



James Burton

Lab Report 3 – Calorimetry

University of Wales, Trinity St Davids
Ordnance, Munitions and Explosives(Beng) – Chemistry

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1 Introduction

For this experiment the aim is to understand how heat transfer effects the specific heat capacity of water, a metal material, in this case an aluminium block, and a calorimeter, the equipment used to measure specific heat capacity which is made up of a closed styrofoam cup, a thermometer and a stirring rod.

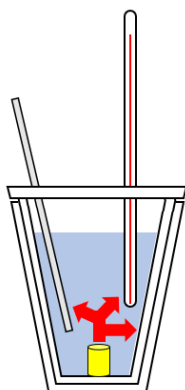


Figure 1 - Calorimeter Setup

This experiment identifies the change in temperature of the water by understanding its starting temperature and the temperature when it reaches equilibrium, which is to say the maximum temperature point when mixed with a substance of a different temperature.

This temperature, along with the mass of the body of water and the specific heat capacity of a material, which is the amount of energy required to raise 1g of material by 1K (or 1°C), can then be used to calculate and identify the heat change in Joules(J).

The Equation used to calculate this is as follows:

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

Equation 1 - Calculating the Energy Change of a Material

Where:

Q = The heat change in Joules(J)

m = The mass of a material in grams(g)

ΔT = The temperature change in Degrees Celsius ($^{\circ}\text{C}$)

C_p = The specific heat capacity in Joules per Gram per Degrees Celsius ($\text{Jg}^{-1}\text{C}^{-1}$)

Other equations used in this experiment are as follows:

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

Equation 2 - Calculating the Change in Energy of Hot water

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

Equation 3 - Calculating the Change in Energy of a Calorimeter

$$-Q_{\text{metal}} = Q_{\text{water}} + Q_{\text{calorimeter}}$$

Equation 4 - Calculating the Change in Energy of a Metal Substance

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

Equation 5 - Combining Equation 1 and Equation 4 to Understand the Relationship Between a Metal Substance and the Calorimeter

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

Equation 6 - Calculating the Total Heat of Reaction

$$n = V \times C$$

Equation 7 - Calculating the Number of Moles Within a Substance

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

Equation 8 - Calculating the Molar Heat of a Reaction Using the Limiting Reactant

Using these equations, it is predicted that the experiment will provide an understanding of heat transfer between the same and different materials, as well

as how heat transfer is effected between materials of different conductivities and reactivities, identifying limiting reactants for the latter.

2 Results

2.1 Tables of results

2.1.1 Measuring the heat capacity of the calorimeter ($HC_{\text{calorimeter}}$)

$$T_{\text{hot}} = 60.0^{\circ}\text{C} \quad m_{\text{hot water}} = 50.0\text{g} \quad \Delta T_{\text{hot water}} = -18.9^{\circ}\text{C}$$

$$T_{\text{cold}} = 20.2^{\circ}\text{C} \quad m_{\text{cold-water}} = 50.0\text{g} \quad \Delta T_{\text{cold water}} = 20.9^{\circ}\text{C}$$

$$T_{\text{max}} = 41.1^{\circ}\text{C} \quad \Delta T_{\text{calorimeter}} = 20.9^{\circ}\text{C}$$

$$Q_{\text{cold-water}} = 4400\text{J} \quad Q_{\text{hot water}} = -4000\text{J} \quad Q_{\text{calorimeter}} = 420\text{J}$$

$$HC_{\text{calorimeter}} = 20\text{Jg}^{-1}\text{C}^{-1}$$

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

$$Q_{\text{Cold-water}} = m_{\text{cold-water}} \times C_{p \text{ cold-water}} \times \Delta T_{\text{cold-water}}$$

$$Q_{\text{Cold-water}} = 50.0(\text{g}) \times 4.186(\text{Jg}^{-1} \text{ }^{\circ}\text{C}^{-1}) \times 20.9(^{\circ}\text{C}) = 4374.37\text{J} = 4400\text{J to 2 S.F.}$$

$$Q_{\text{hot-water}} = m_{\text{hot-water}} \times C_{p \text{ hot-water}} \times \Delta T_{\text{hot-water}}$$

$$Q_{\text{hot-water}} = 50.0(\text{g}) \times 4.186(\text{Jg}^{-1} \text{ }^{\circ}\text{C}^{-1}) \times -18.9(^{\circ}\text{C}) = -3955.77\text{J} = -4000\text{J to 2 S.F.}$$

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

Re-arrange to find $Q_{\text{calorimeter}}$

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

$$Q_{\text{calorimeter}} = 4374.37(\text{J}) - 3955.77(\text{J}) = 418.6\text{J} = 420\text{J to 2 S.F.}$$

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

Re-arrange to find $HC_{\text{calorimeter}}$

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

$$HC_{\text{calorimeter}} = \frac{Q_{\text{calorimeter}}}{\Delta T_{\text{calorimeter}}} = \frac{418.6(\text{J})}{20.9(^{\circ}\text{C})} = 20.03\text{Jg}^{-1} \text{ }^{\circ}\text{C}^{-1} = 20\text{Jg}^{-1} \text{ }^{\circ}\text{C}^{-1}$$

2.1.2 Measuring the specific heat capacity of a metal ($C_{p\text{ metal}}$)

Type of metal = Aluminium

$$T_{\text{hot}} = 91.4^{\circ}\text{C} \quad m_{\text{metal}} = 18.6\text{g} \quad \Delta T_{\text{metal}} = -59.8^{\circ}\text{C}$$

$$T_{\text{cold}} = 21.5^{\circ}\text{C} \quad m_{\text{water}} = 30.0\text{g} \quad \Delta T_{\text{water}} = 10.1^{\circ}\text{C}$$

$$T_{\text{max}} = 31.6^{\circ}\text{C} \quad \Delta T_{\text{calorimeter}} = 10.1^{\circ}\text{C}$$

$$C_{p\text{ metal}} = 1.3\text{Jg}^{-1}\text{C}^{-1}$$

time (s)	$T_{\text{WATER}} (^{\circ}\text{C})$	time (s)	$T_{\text{WATER}} (^{\circ}\text{C})$	time (s)	$T_{\text{WATER}} (^{\circ}\text{C})$
0	31.6	120	27.7	240	26.8
10	31.5	130	27.6	250	26.7
20	31.4	140	27.5	260	26.7
30	29.9	150	27.3	270	26.6
40	29.5	160	27.3	280	26.6
50	29.3	170	27.1	290	26.6
60	28.9	180	27.0	300	26.6
70	28.6	190	26.9	310	26.6
80	28.5	200	26.9	320	26.6
90	28.3	210	26.9	330	26.6
100	28.1	220	26.9	340	26.6
110	28.0	230	26.8	350	26.6

Table 1 - Temperature of Water at 10 Second Intervals from Max Temperature to Equilibrium.

Calculations for $C_{p\text{ metal}}$:

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

Re-arrange to find $C_{p\text{ metal}}$

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

$$C_{p\text{ metal}} = \frac{-(30.0(\text{g}) \times 4.186(\text{Jg}^{-1} \text{ } ^{\circ}\text{C}^{-1}) \times 10.1(\text{ } ^{\circ}\text{C}) + 20.03(\text{Jg}^{-1}) \times 10.1(\text{ } ^{\circ}\text{C}))}{18.6(\text{g}) \times -59.8(\text{ } ^{\circ}\text{C})}$$

$$= 1.32\text{Jg}^{-1} = 1.3\text{Jg}^{-1} \text{ to } 2 \text{ S. F.}$$

2.1.3 Measuring the molar heat of reaction of HCl with NaOH (*q_{reaction}*)

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

$$T_{start} = 19.4^{\circ}\text{C} \quad T_{end} = 26.7^{\circ}\text{C}$$

$$V_{HCl} = 50.0\text{mL} \quad C_{HCl} = 1.0\text{M}(?) \quad n_{HCl} = 0.05\text{ML}^{-1}$$

$$V_{NaOH} = 52.0\text{mL} \quad C_{NaOH} = 1.0\text{M}(?) \quad n_{NaOH} = 0.052\text{ML}^{-1}$$

Write the formula of the limiting reactant:



$$Q_{reaction} = -3300\text{J}$$

$$q_{reaction} = 65\text{KJmol}^{-1}$$

Calculations for $Q_{reaction}$ and $q_{reaction}$:

First, calculate the number of moles for both HCl and NaOH:

$$n = V \times C$$

$$n_{HCl} = V_{HCl} \times C_{HCl} = 0.05(\text{L}) \times 1.0(\text{M}) = 0.05\text{ML}^{-1} = n_{\text{reactant}}$$

$$n_{NaOH} = V_{NaOH} \times C_{NaOH} = 0.052(\text{L}) \times 1.0(\text{M}) = 0.052\text{ML}^{-1}$$

Next calculate the total heat of the reaction:

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

$$Q_{reaction} = -(102(\text{mL}) \times 4.186(\text{Jg}^{-1} \text{ } ^{\circ}\text{C}^{-1}) \times 7.3(^{\circ}\text{C}) + 20.03(\text{Jg}^{-1} \text{ } ^{\circ}\text{C}^{-1}) \times 7.3(^{\circ}\text{C}))$$

$$Q_{reaction} = -3263.1146\text{J} = -3300\text{J to 2 S.F.}$$

Finally calculate $q_{reaction}$:

$$q_{reaction} = \frac{Q_{reaction}}{n_{\text{reactant}}} = \frac{-3263.1146}{0.05} = -65262.292\text{Jmol}^{-1} = 65\text{KJmol}^{-1} \text{ to 2 S.F.}$$

2.2 Graphical representation

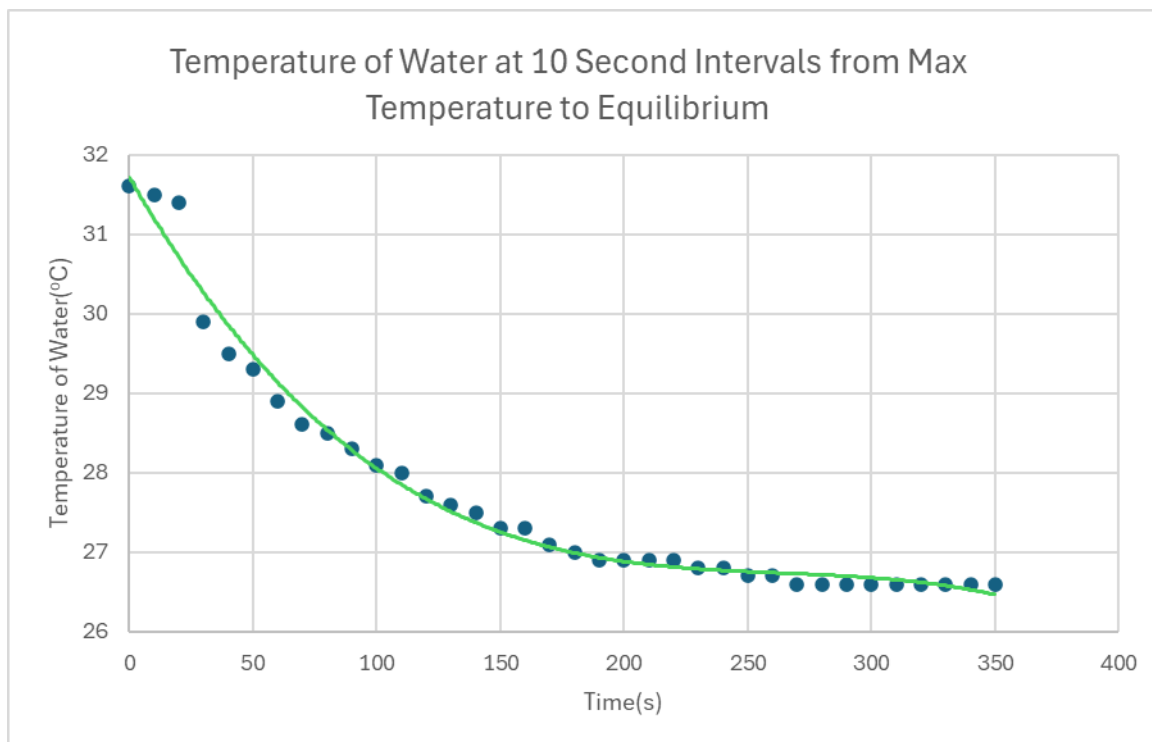


Figure 2 - Temperature Decay to Equilibrium During Hot Metal Reaction

This Graphical representation shows the individual measured figures as well as a line of best fit to understand the trend in which the equilibrium was reached.

2.3 Key Findings

Key findings include understanding and acknowledgement of the transfer of energy from a more conductive material to a less conductive material, where the more conductive material retained and dispersed heat at both a slower rate and much less amount.

Other key findings include understanding how the breaking and formation of bonds between atoms of reactive substances releases energy in the form of heat, as well as how that heat can be measured to understand the amount of energy released within 1 mole of reaction.

3 Discussion

3.1 Significance of findings

The significance of these findings show that the energy transfer as well as energy required to break and forms can be measured and calculated practically, allowing a better understanding of atom interaction on a molecular scale, which in turn would allow prediction and simulation of reactions and outcomes of said reactions.

3.2 Relevance to OME

Within OME, a type of calorimetry known as Bomb Calorimetry is used to understand heat transfer and total heat of the exothermic reaction of a detonation or deflagration.

This can be tested, according to Richard E. Lyons article on '*Thermal Dynamics of bomb calorimeters*' within, he explains: "*The thermal dynamics of bomb calorimeters are modeled using a lumped heat transfer analysis in which heat is released in a pressure vessel/bomb immersed in a stirred water bath that is surrounded by a static air space bounded by an insulated (static) jacket, a constant/controlled temperature jacket (isoperibol), or a changing temperature (adiabatic) jacket.*"[1]

This method is similar to part 3 of the experiment undertaken 'Measuring the molar heat of reaction of HCl with NaOH', except applied to explosives on a much larger scale.

3.3 Limitations and sources of error in the experiment

Limitation of this experiment and the recordings are that the rate of reaction was not a part of the calculation, however with that said an error was made during its conduct where the change in heat during the transfer of energy from metal was not recorded correctly, instead of being recorded at first exposure as was instructed the measurements were taken from the equilibrium point, and only the decay of heat was measured thereafter.

4 Conclusions

4.1 Summary and Evaluation

To summarise, the rate of heat transfer and decay between same and different substances was identified during this experiment, including heat created by the breaking and formation bonds between reactant materials in a solution. This supports the hypothesis that heat transfer is dependent on reactivity of the mixture and conductivity of the materials, as well as identified the limiting reactant of the mixture between HCl and NaOH. A mistake picked up was that the rate of heat transfer during the measuring of the specific heat capacity of the metal, where the heat was recorded after it had reached equilibrium and not from first reaction.

4.2 Direction for Future Research

Future research conducted would take place on other materials and substances to understand the latent heat capacity of materials which may be used in the OME industry, as well as the heat generated by substances when mixed to ensure a full understanding of such substances which may be used in the same industry. It could also be expanded upon to understand the kinetic energy output and therefore expansion or speed of any explosives upon deflagration or detonation[2].

5 References

[1]R.E.Lyon.“Thermal Dynamics”, *Review on Scientific Instruments*, Volume 86, issue 12, Page 1503, 20151204.

[2]A.R.Davis. ND. “Detonation Calorimeter: Application and Operation for Thermobaric Explosive Characterization and Evaluation”. Available at: https://d1wqtxts1xzle7.cloudfront.net/34632181/046-libre.pdf?1409878734=&response-content-disposition=inline%3B+filename%3DDetonation_Calorimeter_Application_and_O.pdf&Expires=1745506620&Signature=EUn8VNHmMqNphwhN0N-OynLJTpLmbKFVq04wGh89P0uiyz05e5lgB7V7ne5905J6LYYNteJW-nfG89nayWkueRopLCcOcP5cBI1PJKcoHIhfZY0xvJ3dENz1aWxIsSI3bU6l81BJnUZ3-KwKzTSFseo9SUdX0w4cilU1h0XxfqguWyDNOMY8q0w-yrYcaqC1OclF6DthccdHrQqQmkDaMlqXRnlxgmTT1nM-oHk5tC3y1afCt-phe3tKiw1crFXqiQQulAsJU0tzawscaPC41rHicGQTjSicaDopFpwuHA9mZRYDUMfKOKn~qVNOdEVWIYX1UtR1dqM1-qJXC57g_&Key-Pair-Id=APKAJLOHF5GGSLRBV4ZA. Accessed 20250424.

6 Appendix

6.1 List of Materials and Equipment

- Bunsen Burner
- Beaker
- Tripod a Gauze
- Heat Mat
- Sittring Rod
- Thermometer(digital)
- Calorimeter
- Block of Aluminium

6.2 Procedure

6.2.1 Measuring the value of the heat capacity of the calorimeter ($HC_{\text{calorimeter}}$)

- (6.2.1.1) 50.0 mL of water was added to the Styrofoam coffee cups, which was then closed with a lid. The thermometer and stirring rod was then added to set up the calorimeter.
- (6.2.1.2) 50.0 mL of water was taken in a separate beaker and heated to about 80 °C. The gas was closed and the apparatus left until the temperature reached 60 °C. When the "hot water" was ready, its temperature was recorded as T_{hot} .
- (6.2.1.3) The temperature of the water in the calorimeter was measured and recorded as T_{cold} .
- (6.2.1.4) The hot water was added to the water in the calorimeter and mixed thoroughly, whilst watching the thermometer. The maximum equilibrium temperature of the mixture was recorded as T_{max} .
- (6.2.1.5) The heat capacity of the calorimeter, $HC_{\text{calorimeter}}$, was calculated using Eq. 1, Eq.2, and Eq.3:

$$-Q_{\text{hot-water}} = Q_{\text{cold-water}} + Q_{\text{calorimeter}} \quad (\text{Eq.2})$$

$$Q_{\text{calorimeter}} = HC_{\text{calorimeter}} \times \Delta T_{\text{calorimeter}} \quad (\text{Eq.3})$$

where $Q_{\text{hot-water}}$ is the heat lost by the hot water, while $Q_{\text{Cold-water}}$ and $Q_{\text{calorimeter}}$ are the amounts of heat gained by the cold water and calorimeter, respectively. $Q_{\text{hot-water}}$ and $Q_{\text{cold-water}}$ was calculated with

Eq.1, then Eq. 2 was used to find $Q_{\text{calorimeter}}$, and finally Eq.3 to obtain the value of heat capacity of the calorimeter, $HC_{\text{calorimeter}}$.

Note: The mass (m) and temperature change (ΔT) for both the *hot* and *cold* water was obtained from the experimental data, also the ΔT of the calorimeter was found from the same data. For example, $\Delta T_{\text{cold-water}} = T_{\text{max}} - T_{\text{cold}}$. Assume that the calorimeter is in thermal equilibrium with the water during the experiment. The specific heat capacity of water used $c_p \text{ water} = 4.186 \text{ J/(g}^\circ\text{C)}$.

6.2.2 Measuring the specific heat capacity of a metal ($c_p \text{ metal}$)

Using the same apparatus as before (Figure 1).

- (6.2.2.1) A piece of the metal sample was obtained and weighed, with its mass recorded as m_{metal} .
- (6.2.2.2) A water bath was set up and heated until the water was boiling, and then the metal was placed carefully into it. It was kept boiling for another 5 minutes, to allow the metal to reach the same temperature as the water. The gas was closed after 5 min and left for 2 minutes for the temperature of boiling water and piece of metal to equilibrate.
- (6.2.2.3) Whilst this was being done, 30.0 mL of water was measured and added to the calorimeter. The temperature of the water in the calorimeter was measured, as done previously, and recorded as T_{cold} .
- (6.2.2.4) Once the metal had reached "thermal equilibrium" with the boiling water, the temperature of the hot water was measured and recorded as T_{hot} , then quickly the metal was added to the water in the calorimeter using the tongs.
- (6.2.2.5) The water was stirred, and the temperature recorded every 10 seconds, filling in the datasheet provided with the entries (*time*, T_{water}). This was continued until the temperature of the water has reached a maximum and then cooled down by about 2 $^\circ\text{C}$. The maximum temperature reached by the water was recorded as T_{max} .
- (6.2.2.6) The specific heat of the metal ($c_p \text{ metal}$) was calculated using Eq.5 and the value of heat capacity of the calorimeter found previously. Assuming that calorimeter and water are in thermal equilibrium, $c_p \text{ water} = 4.186 \text{ J/(g}^\circ\text{C)}$.

6.2.3 Measuring the molar heat of reaction of HCl with NaOH (q_{reaction})

Use the same apparatus as before (Figure 2).

- (6.2.3.1) 52.0 mL of 1.0 M NaOH was placed into the calorimeter and 50.0 mL of 1.0 M HCl poured into a beaker.
- (6.2.3.2) The two were placed side-by-side until they attained the same temperature. This value was recorded as T_{start} .
- (6.2.3.3) The HCl was added quickly to the calorimeter and the temperature recorded when it reached a maximum as T_{end} .
- (6.2.3.4) The heat of reaction, Q_{reaction} , was calculated using Eq.6 and the heat capacity of the calorimeter found previously. Again, it was assumed that calorimeter and water are in thermal equilibrium, $c_{\text{p water}} = 4.186 \text{ J/(g}^\circ\text{C)}$.
- (6.2.3.5) The molar heat of reaction, q_{reaction} , was calculated as the heat of reaction per mole of the **limiting reactant**, i.e.:

$$q_{\text{reaction}} = \frac{Q_{\text{reaction}}}{n_{\text{reactant}}} \text{ (Eq.8)}$$

where the number of moles of reactant is:

$$n_{\text{reactant}} = V_{\text{reactant}} \times C_{\text{reactant}} \text{ (Eq.7),}$$

where:

V_{reactant} is the volume of LIMITING reactant

C_{reactant} is the concentration of LIMITING reactant

n_{reactant} is the number of moles of reactant.

Note: The limiting reactant is the reactant that gets consumed first in a chemical reaction and therefore limits how much product can be formed.

6.3 Screenshot of Data Sheets

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DATA SHEET to RECORD OBSERVATIONS, CALCULATIONS and RESULTS

STUDENT'S NAME: James Butler

PARTNERS' NAMES: Joseph Matthews & Thomas (Cowell)

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.

$T_{\text{hot}} = 60.0^{\circ}\text{C}$ $m_{\text{hot water}} = 50.0\text{g}$ $\Delta T_{\text{hot water}} = -18.9^{\circ}\text{C}$
 $T_{\text{cold}} = 20.2^{\circ}\text{C}$ $m_{\text{cold water}} = 50.0\text{g}$ $\Delta T_{\text{cold water}} = +20.9^{\circ}\text{C}$
 $T_{\text{max}} = 41.1^{\circ}\text{C}$ $\Delta T_{\text{calorimeter}} = +20.9^{\circ}\text{C}$

$Q_{\text{cold water}} =$ _____ $Q_{\text{hot water}} =$ _____ $Q_{\text{calorimeter}} =$ _____
 $HC_{\text{calorimeter}} =$ _____

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

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Figure 3 - Original Calorimetry Data Sheet 1

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 $T_{\text{hot}} =$ 91.4°C $m_{\text{metal}} =$ 18.6g $\Delta T_{\text{metal}} =$ -59.8°C $T_{\text{cold}} =$ 21.5°C $m_{\text{water}} =$ 30.0g $\Delta T_{\text{water}} =$ +10.1°C $T_{\text{max}} =$ 31.6°C $\Delta T_{\text{calorimeter}} =$ +10.1°C $c_{p \text{ metal}} =$ _____

time (s)	$T_{\text{WATER}} (^{\circ}\text{C})$
0	31.6
10	31
20	30.4
30	29.9
40	29.5
50	29.3
60	28.9
70	28.6
80	28.5
90	28.3
100	28.1
110	28.0

time (s)	$T_{\text{WATER}} (^{\circ}\text{C})$
120	27.7
130	27.6
140	27.5
150	27.5
160	27.3
170	27.3
180	27.1
190	27.0
200	26.9
210	26.9
220	26.9
230	26.8

time (s)	$T_{\text{WATER}} (^{\circ}\text{C})$
240	26.8
250	26.7
260	26.7
270	26.6
280	26.6
290	26.6
300	26.6
310	26.6
320	26.6
330	26.6
340	26.6
350	26.6

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

Figure 4 - Original Calorimetry Data Sheet 2

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

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

$T_{\text{start}} = 19.4^{\circ}\text{C}$ $T_{\text{end}} = 26.7^{\circ}\text{C}$

$V_{\text{HCl}} = 50.0$ $C_{\text{HCl}} =$ $n_{\text{HCl}} =$

$V_{\text{NaOH}} = 52.0$ $C_{\text{NaOH}} =$ $n_{\text{NaOH}} =$

Write the formula of the limiting reactant: _____

$Q_{\text{reaction}} =$ _____

$q_{\text{reaction}} =$ _____

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Figure 5 - Original Calorimetry Data Sheet 3