

Thomas Lumsden - Calorimetry Lab Report

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Submission date: 02-May-2025 02:09PM (UTC+0100)

Submission ID: 257625212

File name: 60349_Thomas_Lumsden_Thomas_Lumsden_-
_Calorimetry_Lab_Report_590575_2029256844.docx (610.08K)

Word count: 1823

Character count: 8744

CALORIMETRY LAB REPORT

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highly professional presentation

1. Introduction

a) Purpose of experiment

The purpose of this calorimetry experiment is to measure the amount of thermal energy transferred in a chemical or physical process between system and surroundings. In this instance, it is to measure value of the heat capacity of the calorimeter, the specific heat capacity of aluminium & the molar heat of the reaction of HCl with NaOH. *clear and concise purpose*

b) Hypotheses undergoing testing

If all relevant parameters have been found and have been accurately measured, then these can be used alongside the required equations to calculate a precise value for the specific heat capacity of the calorimeter and aluminium, and the molar heat of the reaction.

c) Variables & Equations

The heat change Q (J) of the aluminium is calculated using mass (g), c_p is the specific heat capacity (J per g per °C) and ΔT is temperature change (°C):

$$Q = m \times c_p \times \Delta T$$

This equation is used to obtain the value of heat capacity of the calorimeter, $HC_{\text{calorimeter}}$:

$$Q_{\text{calorimeter}} = HC_{\text{calorimeter}} \times \Delta T_{\text{calorimeter}}$$

Calculate $Q_{\text{hot-water}}$ and $Q_{\text{cold-water}}$ with the equation above to find $Q_{\text{calorimeter}}$ to use with this equation:

$$-Q_{\text{hot-water}} = Q_{\text{cold-water}} + Q_{\text{calorimeter}}$$

This equation can be used to determine the specific heat capacity of a metal ($c_{p \text{ metal}}$). Only when all other parameters in question are found ($c_{p \text{ water}}$ is 4.186 J/(g°C)):

$$\begin{aligned} m_{\text{metal}} \times c_{p \text{ metal}} \times \Delta T_{\text{metal}} &= \\ &= - (m_{\text{water}} \times c_{p \text{ water}} \times \Delta T_{\text{water}} + HC_{\text{calorimeter}} \times \Delta T_{\text{calorimeter}}) \end{aligned}$$

To measure heat of reaction for a chemical process, heat exchanged by the metal (Q_{metal}) is substituted by the heat exchanged by the reaction:

$$Q_{\text{reaction}} = - (m_{\text{water}} \times C_{p \text{ water}} \times \Delta T_{\text{water}} + HC_{\text{calorimeter}} \times \Delta T_{\text{calorimeter}})$$

The number of moles of reactant is defined as $n_{\text{reactant}} = V_{\text{reactant}} \times C_{\text{reactant}}$, where V_{reactant} is the volume and C_{reactant} is the concentration.

$$n_{\text{reactant}} = V_{\text{reactant}} \times C_{\text{reactant}}$$

This equation is to find the molar heat of reaction, as the heat of reaction per mole of the limiting reactant:

$$q_{\text{reaction}} = \frac{Q_{\text{reaction}}}{n_{\text{reactant}}}$$

2. Results

a) Experimental Data

Results for measuring the heat capacity of the calorimeter:

$T_{\text{hot}} = 60.0 \text{ degC}$	$m_{\text{hot water}} = 50 \text{ ml}_{\text{sig fig}}$	$\Delta T_{\text{hot water}} = -15.4$
$T_{\text{cold}} = 23.1 \text{ degC}$	$m_{\text{cold water}} = 50 \text{ ml}_{\text{sig fig}}$	$\Delta T_{\text{cold water}} = 21.5$
$T_{\text{max}} = 44.6 \text{ degC}$		$\Delta T_{\text{calorimeter}} = 21.5$
$Q_{\text{cold water}} = 4499.95 \text{ J}$	$Q_{\text{hot water}} = -3223.22 \text{ J}$	$Q_{\text{calorimeter}} = -1276.73 \text{ J}$
$HC_{\text{calorimeter}} = -59.38 \text{ J/g}^\circ\text{C}$	<i>negative value of HC is incorrect; the final temperature reading was measured too high</i>	

$Q = m \times C_p \times \Delta T$ $Q_{\text{hot}} = 50 \times 4.186 \times -15.4$ $= -3223.22 \text{ J}$ $Q_{\text{cold}} = 50 \times 4.186 \times 21.5$ $= 4499.95 \text{ J}$	$Q_{\text{calorimeter}} = -Q_{\text{hot}} - Q_{\text{cold}}$ $= 3223.22 - 4499.95$ $= -1276.73 \text{ J}$ $HC_{\text{calorimeter}} = \frac{Q_{\text{calorimeter}}}{\Delta T_{\text{calorimeter}}}$ $HC_{\text{calorimeter}} = -1276.73 / 21.5$ $= -59.38 \text{ J/g}^\circ\text{C to 2 d.p}$
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Results for measuring the heat capacity of the metal:

Type of metal = Aluminium		
T _{hot} = 91°C	m _{metal} = 18.6g	ΔT _{metal} = -61.4°C
T _{cold} = 23.6°C	m _{water} = 30ml <i>ml is not a unit of mass</i>	ΔT _{water} = 6°C
T _{max} = 29.6°C		ΔT _{calorimeter} = 6°C
C _p _{metal} = 0.3478J/g°C		

all calculations are correct

time (s)	T _{WATER} (°C)
10	24.7
20	27.1
30	28.8
40	28.8
50	29.3
60	29.4
70	29.5
80	29.6
90	29.6
100	29.6
110	29.6
120	29.6

time (s)	T _{WATER} (°C)
130	29.6
140	29.6
150	29.6
160	29.5
170	29.6
180	29.6
190	29.6
200	29.6
210	29.5
220	29.5
230	29.5
240	29.5

time (s)	T _{WATER} (°C)
250	29.5
260	29.5
270	29.5
280	29.4
290	29.4
300	29.3
310	29.3
320	29.3
330	29.3
340	29.3
350	29.3
360	29.3

$$m_{\text{metal}} \times C_{p\text{metal}} \times \Delta T_{\text{metal}} =$$

$$= - (m_{\text{water}} \times C_{p\text{water}} \times \Delta T_{\text{metal}} + HC_{\text{calorimeter}} \times \Delta T_{\text{calorimeter}})$$

$$C_{p\text{metal}} =$$

$$= - \frac{(m_{\text{water}} \times C_{p\text{water}} \times \Delta T_{\text{metal}} + HC_{\text{calorimeter}} \times \Delta T_{\text{calorimeter}})}{m_{\text{metal}} \times \Delta T_{\text{metal}}}$$

$$= - \frac{((30 \times 4.186 \times 6) + (-59.38 \times 6))}{18.6 \times -61.4}$$

$$= 0.3478 \text{J/g}^\circ\text{C to 4 d.p}$$

Results for measuring the heat capacity of the molar heat of the reaction of:
 $\text{HCl} + \text{NaOH} \rightarrow \text{NaCl} + \text{H}_2\text{O}$:

$T_{\text{start}} = 26.9_{\text{degC}}$	$T_{\text{end}} = 32.9_{\text{degC}}$	
$V_{\text{HCl}} = 50\text{ml}$ <i>sig fig</i>	$C_{\text{HCl}} = 1\text{M}$	$n_{\text{HCl}} = 0.05\text{mol}$
$V_{\text{NaOH}} = 52\text{ml}$ <i>sig fig</i>	$C_{\text{NaOH}} = 1\text{M}$	$n_{\text{NaOH}} = 0.052\text{mol}$
$Q_{\text{reaction}} = -2206\text{J}$		$\Delta T_{\text{calorimeter}} = 6^\circ\text{C}$
$q_{\text{reaction}} = -44.11\text{kJ/mol}$		

all calculations are correct

$$\begin{aligned}
 Q_{\text{reaction}} &= -(m_{\text{water}} \times C_{p\text{water}} \times \Delta T_{\text{water}} + H C_{\text{calorimeter}} \times \Delta T_{\text{calorimeter}}) \\
 &= -((102 \times 4.186 \times 6) + (-59.38 \times 6)) \\
 &= -2205.552\text{J}
 \end{aligned}$$

$$n_{\text{reactant}} = V_{\text{reactant}} \times C_{\text{reactant}}$$

$$\begin{aligned}
 n_{\text{HCl}} &= 50 \times 10^{-3} \times 1 \\
 &= 0.05\text{mol}
 \end{aligned}$$

$$\begin{aligned}
 n_{\text{NaOH}} &= 52 \times 10^{-3} \times 1 \\
 &= 0.052\text{mol}
 \end{aligned}$$

$$q_{\text{reaction}} = \frac{Q_{\text{reaction}}}{n_{\text{reactant}}}$$

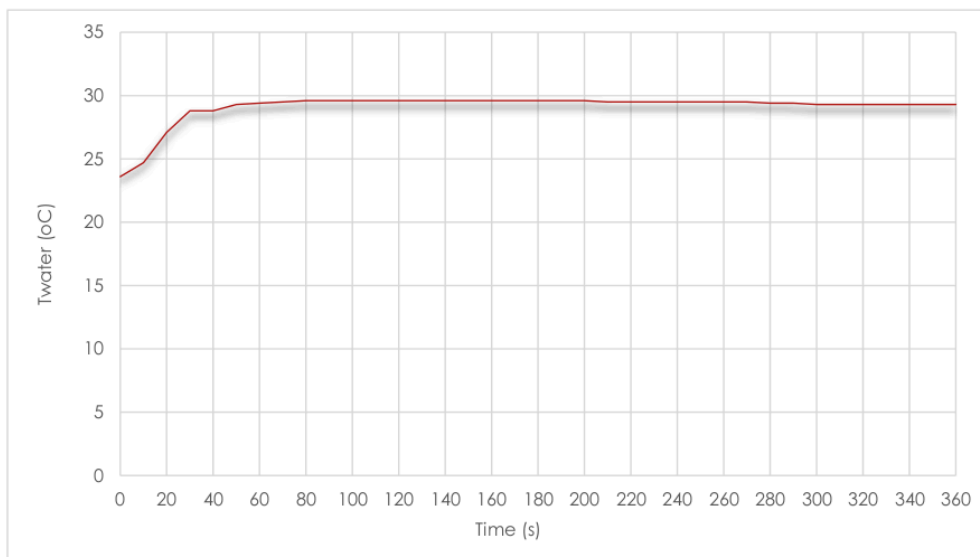
$$= -2205.55 / 0.05$$

$$q_{\text{reaction}} = -44.111 \text{ kJ/mol}$$

b) Results in tables/ graphs

Fig 1. Water temperature against time

~~Time against water temperature graph~~



c) Key findings and patterns

When measuring the time against water, the results gathered are as expected, as the temperature begins at T_{cold} which is 23.6 degrees, then quickly increases and eventually comes to a point where the temperature stays the same, until near the end where it slowly begins to lose temperature.

3. Discussion

a) Interpretation of experimental data *negative value of calorimeter heat capacity is not discussed*

The value calculated from the use of measurements and calculations for the specific heat capacity of the aluminium came out to $0.3478 \text{ J/g}^\circ\text{C}$. This value is lower than what was expected, as the specific heat capacity of aluminium is $0.897 \text{ J/g}^\circ\text{C}$. This suggests that either measurements were inaccurate, or a calculation has been done incorrectly.

The final value for the molar heat of the $\text{HCl} + \text{NaOH} \rightarrow \text{NaCl} + \text{H}_2\text{O}$ reaction came out to -44.111 kJ/mol and the heat of the reaction at -2205.552 J . Both these values came out as a negative. This tells us that the reaction is releasing heat, causing the temperature to rise.

b) Relevance of experiment in OME

Calorimetry can play a crucial role when it comes to developing new explosives as it provides knowledge into the energy released by the explosive, and the stability/safety variables at play. The partitioning of energy, and the rate of energy is controlled by either chemical, kinetic, or diffusion processes. Detonation calorimetry is used to investigate these processes [1].

Differential scanning calorimetry has been found to be a useful tool in energetic materials examinations in explosives. "This method is an application for direct monitoring of the changes of phase transitions and for assessment of the heat energy uptake, which occurs in a sample within a regulated increase or decrease in temperature" [2].

c) Limitations or potential error

A potential error that could take place when doing this experiment is if only a single styrofoam coffee cup is used. When stirring the solution with the stirring rod, it is possible to pierce through the single cup resulting in a spill of the liquid and loss of volume for the experiment. Using a single cup can also face consequence when pouring hot water, as when the water is boiled and poured into the cup, it is possible that it can melt through the thin layer of one cup instead of two. This could result in the experiment being a failure and a possible safety risk.

Exposure of the aluminium to air before it is used within the experiment could hinder the heat transfer, resulting in inaccurate readings. The layer of oxidation can impede on the rate at which the heat is transferred from the aluminium to the liquid, this reduces the amount of heat transferred within the measured time. *aluminum does not oxidise quickly in air; this is not a cause of error*

4. Conclusion

a) Summary of main findings

In conclusion, the experiment of calorimetry was successfully conducted, with correlating calculations and reasonable measurements. This led to being able to use the equations at hand to determine values for the heat capacity of the calorimeter, the specific heat capacity of aluminium and the molar heat of the reaction. This summary somewhat supports the hypothesis, as the values obtained were unexpected. This suggest there was a mishap with either calculations, or an inaccurate measurement of a substance.

b) Future research

Another area for further research that I have identified is conducting calorimetry experiments with different chemicals/ metals to be able to see how different chemicals react. Then compare their specific heat capacity to the answer that was derived from this one with aluminium. The same will be done with the molar heat of the reaction and the heat capacity of the calorimeter.

5. References

[1] Ornellas, D. L., "Calorimetric Determinations of the Heat and Products of Detonation for Explosives: October 1961 to April 1982", STIN...03, 1982.

[2] F. Bojana, S. Danica, D. Mirjana, T. Slavika, "Differential Scanning Calorimetry and Vacuum Stability Test as Methods to Determine Explosives Compatibility", Scientific Technical Review, 2020, Vol.70, No.3, pp.35-40. *inconsistency in authors' names*

6. Appendix

a) Materials & Equipment

Chemicals:

- Aluminium
- 52ml of NaOH
- 50ml of HCl
- Water

Equipment:

- 2x Styrofoam cups
- Lid
- Thermometer
- Stirring rod
- Stand & Clamp
- Tongs
- Bunsen Burner
- Glass beaker

b) Experimental procedure

Procedure to measure $H_{C_{\text{calorimeter}}}$:

- Add 50ml of water to the Styrofoam coffee cups, and seal with the lid. Add the thermometer and stirring rod.
- Take 50ml of water in a separate beaker and heat up to 80°C. Wait till the temperature reaches 60 °C. When the water has cooled off, record its temperature as T_{hot} .
- Measure the temperature of the water in the calorimeter and record it as T_{cold} .
- Add the hot water to the water in the calorimeter, and stir, while watching the thermometer, record the maximum equilibrium temperature of the mixture, record it as T_{max} .

Procedure to measure the specific heat capacity of the aluminium($C_{p, metal}$)

- Weigh the aluminium and record its mass as m_{metal} .
- Heat water until boiling and put aluminium into it. Continue boiling for another 5 minutes, to allow the metal to reach the same temperature as the water.
- While this is being done, measure 30.0ml of water and add it to the calorimeter. Measure the temperature of the water in the calorimeter and record it as T_{cold} .
- Once the metal has reached thermal equilibrium, measure and record the temperature of the hot water as T_{hot} , and quickly add the metal to the water in the calorimeter using tongs.
- Stir the water and record the temperature every 10 seconds ($time$, T_{water}). Record the maximum temperature reached by the water as T_{max} .

Procedure to measure the molar heat of reaction of HCl with NaOH ($q_{reaction}$)

- Place 52.0ml of 1.0 M NaOH into the calorimeter and pour 50.0 mL of 1.0 M HCl into a beaker.
- Place the two side-by-side until they attain the same temperature. Record this value as T_{start} .
- Add the HCl quickly to the calorimeter and record the temperature when it reaches a maximum as T_{end} .

End

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GRADEMARK REPORT

FINAL GRADE

62/100

GENERAL COMMENTS

Engagement with Literature Skills 9/15

Two sources are cited, one of which is outdated (1982), and IEEE formatting is inconsistent (e.g., author names and publication structure). Literature is confined to the OME relevance section and is not used to interpret experimental results or support calculations.

Feedback: Expand literature use throughout, apply correct IEEE formatting, and include references to support and interpret experimental results.

Knowledge and Understanding Skills 13/20

The aim and hypotheses are clear but general. Theoretical equations are presented correctly. Variables are discussed but not formally classified. general knowledge and understanding are demonstrated.

Feedback: Define variables.

Cognitive and Intellectual Skills 14/25

The report acknowledges experimental errors (e.g., calorimeter leaks or oxidation of aluminium - does not happen). Results are compared to expected values, but analysis remains superficial.

Feedback: Improve by analysing why results differ from literature values.

Practical Application Skills 16/25

The specific heat of aluminium ($0.3478 \text{ J/g}\cdot^\circ\text{C}$) and heat of reaction are correctly calculated but the final temperature of calorimeter in part 1 was measured too early and the value of HC although correctly calculated is not right. There are inconsistencies in units and sig figs.

Feedback: Attach raw data, ensure consistent units, and critically assess whether values are physically reasonable.

Transferable/Professional Skills 10/15

The report has a clear structure with headings, tables, and appendix. Writing is mostly appropriate, though some first-person statements are used, and a figure is included without full description. Language is generally fluent but lacks precision in places.

Feedback: Maintain good structure and tone, avoid first-person writing, and ensure all figures are fully referenced and discussed.

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PAGE 2

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PAGE 3

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PAGE 4

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