

Analysing the effectiveness of Calorimetry to test SHC in a metal specimen

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ABSTRACT

Calorimetry is the process of measuring the amount of heat released or absorbed during a chemical reaction. This can also be used to determine whether the reaction is exothermic or endothermic in nature¹.

1 INTRODUCTION

Calorimetry is primarily used in the lab to determine the amount of heat transferred in a chemical or physical process. One of the most common uses of calorimetry is to determine the enthalpy of chemical reactions - Enthalpy is the measurement of the total energy of a system. The purpose of the experiment was to find the specific heat capacity of an aluminium specimen within a lab environment.

2 THEORY

Calorimetry works by isolating the specimen within a predetermined amount of water to measure how much energy is dissipated from the specimen to heat the water until thermal equilibrium is reached. Thermal equilibrium is the process of one system transferring heat to another, an example of this would be a 100°C object placed in a 0°C solution the heat will be transferred until both the object and the solution are both at 50°C - thermal equilibrium has been achieved. The experiment can be used to measure specific heat of a material. Specific heat is the amount of energy required to raise the temperature of a material by one degree³.

To work out specific heat use the following equation²:

$$Q = mC_p\Delta T$$

Where Q is the heat change (in Joules) of an object, (m) is the mass (in grams), ΔT is the temperature change and C_p is the specific heat capacity (J/g/°C). If the value of ΔT is a negative, the object is cooling down and when it is positive the object is heating up. The same is true of the Q value. According to the first Law of thermodynamics *Energy cannot be created or destroyed only transferred between an object and its surroundings* to put simply heat loss by an object or surroundings must be gained by the subsequent object or surrounding.

Calorimetry is also very common in the food industry, where a food calorimeter is used to determine the calorie content of food. A sample is placed in an insulated chamber surrounded by water, the same process is used to measure specific heat capacity (SHC) for example if the water increases in temperature by 10°C then the food sample will contain 10 calories. This method is called *direct* calorimetry. As can be seen from figure 1, this is a laboratory grade calorimetry bomb which is prone to less errors than the one that was used in this experiment.

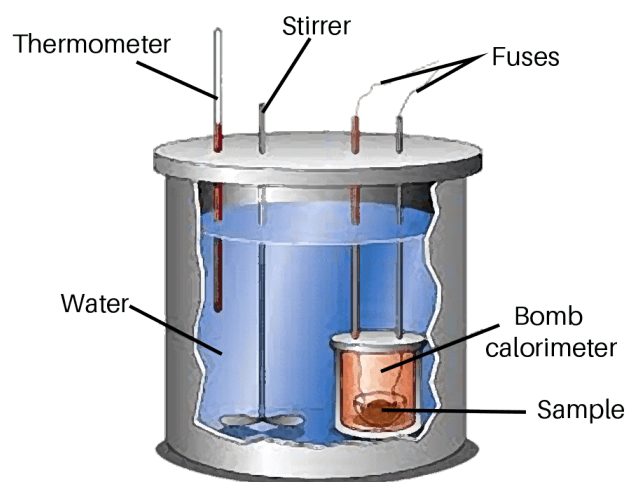


Fig. 1. A calorimetry bomb⁴

3 METHODS

3.1 Apparatus

Under normal circumstances a Bunsen burner would be used to provide a constant heat to the metal sample, however due to an issue with the laboratory gas system; a domestic electric kettle was used to boil the water. A basic calorimetry bomb was made using two Styrofoam coffee cups, a thermometer, a stirring rod and a lid.

3.2 Procedure

Procedure to measure the SHC of the calorimeter as dictated from the data sheet provided for this experiment: 1. Add 50.0 mL of water to the Styrofoam coffee cups, and close with the lid. Add the stirring rod and thermometer to set up the calorimeter. 2. Take 50.0 mL of water in a separate beaker and heat to 80°C. Close the gas and wait until the temperature is at 60°C. When the "hot" water is ready, record its temperature as T_h . As previously stated due to an issue a kettle was used which means that the exact temperature varies from the given. 3. Measure the water temperature in the calorimeter, and record it as T_c . 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_m . 5. Calculate the Heat capacity of the calorimeter. The calculations can be seen in figure 2

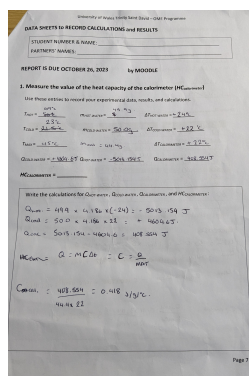


Fig. 2. The calculations to determine SHC of the Calorimeter

Procedure to determine the SHC of the metal specimen as dictated from the data sheet provided for this experiment: (Using the same apparatus as before) 1. Obtain a metal specimen and weigh it record its mass as m . 2. Set up a water bath, heat the water until boiling and then carefully put your metal into it. Keep boiling for another 5 minutes, to allow the metal to reach the same temperature as the water. Avoid heating the specimen directly. To reduce the effect of direct heating, close the gas after 5 minutes and wait 2 minutes for the temperature of the boiling water and the specimen to reach thermal equilibrium. 3. While this is happening, 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_c . 4. When the metal has reached thermal equilibrium with the boiling water, measure and record the temperature of the hot water as T_h , 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 data sheet provided. The temperature will increase at the start. Continue until the water has reached a maximum and then cooled down by 2C. Record the maximum temperature reached by the water as T_m . 6. Calculate the $C_{p,metal}$ using the equation²

$$m_{metal} \cdot C_p(metal) \cdot \Delta T_{metal} =$$

$$-m_{water} \cdot C_p(water) \cdot \Delta T_{water} + HC_{calorimeter} \cdot \Delta T_{calorimeter}$$

Please refer to figure 3 for calculations.

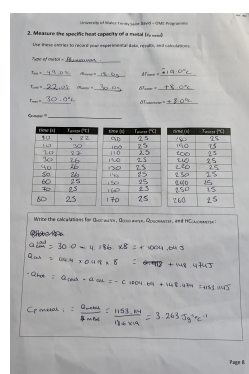


Fig. 3. The calculations to determine SHC of the metal specimen

4 RESULTS

The results data gained from this experiment can be seen in figures 2 and 3 respectively and show the specific heat capacity of the calorimeter and the aluminium specimen. It also shows how thermal equilibrium was achieved in what space of time. Using the trend from figure 3 it can be inferred that over a 5 minute period the temperature stabilised.

5 DISCUSSION

5.1 Analysis

When interrogating the results, it can be seen how this experiment may be used in the broader field of thermodynamic research and energy transference. When looking at previous experiments and well documented data we can see that the data from this experiment has a 113% error, as the actual SHC of aluminium is $0.900 J/g/C$ when compared to the $3.263 J/g/C$ gathered here. A limitation of this experiment is the lack of comparable specimens as only one was tested, a range of materials could be used to compare the different rates of thermal equilibrium and Specific heat capacities. Another limitation is the lack of professional equipment, a problem that causes large margins of errors especially as a control was not established. Styrofoam coffee cups are not suitable to gain accurate data and would not be consistent enough to repeat the experiment to verify results. Human error is also a reason that results are not accurate, as the experiment relies on the on the accuracy of the scientists in interpreting the results as an analogue thermometer was used to measure the temperature. This can invite ambiguity subsequently causing differing results. The three experiments yielded very different results further indicating the inaccuracy of the experiment, however the use of a domestic kettle and not a Bunsen burner lead to differences in the temperature of the water.

5.2 Recommendations

An accurate calorimeter bomb was not used, leading to inconsistent results and unverifiable data. A digital thermometer could be used to eliminate the human error of reading an analogue thermometer, this would provide better starting temperature points when starting the experiments. A control calorimeter could have been used to allow comparisons to be made

6 CONCLUSION

As can be seen from above, this type of calorimetry is not suitable for higher levels of experimentation and data collection. However at a lower level in Universities and colleges it will allow students to understand the principles and concepts of SHC and thermodynamics in a practical environment. The purpose of this experiment was to understand how thermal equilibrium is measured in terms of enthalpy and heat capacity. Overall the experiment worked - if not giving absolute values as it could be determined that thermal equilibrium was achieved.

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