

ACDB40011 Calorimetry

by Ellie Martin

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CALORIMETRY – ELLIE MARTIN 2425617



Ewa Kazimierska

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1 Introduction

Calorimetry technique which is used in thermodynamics to measure the amount of heat which is transferred in a chemical reaction or physical object. This method is used to determine the enthalpy changes and the specific heat capacities from the reaction. This is important based from the law of conservation of energy as energy cannot be created or destroyed- only transferred [1]. It is hypothesised that by accurately measuring the specific heat capacity of a substance then the heat which is emitted or absorbed during the reaction is directly proportional to the mass of the object [2] and the change in temperature as demonstrated in (Eq 1); *symbol of mass is m, C is rather concentration, not*

$$Q = MC\Delta T \quad \text{specific heat, cpc}$$

Equation 1: Heat energy transfer [2]

The independent variable in this experiment is the object that is being used which is a known mass of aluminium metal and measuring the molar mass of the reaction which occurs when reacting hydrochloric acid (HCL) and sodium hydroxide (NaOH). The dependent variable is the ~~change in~~ *equilibrium* temperature of the metal or the water in the calorimeter. The controlled variables include initial temperature of the water before heating and the mass of the water. It is also important to insulate the system to prevent h loss from the system. In this report the principles of calorimetry will be investigated by the measurement of heat exchange that occur during a chemical process. By the measurement of temperature changes and masses and using the laws of thermodynamics specifically the laws of the conservation on energy [1] and how the thermal energy is transferred within in three different reactions one of which being measuring the enthalpy change which occur during a neutralization reaction between an acid and alkali.

2 Results

The results which are outlined in this section were obtained in the methodology in appendix 1.

2.1 Heat capacity of the calorimeter

Below are the temperatures collected from experiment 1 which was conducted and are accurate to $\pm 0.05^\circ\text{C}$. The digital thermometer which was used to record the temperature and to measure the volume of the water a graduated measuring cylinder was used which is accurate to 0.5ml which correlate to these tolerances.

Table 1: ...

	Temperature (C)	Mass (Grams)	ΔT
Hot	60	50	-22
Cold	22	50	16
Max	38		

each measurement should have 1 decimal; sig figs

From these results we can then calculate the heat capacity of the calorimeter by using Eq 1, Eq 2 and Eq 3.

$$-Q_{\text{Hot water}} = Q_{\text{Cold water}} + Q_{\text{Calorimeter}}$$

Equation 2: heat exchange [4]

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$$Q_{\text{Calorimeter}} = HC_{\text{Calorimeter}} + \Delta T_{\text{Calorimeter}}$$

Equation 3: heat capacity of calorimeter [4]

By initially using the first equation, Q_{Hot} and Q_{Cold} is calculated. the specific heat capacity of water which is 4.186 J/(g°C) [5] can then be used to determine:

$Q_{\text{Hot water}}$	$Q_{\text{Cold water}}$	$Q_{\text{Calorimeter}}$	$HC_{\text{Calorimeter}}$
-4604.6 J	3348.8 J	-1255.8 J	-76.61 J/(g°C)

$$Q_{\text{cal}} = -Q_{\text{hot water}} - Q_{\text{cold water}} = -(-4604.6) - 3348.8 = 1255.8 \text{ J}$$

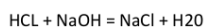
2.2 Specific heat capacity of a metal

To determine the specific heat capacity of the aluminium metal used Eq 4 is used to calculate the heat which is lost from the metal and thus gained by the water and the calorimeter. Below is the time in which is took the metal to cool two degrees once thermal equilibrium was reached with the boiling water

Time (s)	Twater (C)	Time (s)	Twater (C)	Time (s)	Twater (C)	Time (s)	Twater (C)
10	29.8	130	30.5	250	30.5	380	30.1
20	31.6	140	30.5	260	30.3	390	29.9
30	30.9	150	30.5	270	30.3	400	29.6
40	30.7	160	30.5	280	30.2		
50	30.7	170	30.5	290	30.2		
60	31.1	180	30.5	300	30.2		
70	30.8	190	30.5	310	30.2		
80	30.8	200	30.5	320	30.2		
90	30.8	210	30.5	330	30.2		
100	30.8	220	30.5	340	30.2		
110	30.7	230	30.5	360	30.2		
120	30.7	240	30.5	370	30.1		

where are all calculations?

2.3 Molar heat of HCl with NaOH



Mass = 52.00ml + 50.00ml (HCl is the limiting factor)

$$Q = MC\Delta T$$

Equation 4: heat capacity[6]

m

M = mass

$c_p c$

C = specific heat of water 4.184J/g °C

ΔT = change in temperature 31.4- 25.2= 6.2 °C

$$= 50\text{g} \times 0.88 \text{ J/g} \cdot ^\circ\text{C} \times 6.2 \cdot ^\circ\text{C}$$

$$= 272.8 \text{ J}$$

$$= 6.9 \text{ J/g}^{\circ}\text{C} \times 6.2^{\circ}\text{C} = 42.78$$

$$2050.16 \text{ J} + 33.81 \text{ J} + 215. \text{J} = 1274.49 \text{ J (total q)}$$

$$q = Q/n$$

$$1274.49/50 = 25.289 \text{ KJ/mol}$$

3 Discussion

The results obtained from these experiments allows the heat involved in a chemical reaction and in a physical object to be quantified. By measuring the enthalpy changes the effectiveness of system can be determined, this technique is important in defence as it is important to establish how different explosives, and component will react together and the behaviours in which will be displayed. For example, understanding how a material will release and absorb heat- this information can then be used to select materials for artillery shells. The principles of thermodynamics and the conservation of energy means that the principle from coffee cup calorimetry, the measurement of energy in the form of heat which is released during a reaction can be applied to reactions which occur with explosives. Understanding the large amount of energy which is released by explosives during thermal decomposition [8] is pinnacle for the successful military application. Ensuring uniformity of detonation to ensure the desired result every time whilst minimising the risk of accidental detonation and ensuring correct implementation of safety procedures.

To accurately determine the heat which is released apparatus known as the bomb calorimeter is used as this will be able to accurately determine the heat which is emitted from a known volume of fuel. This would minimise the amount of heat which is lost to the surroundings due to the lack of sufficient installation. One of the main difficulties when conducting these experiments is the potential of human error when taking the measurements and when recording the data which would cause issues in the enthalpy values calculated. As highlighted by R.Chang [7] ensuring that the temperatures of the water is accurate and allowing for enough time for the mixture to reach thermal equilibrium is important to accurately determine the water equivalent of the calorimeter.

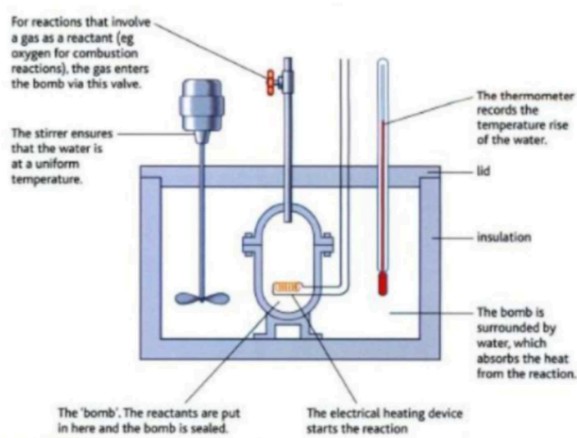


Figure 2: Bomb calorimeter [3]

The method of bomb calorimetry as shown in figure 1 is more accurate than the method implemented in the coffee cup calorimetry as the sample is placed in a sealed container which is pressurised with oxygen and has an electric current pass through it [6] - The pressurised vessel 'bomb' is placed in a water bath with a known volume of water which will absorb any heat energy which is released by the reaction. The thick insulation is in place to minimise the heat lost to the surrounding. The change in temperature is measured and then can be used to determine the energy content from the explosive. Importantly, by measuring the amount of energy which can be emitted by a small sample allows the determination of how much of an explosive would be required to deliver the desired explosive impact for defence purposes.

4 Conclusion

Calorimetry demonstrates how the measurement of heat exchanged which occur in chemical and physical processes. This method can be applied in industry to ensure the correct selection of material, or the behaviour of a chemical system is understood to allow the appropriate safety measures are taken to minimise accidental detonation. The experiments which were carried out confirm the thermodynamic principles such as the law of conservation of energy [1]. The experiments which were carried out partially support the hypothesis proposed. However, due to errors when carrying out the investigations effected the accuracy of calculations as heat was lost from the calorimeter into the external environment due to gaps around the thermometer and stirring rod which effected the determination of the equilibrium temperature and the accurate recording of the temperature in the other experiments.

5 References

[1]

E. Mach, "ON THE PRINCIPLE OF THE CONSERVATION OF ENERGY on JSTOR," *The Monist*, vol. Vol 5, no. No 1, pp. 22–25, Oct. 1989, doi: <https://doi.org/10.2307/27897203>.

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"Calorimetry -Water equivalent Calorimetry (Theory) : Physical Chemistry Virtual Lab : Chemical Sciences : Amrita Vishwa Vidyapeetham Virtual Lab," *Amrita.edu*, 2012. <https://vlab.amrita.edu/?sub=2&brch=190&sim=1352&cnt=1> (accessed Apr. 28, 2025).

[5]

BBC, "Energy and heating - AQA - Revision 5 - GCSE Physics (Single Science) - BBC Bitesize," *BBC Bitesize*, 2019. <https://www.bbc.co.uk/bitesize/guides/z2gjt4/revision/5> (accessed Apr. 28, 2025).

[6]

A. Burrows and E. Al, *Chemistry3 : introducing inorganic, organic and physical chemistry*. Oxford: Oxford University Press, Cop, 2013, pp. 687–694.

[7]

R. Chang, *Chemistry*. Boston: Mcgraw Hill Learning Solutions, 2007.

[8]

J. Akhavan, *The chemistry of explosives*, Fourth edition. Cambridge: Royal Soc. Of Chemistry, 2012.

6 Appendix 1

Equipment

- Styrofoam cups with lid
- Thermometer
- Stirring rod
- Stand and clamp
- Beaker
- Bunsen burner
- Tongs

Procedure to measure Hc calorimeter

- 50ml of water added to the Styrofoam cups, close lid and insert thermometer and stirring rod to complete the calorimeter.
- 50ml taken in separate beaker and heated to 80°C. Bunsen burner is turned off and water is left to cool to 60 °C. This is recorded as T_{hot} .
- Water in the calorimeter is also measured as T_{cold} .
- Hot water added to the calorimeter and mixed thoroughly whilst watching the thermometer to determine when the maximum equilibrium temperature of the mixture is reached.

Procedure to measure specific heat capacity

- Using the apparatus from previous experiment
- Collect metal sample and weigh it and record mass as M_{metal} .
- Set up water bath and allow it to boil before putting metal sample in. allow it to boil for 5 minutes and then wait 2 minutes for the metal and the water to equilibrate.
- While this is being done measure 30ml of water and add it to calorimeter, measure the temperature of the water and record as T_{cold} .
- Once metal has reached thermal equilibrium with boiling water measure and record temperature as T_{hot} , quickly add metal to the water in the calorimeter using tongs.
- Stir the water and record the temperature every 10 seconds. Continue to do this until the water has reached maximum temperature and then cooled by 2 °C, record max temperature as T_{max} .

Procedure to measure the molar heat of reaction HCL and NaOH

- Use same apparatus as previous experiment
- Place 52.00ml of 1.0M NaOH into calorimeter and pour 50.00ml of 1.0M HCL into beaker
- Place next to each other until they both reach the same temperature record as T_{start} .
- Add HCL to calorimeter and record the temperature when it reaches a maximum record as T_{end} .

University of Western Australia - School of Chemistry

2. Measure the specific heat capacity of a metal (continued)

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

Type of metal: Aluminium

Mass of metal: 28.50 g $\Delta T_{\text{metal}} =$ 1.0 $\Delta T_{\text{water}} =$ 1.0

Mass of water: 100.0 g $\Delta T_{\text{metal}} =$ 1.0 $\Delta T_{\text{water}} =$ 1.0

Mass of calorimeter: 15.0 g $\Delta T_{\text{metal}} =$ 1.0 $\Delta T_{\text{water}} =$ 1.0

Time (s)	Temp (°C)	Time (s)	Temp (°C)	Time (s)	Temp (°C)
10	21.5	150	21.5	150	21.5
20	21.5	160	21.5	160	21.5
30	21.5	170	21.5	170	21.5
40	21.5	180	21.5	180	21.5
50	21.5	190	21.5	190	21.5
60	21.5	200	21.5	200	21.5
70	21.5	210	21.5	210	21.5
80	21.5	220	21.5	220	21.5
90	21.5	230	21.5	230	21.5
100	21.5	240	21.5	240	21.5
110	21.5	250	21.5	250	21.5
120	21.5	260	21.5	260	21.5

Write the calculations for Q_{metal}

$Q_{\text{metal}} = m_{\text{metal}} \times \Delta T \times C_P$

$Q_{\text{metal}} = 28.5 \times (21.5 - 20.5) \times 0.897$

$Q_{\text{metal}} = 2.35 \text{ J}$

Write the calculations for Q_{water}

$Q_{\text{water}} = m_{\text{water}} \times \Delta T \times C_P$

$Q_{\text{water}} = 100.0 \times (21.5 - 20.5) \times 4.184$

$Q_{\text{water}} = 418.4 \text{ J}$

Write the calculations for $Q_{\text{calorimeter}}$

$Q_{\text{calorimeter}} = m_{\text{calorimeter}} \times \Delta T \times C_P$

$Q_{\text{calorimeter}} = 15.0 \times (21.5 - 20.5) \times 0.897$

$Q_{\text{calorimeter}} = 1.34 \text{ J}$

Page 1

STUDENT'S NAME: Elinor Macleod

PARTNER'S NAME: Jack Macleod

REPORT IS DUE MAY 02, 2025 (DO NOT, 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.

Mass of water: 100.0 g $\Delta T_{\text{water}} =$ 1.0 $\Delta T_{\text{metal}} =$ 1.0

Mass of metal: 28.5 g $\Delta T_{\text{water}} =$ 1.0 $\Delta T_{\text{metal}} =$ 1.0

Mass of calorimeter: 15.0 g $\Delta T_{\text{water}} =$ 1.0 $\Delta T_{\text{metal}} =$ 1.0

Mass of water: 100.0 g $\Delta T_{\text{water}} =$ 1.0 $\Delta T_{\text{metal}} =$ 1.0

Mass of metal: 28.5 g $\Delta T_{\text{water}} =$ 1.0 $\Delta T_{\text{metal}} =$ 1.0

Mass of calorimeter: 15.0 g $\Delta T_{\text{water}} =$ 1.0 $\Delta T_{\text{metal}} =$ 1.0

Write the calculations for Q_{water} , $Q_{\text{calorimeter}}$, and $HC_{\text{calorimeter}}$

$Q_{\text{water}} = m_{\text{water}} \times \Delta T \times C_P$

$Q_{\text{water}} = 100.0 \times (21.5 - 20.5) \times 4.184$

$Q_{\text{water}} = 418.4 \text{ J}$

$Q_{\text{calorimeter}} = m_{\text{calorimeter}} \times \Delta T \times C_P$

$Q_{\text{calorimeter}} = 15.0 \times (21.5 - 20.5) \times 0.897$

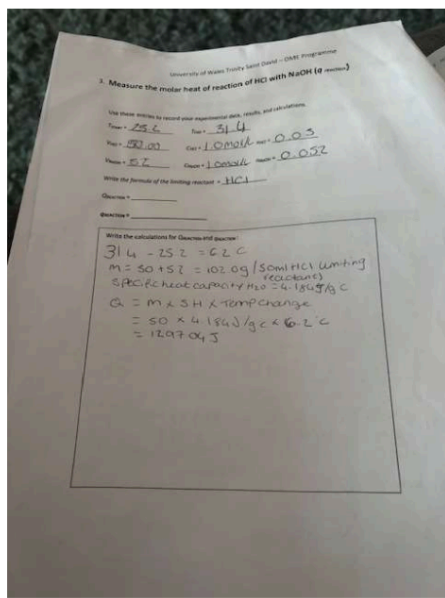
$Q_{\text{calorimeter}} = 1.34 \text{ J}$

$HC_{\text{calorimeter}} = \frac{Q_{\text{water}}}{\Delta T}$

$HC_{\text{calorimeter}} = \frac{418.4}{1.0} = 418.4 \text{ J/}^\circ\text{C}$

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FINAL GRADE

GENERAL COMMENTS

60/100

Engagement with Literature Skills 10/15

The student cites eight sources, mostly textbooks and educational websites. IEEE formatting is mostly applied correctly, and access dates are included. Literature is only used for background and to discuss OME applications. However, no reference is provided for the standard value of specific heat of aluminium, which weakens the scientific comparison.

Feedback: Always provide references when citing known values (e.g. specific heat of aluminium) to allow scientific validation of comparisons.

Knowledge and Understanding Skills 12/20

The purpose is clearly stated and the report introduces calorimetry as a technique. The first law of thermodynamics is briefly referenced in the introduction as conservation of energy, which is a strength. Equations are correctly included and explained. Hypotheses are general and do not clearly apply to each experimental part. Variables are identified. The dependent variable is not recognised as equilibrium temperature.

Feedback: Maintain your clear explanation of theory. Improve by writing specific hypotheses for each experiment and formally classifying all variables.

Cognitive and Intellectual Skills 13/25

The heat capacity of the calorimeter is calculated but not questioned, even though the value is physically unrealistic. The specific heat of aluminium is not calculated. The heat of reaction is not compared to literature values. The OME application is only briefly mentioned in passing in connection with bomb calorimetry and is not fully developed. No mitigation of errors or uncertainty estimation is discussed.

Feedback: Always compare experimental values with literature data and explain discrepancies. Expand your OME section and include suggestions to minimise errors.

Practical Application Skills 14/25

The calorimeter heat capacity result suggests issues with measurement timing (likely recorded too early), but this is not addressed. Most calculations are otherwise correct. Units are mostly consistent but not

enough significant figures are used for temperature and mass values. Data presentation is clear

Feedback: consider better significant figures.

Transferable/Professional Skills 11/15

The report is well structured and mostly formal. Headings and equations are used effectively. Some informal phrases slightly detract from professionalism.

Feedback: maintain consistently formal scientific language.

PAGE 1

PAGE 2

PAGE 3

Text Comment. keep all the tables, ToC, Table of tables, figures, etc . on one page

PAGE 4

Text Comment. symbol of mass is m, C is rather concentration, not specific heat, cpc

Text Comment. HCl not HCL

Text Comment. equilibrium

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Text Comment. Table 1: ...

Text Comment. each measurement should have 1 decimal; sig figs

PAGE 5

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Text Comment. where are all calculations?

Text Comment. m

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Text Comment. cpc

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