

Calorimetry - Lab 3

By William Critchley

(Lab partners - Emma Biggs & Jamie Hamilton Swingewood)

L4 - Chemistry (OME BEng Sem2 23/24) (ACDB4011)

Contents

1. Title page pg 1
2. Contents pg 2
3. Introduction pg 3
4. Results pg 4
5. Discussion pg 5
6. Conclusions pg 6
7. References pg 7
8. Appendix - Methods and materials pg 8

Introduction

Bomb Calorimetry is a widely accepted and accurate method of determining the amount of energy released in the combustion of a material [1]. In this experiment a basic form of Bomb Calorimetry using polystyrene cups was undertaken. The aim was to determine the specific heat capacity of a metal block of known mass, based on the mass of the metal object and its surface colour and finish a Hypothesis that the metal was aluminium was put forward so the results will be compared with a known value to see how accurate they were (0.89 J/g °C)[2].

Equations used:

Equation 1 (Eq 1): Specific Heat Capacity - $Q = m \times C_p \times \Delta T$

Equation 2 (Eq 2): heat lost by metal - $Q_{metal} = Q_{water} + Q_{Calorimeter}$

Equation 3 (Eq 3): combination for specific heat capacity of the metal

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

Equation 4 (Eq 4): heat lost by water - $Q_{hot\ water} = Q_{cold\ water} + Q_{Calorimeter}$

Equation 5 (Eq 5): heat capacity of calorimeter I -

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

Results

After calculating the the heat capacity of the calorimeter ($HC_{\text{Calorimeter}}$) which was found to be $65.4 \text{ J/g } ^\circ\text{C}$. This value could the be plugged into Eq 3 along with other observed values to calculate an approximate value for the specific heat capacity of the metal sample ($1.63 \text{ J/g } ^\circ\text{C}$).

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.

$T_{\text{hot}} = 60^\circ$ $m_{\text{hot water}} = 50 \text{ g}$ $\Delta T_{\text{hot water}} = 21$
 $T_{\text{cold}} = 23^\circ$ $m_{\text{cold-water}} = 50 \text{ g}$ $\Delta T_{\text{cold water}} = 16$
 $T_{\text{max}} = 39$ $\Delta T_{\text{calorimeter}} = 16$
 $Q_{\text{cold-water}} = 3348.9$ $Q_{\text{hot water}} = -4395.3$ $Q_{\text{calorimeter}} = 1046.4$
 $HC_{\text{calorimeter}} = 65.4 \text{ J/g } ^\circ\text{C}$

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

$$Q_{\text{HOT}} = 50 \times 4.186 \times 21$$

$$Q_{\text{COLD}} = 50 \times 4.186 \times 16$$

Figure 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
 $T_{\text{hot}} = 84$ $m_{\text{metal}} = 10$ $\Delta T_{\text{metal}} = 48$
 $T_{\text{cold}} = 24$ $m_{\text{water}} = 30$ $\Delta T_{\text{water}} = 5$
 $T_{\text{max}} = 32$ $\Delta T_{\text{calorimeter}} = 8$
 $c_{p \text{ metal}} = 1.03$

time (s)	T _{WATER} (°C)	time (s)	T _{WATER} (°C)	time (s)	T
10	29	100	32		
20	35	110	32		
30	35	120	32		
40	32	130			
50	32	140			
60	32	150			
70	32	160			
80	32				
90	32				

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

Figure 2

Discussion

In the experiment the specific heat capacity of the metal was calculated to be 1.63 J/g °C, this value is odd as after doing research online no metals could be found that had similar specific heat capacities. This is significant as it suggests there is an issue with either the maths of the equipment so more research should be undertaken to attempt to determine what went wrong.

The way this specific experiment related to OME is its ability to calculate the amount of energy output by the combustion of a substance, this allows for characterization and analysis of potential uses for a substance.

Potential sources of error mainly come from both human error and the crudeness of our equipment compared to an industrial bomb calorimeter eg ours was made of polystyrene cups with a mercury thermometer to measure temperature.

Conclusions

The data collected in this experiment sadly does not match the expected value, it is nearly twice as big which leads to assumptions of errors in calculations or errors in equipment or just crude equipment making accurate measurements difficult as the calculated value is closer to ice [2] ($2.03 \text{ J/g } ^\circ\text{C}$). Future research could determine exactly what kind of metal it is and then conduct a proper bomb calorimetry to more accurately calculate the specific heat capacity and then compare it to the rough value.

References

- [1] D. Theodorou, Y. Zannikou, G. Anastopoulos, F. Zannikos "Coverage interval estimation of the measurement of Gross Heat of Combustion of fuel by bomb calorimetry: Comparison of ISO GUM and adaptive Monte Carlo method" , Thermochemica Acta 526 (2011) pg 122-129 Available: <https://pdf.sciencedirectassets.com/271405/>
- [2] The University of Texas at Austin, (2024 May 15th), "Heat Capacities for Some Select Substances" [Online], Available: <https://gchem.cm.utexas.edu/data/section2.php?target=heat-capacities.php>

Appendices

Materials and Equipment:

- Polystyrene cup calorimeter
- Thermometer
- Bunsen burner
- Heat-proof mat
- Gauze
- Metal stand
- Beakers
- Tap water (specific heat capacity $4.186 \text{ J/g}^\circ\text{C}$)
- Clamp stand
- Clamp
- Tongs
- Metal sample

Method

1. Assemble the polystyrene cup calorimeter and fill it with a known amount of water and then heat the same amount of water to a temperature eg 60°C
2. Measure the temperatures of both sets of water and then mix the hot water into the calorimeter thoroughly
3. Record the equilibrium temperature when it has settled
4. Calculate the heat capacity of the calorimeter with the equations listed above (Eq 1,2 & 3)
5. Weigh the metal sample and then heat it in a water bath to a known temp eg 80°C
6. Add a known volume of room temperature water to the calorimeter then measure both temperatures and record them
7. Add the hot metal and then record the temperature change as seen in Fig 2
8. Then use the data collected with Eq 3 to calculate the specific heat capacity of the metal sample