

Calorimetry Lab Report

by Pippa Shay

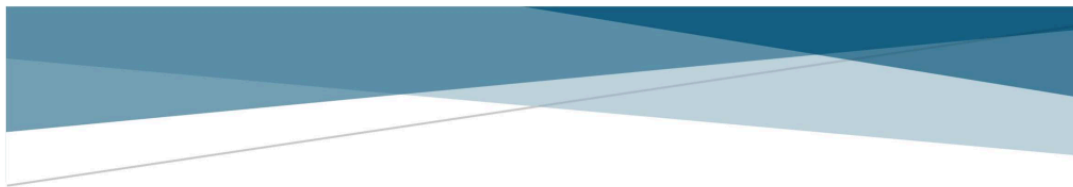
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Lab Report 3 – Calorimetry Experiment

Chemistry ACDB4011

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Section 1: Introduction

1.1 The purpose

The purpose of these experiments was to calculate specific heat capacity of a metal and reaction. Specific heat capacity is the amount of heat energy needed to raise the temperature of a unit mass of a substance by one degree Celsius [1,2]. This is an important measurement of a material as it is paramount to creating more efficient thermal management systems [2].

1.2 The Hypothesis

1.2.1 Experiment 1

The aim of this experiment was to calculate the heat capacity of the calorimeter by measuring the heat loss of the water inside it.

1.2.2 Experiment 2

The aim of this experiment was to calculate the specific heat capacity of a metal by measuring how much a hot piece of metal can raise the temperature of a specified amount of water in the calorimeter.

1.2.3 Experiment 3

The aim of this experiment was to calculate the molar heat of a reaction by calculating the temperature rise during the experiment.

these are all aims; hypothesis should have format: 'because of something, something else can be ...'

1.3 Variables

The control variables across all three experiments were:

- The calorimeter
- Ambient temperature
- The same thermometer

The independent variable in the first experiment was the temperature of the hot water added to the cold water. The independent variable for the second experiment was the temperature of the metal added to the cold water. The independent variable of the third experiment was amount of HCl added to the NaOH.

equilibrium

The dependent variable for the first experiment was the temperature of the combined water. The dependent variable for the second experiment was the maximum temperature the cold water reached with the hot piece of metal. The dependent variable of the third experiment was the maximum temperature reached in the reaction between HCl and NaOH.

Section 2: Results

2.1 Experiment 1

In this experiment two different temperature waters were mixed in a calorimeter giving one combined temperature. The results are shown below:

Table 1 – Results of Mixing Different Temperature Waters

	Original Temperature (°C)	Mass of Water (mL)	Temperature Change (°C)
Hot water	60.0	50	-13.4
Cold water	24.9	50	21.7

The maximum temperature of the water once mixed was 46.6 °C.

The purpose of this experiment was to determine the calorimeter's heat capacity. The above data could be used to find the energy lost or gained by the hot and cold water along with the calorimeter. These are found to be: *negative value of HC is incorrect; the final temperature reading was inaccurately measured too high*

Table 2 – Energies of Water and Calorimeter

Energy for Cold Water	Energy for Hot Water	Energy for Calorimeter
4500 J	-2800J	-1700 J

Using $HC_{\text{Calorimeter}} = Q_{\text{Calorimeter}} / \Delta T_{\text{Calorimeter}}$ the heat capacity for the calorimeter can be found to be -80.1J°C⁻¹.

2.2 Experiment 2

In this experiment a piece of metal was heated up then placed into cold water in the calorimeter. The temperature of the water at 10 second intervals after the hot metal was placed in are shown below:

Table 3 – Water Temperature Results

Time (s)	Temperature of Water (°C)
0	28.2
10	28.5
20	28.8
30	29.1
40	29.5
50	29.5
60	29.5
70	29.4
80	29.4
90	29.4
100	29.4
110	29.4
120	29.3
130	29.3
140	29.3
150	29.3

160	29.3
170	29.3
180	29.3
190	29.3
200	29.1
210	29.1
220	29.1
230	29.1
240	29.1
250	29.0
260	29.0
270	29.0
280	29.0
290	29.0
300	29.0
310	29.0
320	29.0
330	28.8
340	28.8
350	28.7

The maximum temperature was 29.5°C

.0

Using the temperature change and mass of the metal and water the specific heat capacity of the metal can be calculated. Those results can be seen below:

Table 4 – Temperature Change of the Metal and Water

	Temperature at Start (°C)	Mass (g)	Temperature Change <i>cpc of H₂O calculated properly</i>
Metal	75.0	18.5	-45.5
Water	21.7	30	7.8

The calorimeter is to be seen as in thermal equilibrium with the water so the temperature change for it is also 7.8 °C.

Using $m_{\text{metal}} \times c_{\text{p metal}} \times \Delta T_{\text{metal}} = -(m_{\text{water}} \times c_{\text{p water}} \times \Delta T_{\text{water}} + HC_{\text{calorimeter}} \times \Delta T_{\text{Calorimeter}})$ the specific heat capacity of the metal can be calculated to be 0.42 J/ (g °C).

.0

2.3 Experiment 3

In this experiment hydrochloric acid (HCl) and sodium hydroxide (NaOH) were mixed in the calorimeter to measure the temperature change during the reaction to be able to calculate the energy change. The information on the reactants used in the experiment can be seen below:

Table 5 – Information on Reactants

	Mass (g)	Concentration (mol)	Number of mols
HCl	50	1	1.4
NaOH	52	1	1.3

The start temperature of both reactants was 20.3 °C and the maximum temperature reached during the reaction was 26.9 °C giving a 6.3 °C temperature increase. *molar heat is measured in J/mol not J/g*

The energy in the reaction can be calculated using:

$$Q_{\text{reactant}} = - (m_{\text{water}} \times c_{p_{\text{water}}} \times \Delta T_{\text{water}} + HC_{\text{calorimeter}} \times \Delta T_{\text{calorimeter}})$$

This equation gives an answer of -2200J. *excellent statement; what could be done wrong?*

Meaning the molar heat can now be calculated, giving -21.4J g⁻¹ in this case.

Section 3: Discussion

excellent statement

3.1 General Overview

In experiment one the heat capacity of the calorimeter was found to be negative indicating that one of the calculations or results may be incorrect as in most situations it is impossible for the heat capacity to be negative. *excellent statement again*

In experiment two the specific heat capacity of the metal which was identified to be aluminium was 0.42 J/ (g °C). The printed specific heat capacity is 0.9 J/g °C [3] meaning the specific heat capacity found in the experiment had a high error percentage. This may have been due to the error in calculating the heat capacity of the calorimeter in experiment 1.

In experiment three the energy change in the experiment was negative meaning it was an exothermic reaction; this is further backed up by the temperature change being positive which also indicated an exothermic reaction.

3.2 Relevance to OME

Explosives only have a certain shelf life before they potentially self-ignite, the lifetime of high explosives and propellants containing nitrate esters can be determined by their decomposition time at ambient temperature [4]. This can also be called an aging reaction [5]. The time for this reaction to take place is determined by heat-flow calorimetry, usually at temperatures around 40°C-80°C, this data can then be extrapolated to ambient temperature [5].

3.3 Limitations and errors

In experiment 1 there was likely an error as the heat capacity was calculated to be a negative number which is impossible unless in certain circumstances. This could be due to insufficient stirring of the different temperature waters. Further testing where the experiment would be repeated is required to give a better idea.

Section 4: Conclusions

4.1 Summary

access date

Each experiment did give enough data to be able to calculate the required number. For experiment one the heat capacity of the calorimeter, for experiment two the specific heat capacity of the piece of metal and for experiment three the molar heat energy.

access date

4.2 Directions for Further Use *access date*

For these experiments results to become reliable they would have to be repeated many times. This would also help check if there was an error in experiment one.

Section 5: References

[1] S. Facts, "Specific Heat and Heat Capacity," 11 August 2024. [Online]. Available:

<https://www.sciencefacts.net/specific-heat.html>.

[2] D. Horizons "Understand Specific Heat Capacity: Factors and Engineering Applications" 2 July

2024. [Online] Available: [Understanding Specific Heat Capacity: Factors and Engineering Applications - DesignHorizons](#)

[3] N. Connor "Aluminium – Specific Heat Capacity" 13 November 2020. [Online] Available:

[Aluminium - Specific Heat Capacity](#)

[4] P. Bunyan, C. Baker, N. Turner, "Application of Heat Conduction Calorimetry to High Explosives" *Thermochimica Acta*, Vol. 401, Issue 1, pages 9-16, 12th May 2003.

[5] H. Bircher, "Explosive Substances and Their Applications: An Overview", *CHIMIA*, Vol. 58, Issue 6, page 355, 2004.

Section 6: Appendix

6.1 Materials and Method

6.1.1 Apparatus Needed for all Experiments

The apparatus needed are:

- Two stacked Styrofoam cups
- A lid
- A thermometer
- A stirring rod
- A clamp and stand

6.1.2 Experiment 1 Method

1. Add 50.0 mL of water to the Styrofoam coffee cups, and close with a lid. Add the thermometer and stirring rod to set up your calorimeter.
2. Take 50.0 mL of water in a separate beaker and heat to about 80 °C. Close the gas and wait till the temperature reaches 60 °C. When the "hot water" is ready, record its temperature as T_{hot} .
3. Measure the temperature of the water in the calorimeter and record it as T_{cold} .
4. Add the hot water to the water in the calorimeter, and mix thoroughly, while watching the thermometer. Record the maximum equilibrium temperature of the mixture, record it as T_{max} .
5. Calculate the **heat capacity of the calorimeter, $HC_{calorimeter}$**

6.1.3 Experiment 2 Method

1. Obtain a piece of the metal sample. Weigh the metal and record its mass as m_{metal} .
2. Set up a water bath, heat the water until boiling, and then carefully put the metal into it. Keep boiling for another 5 minutes, to allow the metal to reach the same temperature as the water. Try to avoid heating the metal directly! To reduce the effect of direct heating, close the gas after 5 min and wait 2 minutes for the temperature of boiling water and piece of metal to equilibrate.
3. While this is being done, measure 30.0 mL of water and add it to the calorimeter. Measure the temperature of the water in the calorimeter, as done previously, and record it as T_{cold} .
4. Once the metal has reached "thermal equilibrium" with the boiling water, measure and record the temperature of the hot water as T_{hot} and quickly add the metal to the water in the calorimeter using the tongs.
5. Stir the water and record the temperature every 10 seconds, filling in the datasheet provided at the end of this script with the entries (*time, T_{water}*). The temperature will increase at the start. Continue until the temperature of the water has reached a maximum and then cooled down by about 2 °C. Record the maximum temperature reached by the water as T_{max} .
6. Calculate $c_{p, metal}$ the **specific heat of the metal**

6.1.4 Experiment 3 Method

1. Place 52.0 mL of 1.0 M NaOH into the calorimeter and pour 50.0 mL of 1.0 M HCl into a beaker.
2. Place the two side-by-side until they attain the same temperature. Record this value as T_{start} .
3. Add the HCl quickly to the calorimeter and record the temperature when it reaches a maximum as T_{end} .
4. Calculate $Q_{reaction}$, the heat of reaction
5. Calculate $q_{reaction}$, the molar heat of reaction

6.2 Scan on the original data sheet

University of Wales Trinity Saint David – OME Programme

DATA SHEET to RECORD OBSERVATIONS, CALCULATIONS and RESULTS

STUDENT'S NAME: Pippa Shay
PARTNERS' NAMES: Charlotte McCombe

REPORT IS DUE MAY 02, 2025 (DD May 09, 2025) submitted via Moodle

1. Measure the value of the heat capacity of the calorimeter ($HC_{\text{calorimeter}}$)

Use these entries to record your experimental data, results, and calculations.

$T_{\text{hot}} = 60.0^{\circ}\text{C}$ $m_{\text{hot water}} = 50\text{ml}$ $\Delta T_{\text{hot water}} = -13.4^{\circ}\text{C}$
 $T_{\text{cold}} = 24.9^{\circ}\text{C}$ $m_{\text{cold water}} = 50\text{ml}$ $\Delta T_{\text{cold water}} = 21.7^{\circ}\text{C}$
 $T_{\text{max}} = 46.6^{\circ}\text{C}$ $\Delta T_{\text{calorimeter}} = 21.7^{\circ}\text{C}$
 $Q_{\text{cold water}} = 4,500\text{J}$ $Q_{\text{hot water}} = -2,800\text{J}$ $Q_{\text{calorimeter}} = -1,700\text{J}$
 $HC_{\text{calorimeter}} = -80.1\text{J}^{\circ}\text{C}^{-1}$

Write the calculations for $Q_{\text{HOT-WATER}}$, $Q_{\text{COLD-WATER}}$, $Q_{\text{CALORIMETER}}$, and $HC_{\text{CALORIMETER}}$:

$$\begin{aligned} 46.6 - 24.9 &= \Delta T_{\text{cold water}} = 21.7 \\ 46.6 - 60.0 &= \Delta T_{\text{hot water}} = -13.4 \\ Q &= m \times c_p \times \Delta T \\ Q_{\text{cold}} &= 50\text{g} \times 4.186\text{J}/(\text{g}^{\circ}\text{C}) \times 21.7^{\circ}\text{C} = 4541.81\text{J} \\ Q_{\text{hot}} &= 50\text{g} \times 4.186\text{J}/(\text{g}^{\circ}\text{C}) \times -13.4^{\circ}\text{C} = -2804.62\text{J} \\ -Q_{\text{hot}} &= Q_{\text{cold}} + Q_{\text{calorimeter}} \\ -(-2804.62) &= 4541.81 + Q_{\text{calorimeter}} \\ Q_{\text{calorimeter}} &= 2804.62 - 4541.81 = -1737.19\text{J} \\ Q_{\text{calorimeter}} &= HC_{\text{calorimeter}} \times \Delta T_{\text{calorimeter}} \\ HC_{\text{calorimeter}} &= \frac{Q_{\text{calorimeter}}}{\Delta T_{\text{calorimeter}}} = \frac{-1737.19\text{J}}{21.7^{\circ}\text{C}} = -80.05483871\text{J}^{\circ}\text{C}^{-1} \end{aligned}$$

2. Measure the specific heat capacity of a metal ($c_{p \text{ metal}}$)

Use these entries to record your experimental data, results, and calculations.

Type of metal = aluminium $T_{\text{hot}} =$ 75.0 °C $m_{\text{metal}} =$ 18.5g $\Delta T_{\text{metal}} =$ -45.5 °C $T_{\text{cold}} =$ 21.7 °C $m_{\text{water}} =$ 30mL $\Delta T_{\text{water}} =$ 7.8 °C $T_{\text{max}} =$ 29.5 °C $\Delta T_{\text{calorimeter}} =$ 7.8 °C $c_{p \text{ metal}} =$ 0.425 J/(g °C)

time (s)	$T_{\text{WATER}} (^{\circ}\text{C})$
0	~~28.2~~ 28.2
10	28.5
20	28.8
30	29.1
40	29.5
50	29.5
60	29.5
70	29.4
80	29.4
90	29.4
100	29.4
110	29.4

time (s)	$T_{\text{WATER}} (^{\circ}\text{C})$
120	29.3
130	29.3
140	29.3
150	29.3
160	29.3
170	29.3
180	29.3
190	29.3
200	29.1
210	29.1
220	29.1
230	29.1

time (s)	$T_{\text{WATER}} (^{\circ}\text{C})$
240	29.1
250	29.0
260	29.0
270	29.0
280	29.0
290	29.0
300	29.0
310	29.0
320	29.0
330	28.8
340	28.8
350	28.8

Write the calculations for $c_{p \text{ metal}}$:

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

$$18.5 \text{ g} \times c_{p \text{ metal}} \times -45.5 ^{\circ}\text{C} = -(30 \text{ g} \times 4.186 \text{ J/(g } ^{\circ}\text{C}) \times 7.8 + 80 \text{ J } \times 7.8)$$

$$c_{p \text{ metal}} = \frac{-(30 \text{ g} \times 4.186 \text{ J/(g } ^{\circ}\text{C}) \times 7.8 + 80 \text{ J } \times 7.8)}{18.5 \text{ g} \times -45.5 ^{\circ}\text{C}}$$

$$c_{p \text{ metal}} = 0.4214365 \text{ J/g } ^{\circ}\text{C} \rightarrow 0.42 \text{ J/g } ^{\circ}\text{C}$$

3. Measure the molar heat of reaction of HCl with NaOH (q_{reaction})

Use these entries to record your experimental data, results, and calculations.

$T_{\text{start}} = 20.3 \quad T_{\text{end}} = 26.9$

$V_{\text{HCl}} = 50 \text{ mL} \quad C_{\text{HCl}} = 1 \text{ mol} \quad n_{\text{HCl}} = 1.4$

$V_{\text{NaOH}} = 52 \text{ mL} \quad C_{\text{NaOH}} = 1 \text{ mol} \quad n_{\text{NaOH}} = 1.3$

Write the formula of the limiting reactant: NaOH

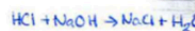
$Q_{\text{reaction}} = -2200 \text{ J}$

$q_{\text{reaction}} = -21.4 \text{ Jg}^{-1}$

$$\frac{m}{n \mid \text{MM}}$$

$$\frac{50 \text{ g}}{35 \text{ g/mol}}$$

$$\frac{52 \text{ g}}{40 \text{ g/mol}}$$

Write the calculations for Q_{reaction} and q_{reaction} .

$$\begin{aligned}
 Q_{\text{reaction}} &= - (m_{\text{water}} \times C_{p_{\text{water}}} \times \Delta T_{\text{water}} + m_{\text{calorimeter}} \times \Delta T_{\text{calorimeter}}) \\
 &= - (102 \text{ g} \times 4.186 \text{ J/g}^\circ\text{C} \times 6.3^\circ\text{C} + (-80.0 \text{ J}^\circ\text{C}^{-1}) \times 6.3^\circ\text{C}) \\
 &= -2185.2936 \text{ J}
 \end{aligned}$$

$$\begin{aligned}
 q_{\text{reaction}} &= \frac{Q_{\text{reaction}}}{m_{\text{reactant}}} \\
 &= \frac{-2185.2936 \text{ J}}{102 \text{ g}} = -21.4244 \text{ Jg}^{-1}
 \end{aligned}$$

Calorimetry Lab Report

GRADEMARK REPORT

FINAL GRADE

60/100

GENERAL COMMENTS

Engagement with Literature Skills 9/15

Five references are cited, mostly websites, which lowers scientific quality. IEEE formatting is mostly consistent but access dates for online sources are missing. Literature is mainly used for background, with little application to data analysis or calculations.

Feedback: Prioritise peer-reviewed sources and add access dates. Integrate literature to support and evaluate your findings.

Knowledge and Understanding Skills 12/20

The report states a clear aim and valid hypothesis based on energy conservation. Scientific principles of calorimetry are briefly introduced. Key equations such as

=

Δ

$Q=mc\Delta T$ are presented but not fully discussed or related to the experimental design. Variables are correctly identified for each experiment. However, the report incorrectly refers to “maximum temperature” instead of the correct term, “equilibrium temperature”, which is the point at which heat exchange ceases.

Feedback: Explain scientific principles in more depth, clarify how equations relate to your objectives, and use correct terminology (“equilibrium temperature”).

Cognitive and Intellectual Skills 13/25

The negative calorimeter heat capacity is acknowledged but not explored further. Results are not compared to literature values and uncertainty is not addressed. The OME relevance section is included but only briefly.

Feedback: Analyse result deviations in more depth, compare values to literature, and improve connection between the method and OME applications.

Practical Application Skills 15/25

The experiment is structured logically, and scanned handwritten calculations are provided in the appendix. However, these are not fully explained or referenced in the report text. Units and significant figures are mostly consistent. Moles of HCl and NaOH are incorrectly calculated.

Feedback: Refer clearly to appendix calculations, apply consistent units and sig figs, and critically assess any unexpected results.

Transferable/Professional Skills 11/15

The report is well structured with clear headings and generally formal language. Figures and tables are included but not always referenced or discussed. Minor grammar and formatting issues are present but do not majorly affect clarity.

Feedback: Integrate figures more fully into the discussion.

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PAGE 2

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PAGE 3

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