ/mol

Source : <http://www.cerlabs.com/experiments/10875406092.pdf>

Part 3 - Enthalpy of Dissolution of a Salt:

Part 3 Calculations

Value	Trial #1	Trial #2
$\Delta T_{\text{solution}}$	-5.08°C	-4.30°C
$-Q_{\text{water}}$	$4.10 \times 10^2 \text{ J}$	$3.59 \times 10^2 \text{ J}$
$-E_{\text{salt}}$	8.23 J	6.92 J
ΔH_s	13.1 kJ/mol	11.6 kJ/mol
%error	N/A	N/A

Data	Trial #1	Trial #2
Assigned Salt	C	C

- 16) $\Delta T_{\text{solution}} = T_2 - T_1$
 $\Delta T_{\text{solution}} = 19.90^\circ\text{C} - 24.98^\circ\text{C}$
 $\Delta T_{\text{solution}} = -5.08^\circ\text{C}$
- 17) $-Q_{\text{water}} = -(m_{\text{water}} \times c_{\text{water}} \times \Delta T_{\text{solution}})$
 $-Q_{\text{water}} = -(19.2851 \text{ g}) \times (4.18 \text{ J/g}^\circ\text{C}) \times (-5.08^\circ\text{C})$
 $-Q_{\text{water}} = 4.10 \times 10^2 \text{ J}$
- 18) $-E_{\text{salt}} = -m_{\text{salt}} \times c_{\text{salt}} \times \Delta T_{\text{salt}}$
 $-E_{\text{salt}} = -(5.0760 \text{ g}) \times (0.319 \text{ J/g}^\circ\text{C}) \times (-5.08^\circ\text{C})$
 $-E_{\text{salt}} = 8.23 \text{ J}$
- 19) $\Delta H_s = ((-\text{heat loss of H}_2\text{O}) + (-\text{heat loss of salt})) \div n_{\text{salt}}$
 $\Delta H_s = (4.10 \times 10^2 \text{ J} - 8.23 \text{ J}) \div (5.0760 \text{ g} \div 166.0 \text{ g/mol})$
 $\Delta H_s = (402 \text{ J}) \div (0.0305 \text{ mol})$
 $\Delta H_s = 13.1 \text{ kJ/mol}$

$$20) \quad \%_{\text{error}} = (\Delta H_{\text{S theoretical}} - \Delta H_{\text{S actual}}) \div \Delta H_{\text{S theoretical}} \times 100\%$$

- could not find correct literature value to calculate percent error

Discussion:

This lab consisted of three parts. The purpose of the first part of the lab was to find the specific and approximate molar mass of zinc. During this part, the zinc lost heat and the water temperature increased over time. Due to sources of error, the molar mass obtained was not similar to the actual molar mass of zinc. The molar mass in the first trial was found to be 73.7 g/mol and in the second trial to be 60.5 g/mol. These molar masses compared to the actual molar mass of zinc (65.384 g/mol) display a 12.7% (the molar mass was too high) and -7.47% (the molar mass was too low) error respectively. The reason for this source of error could have been because the specific heat capacity value was based on the assumption that no heat was lost from the calorimeter. However, when the zinc was placed into the calorimeter the lid was opened for a long period of time. Thus the assumption that no heat was lost is incorrect. Another source of error is the inconsistent swirling motion that was required to mix the contents in the calorimeter. This inconsistency led to slight jumps in the temperature observed in table 1.

The purpose of the second part of the lab was to find the enthalpy of neutralization of a strong acid and base. There was a difference in the mass of the measured solution in trial one and two. In trial 1 it was found to be 107.2257g and in trial 2 it was found to be 111.7497 g. There was a 7.2% error and an 11.7% error respectively when they were compared to the ideal mass of the solution. These experimental values were larger than the calculated value. A reason for such an error could be that when the calorimeter was used multiple times some of the other substances were left behind and thus added to the mass of the solution. When compared to a literature value, the enthalpy per mole of water for HCl had a percent error of -14.2% in trial one and -10.8% in trial 2. These experimental values were found to be much less than the real ones. This could have occurred because not all of the heat released by the solution was completely absorbed by the solution. Some of this heat may have escaped. The percent error occurred because the assumption was that no heat was lost. The information received from one of the groups for HNO₃ was not very accurate, as the actual masses and volume were assumed to be exactly the amount written in the lab manual, and no analytical balance was used.

The purpose of the third part of the experiment was to find the enthalpy of solution of an unknown salt. Throughout the experiment the temperature changed continuously. In both trials the temperature was generally decreasing. This means that the solution was releasing heat. In the first trial the temperature decreased rapidly and then stayed constant at 19.90° C. Where as in the second trial the temperature decreased rapidly and at the end the temperature started to increase again. The reason for such a pattern to occur is because the solution released heat for awhile until it reached its lowest possible temperature. After reaching that temperature, its surroundings are extremely hot. Therefore, the temperature of the solution begins to increase striving to reach room temperature.

Conclusion:

The specific molar mass of zinc is 65.384 g/mol. The approximated molar mass was found to be 73.7 g/mol (12.7% error) in trial 1 and 60.5 g/mol (-7.47% error) in trial 2. The enthalpies of neutralization of both acid were found to be for HCl -56.9 kJ/mol (1.89% error) and for HNO₃ -59.4 kJ/mol (-14.2% error). The enthalpies of neutralization of both acids were not found to be equivalent. The enthalpies of the salt were found to be 13.1 kJ/mol in trial 1 and 11.6 kJ/mol in trial 2.