Example IB HL Chemistry Internal Assessment

Received full marks

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Contents

Experiment to investigate the calorific content of foods

Objective

In this experiment, you will burn several types of food in order to determine their heat content per gram.

Materials

- one coke can
- balance
- stirring rod
- retort stand and clamp
- paper clip
- aluminium foil
- thermometer
- cotton wool
- 2-3g sample of each type of food (almonds, pretzels, cheezels)

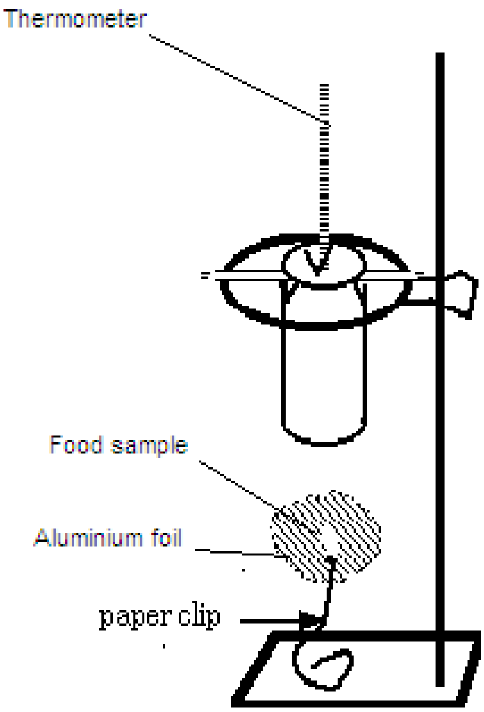
Safety and Environmental Care

- Avoid contact with hot objects, do not put clothing near flame
- If you are allergic to nuts inform your teacher immediately
- Avoid contact with soot that forms on the bottom of the can, it may stain clothing

Method

1. Secure the coke can in the clamp. Weigh 100g water and add this to the can.
2. Place a thermometer in the mouth of the can with a piece of cotton wool to prevent heat loss. Record the initial temperature of the water.
3. Place a heat mat under the can. Weigh a sample of food and place it on a paper clip, with a piece of aluminium under the food sample to collect any burnt material.
4. After the food burns completely, record the final temperature of the water, and determine the actual mass of food that has burned. Repeat the procedure, using a different type of food sample.

Setting Up



Results

Using your data for the mass of the water, the mass of the food that actually burned, and the initial and final temperatures of the water, calculate the heat released per gram of food burned.

Disposal

Discard the ash in the waste basket. Recycle the coke cans.

Background Information

In modern society, the variety of foods consumed has changed dramatically from previous eras. Although this is beneficial for increasing the range of nutrients we consume, the availability and popularity of some less nutritious food has given rise to health problems, most notably obesity (Brown & Ford, 2009, p. 511).

In order to control this disease, the amount of energy a person consumes through their food must be monitored by dieticians. However, the information on the calorific value, or energy content, of any food must first be calculated from experimental data. These foods are burnt in a bomb calorimeter, with their enthalpy of combustion found using the change in mass and temperature during the process (Derry, 2009, p. 76).

The energy content of any food can be calculated according to the equation:

$$\boldsymbol{q = m \times c \times \Delta T}$$

q = energy content (J)

m = mass in (g)

c = specific heat capacity of water (J $°C^{-1}$ g^{-1})

T = temperature (°C)

Raw Data

Table 1.0 - Table to show raw data collected for all three food types

	Initial Mass (±0.01g)	Final Mass (±0.01g)	Initial Temperature (±0.5°C)	Final Temperature (±0.5°C)
Cheezel				
Trial 1	1.59	0.21	20.0	39.0
Trial 2	1.78	0.25	36.5	51.0
Trial 3	1.75	0.40	48.0	55.0
Pretzel				
Trial 1	0.99	0.20	34.5	38.5
Trial 2	1.11	0.14	51.0	53.5
Trial 3	1.17	0.34	52.0	53.5
Almond				
Trial 1	0.98	0.14	60.5	67.5
Trial 2	0.97	0.09	67.0	72.0
Trial 3	1.14	0.15	77.0	88.0

Observations

<u>Cheezels</u>

The cheezels all burned with a large, yellow flame. A great deal of black residue was produced and built up on the bottom of the can. The surface of the Cheezel began to bubble and some of the liquid dripped off onto the foil pan underneath. In trial three, the Cheezel fell off the wire, but continued to burn to completion. All three Cheezels finish combusting within a minute.

<u>Pretzels</u>

The pretzels burned with a yellow flame and a large amount of black smoke, making a crackling noise. There was very little black residue produced. In trial 2, there was some difficulty lighting the pretzel. They burnt in under a minute. Some of the pretzel did not burn entirely.

<u>Almonds</u>

These burned slowly, with a yellow flame and white smoke, producing white ash on the outside of the nut. The almonds took the longest to catch alight when the flame was held to them. There was a slight crackling sound and the flame burned steadily. In trial 3, black smoke was produced. The nuts were not burnt all the way through, with some unburnt material at the centre.

Processed Data

Table 2.0 - Table to show the temperature change in each trial and the average temperature change for each food type.

	Temperature Change (±1°C)	Average Temperature Change (±1°C)
Cheezel		
Trial 1	19.0	13.5
Trial 2	14.5	
Trial 3	7.0	
Pretzel		
Trial 1	4.0	2.7
Trial 2	2.5	
Trial 3	1.5	
Almond		
Trial 1	7.0	7.7
Trial 2	5.0	
Trial 3	11.0	

Figure 2.1 - Example calculation of the temperature change for the first trial of the Cheezels.

$$\Delta\text{Temperature} = \text{Final Temperature} - \text{Initial Temperature}$$
$$= 39.0 - 20.0$$
$$= 19.0℃$$

Uncertainty Calculation

The absolute uncertainties are added:

$$= \pm 0.5℃ + \pm 0.5℃$$
$$= \pm 1℃$$

Figure 2.2 - Example calculation of the average temperature change for the burning of the Cheezels.

$$\text{Mean } \Delta\text{Temperature} = \frac{\sum \Delta \text{ Temperature}}{\text{n}}$$
$$= \frac{19.0 + 14.5 + 7.0}{3}$$
$$= 13.5℃$$

Uncertainty Calculation

When the average of a set of values is taken, the uncertainty remains the same:

±1°C

Given that the specific heat capacity of water is 4.18 J g^{-1} $°C^{-1}$ and 100g of water was used, the calorific value of the food can be found using the equation:

$$\boldsymbol{q = m \times c \times \Delta T}$$

However, it is also necessary to take into account the fact that a proportion of the heat released from the foods was also absorbed by the aluminium can. Based on the assumption that all the heat was evenly distributed throughout the can, and that the can underwent the same rise in temperature as the water, the amount of heat absorbed can be calculated. The specific heat capacity of aluminium is 0.904 J g^{-1} $°C^{-1}$ (Wolfram Alpha, 2011) and the mass of the can was 5.81g.

Table 3.0 - Table to show the heat energy absorbed by the water and can for each food type, the total heat energy and the associated uncertainty.

Food Type	**Energy Absorbed by Water (J)**	**Energy Absorbed by Can (J)**	**Total (J)**	**Uncertainty**
Cheezel	5643.0	70.9	5713.9	±855.9J
Pretzel	1128.6	14.2	1142.8	±847.7J
Almond	3218.6	40.4	3259.0	±852.6J

Figure 3.1 - Example calculation of the heat energy for the Cheezels

Energy Absorbed by Water

$q = m \times c \times \Delta T$

$q = 100 \times 4.18 \times 13.5$

$= 5643.0\,J$

Energy Absorbed by Can

$q = m \times c \times \Delta T$

$q = 5.81 \times 0.904 \times 13.5$

$= 70.9\,J$

Uncertainty Calculation for Water

Temperature

% Uncertainty = $\frac{1.0}{13.5} \times 100$

$= 7.4\%$

Mass

$= \frac{0.01}{100} \times 100$

$= 0.01\%$

Overall uncertainty

$\pm 7.4\% + \pm 0.01\% = \pm 7.41\%$

Uncertainty Calculation for Can

Temperature

% Uncertainty = $\frac{1.0}{13.5} \times 100$

$= 7.4\%$

Mass

$= \frac{0.01}{5.81} \times 100$

$= 0.17\%$

Overall uncertainty

$\pm 7.4\% + \pm 0.17\% = \pm 7.57\%$

Total Heat Energy Absorbed

Total = 5643.0 + 70.9 = 5713.9J

Uncertainty of Total Heat Energy

$5713.9 \times (7.41\% + 7.57\%) = \pm 855.9\,J$

In order to more accurately compare these results, the average energy per gram can be calculated.

$$Energy\ per\ gram = \frac{Energy\ content}{\Delta Mass}$$

Table 4.0 - Table to show the change in mass in each trial and the average change in mass for each food type.

	Change in Mass (±0.02g)	Average Change in Mass (±0.02g)
Cheezel		
Trial 1	1.38	1.42
Trial 2	1.53	
Trial 3	1.35	
Pretzel		
Trial 1	0.79	0.86
Trial 2	0.97	
Trial 3	0.83	
Almond		
Trial 1	0.84	0.90
Trial 2	0.88	
Trial 3	0.99	

Figure 4.1 - Example calculation of the change in mass of the first trial of the Cheezels

$$\Delta \text{Mass} = \text{Initial Mass} - \text{Final Mass}$$
$$= 1.59 - 0.21$$
$$= 1.38g$$

Uncertainty Calculation

The absolute uncertainties are added:

±0.01g + ±0.01g = ±0.02g

Figure 4.2 - Example calculation of the average change in mass of the Cheezels.

$$\text{Mean } \Delta \text{Mass} = \frac{\sum \Delta \text{Mass}}{\text{n}}$$
$$= \frac{1.38 + 1.53 + 1.35}{3}$$
$$= 1.42g$$

Uncertainty Calculation

When the average of a set of values is taken, the uncertainty remains the same:

±0.02g

Table 4.3 - Table to show the average energy per gram for each of the three food types

Food Type	Energy per gram ($J\ g^{-1}$)	Uncertainty ($J\ g^{-1}$)
Cheezel	4023.9	±700.0
Pretzel	1328.8	±1000.0
Almond	3621.1	±1000.0

Figure 4.4 - Example calculation of the energy content per gram for the Cheezels

$$Energy\ per\ Gram = \frac{Energy\ content}{\Delta Mass}$$

$$= \frac{5713.9}{1.42}$$

$$= 4023.9 J\ g^{-1}$$

Uncertainty Calculation

%Uncertainty energy content = ±14.98%

%Uncertainty ΔMass = $\frac{0.02}{1.42} \times 100$

= ±1.41%

<u>Overall Uncertainty</u>

4023.9 x (±14.98% + ±1.41%) = ±661.0J g^{-1}

≈ ±700J g^{-1}

(Rounded to 1 significant figure)

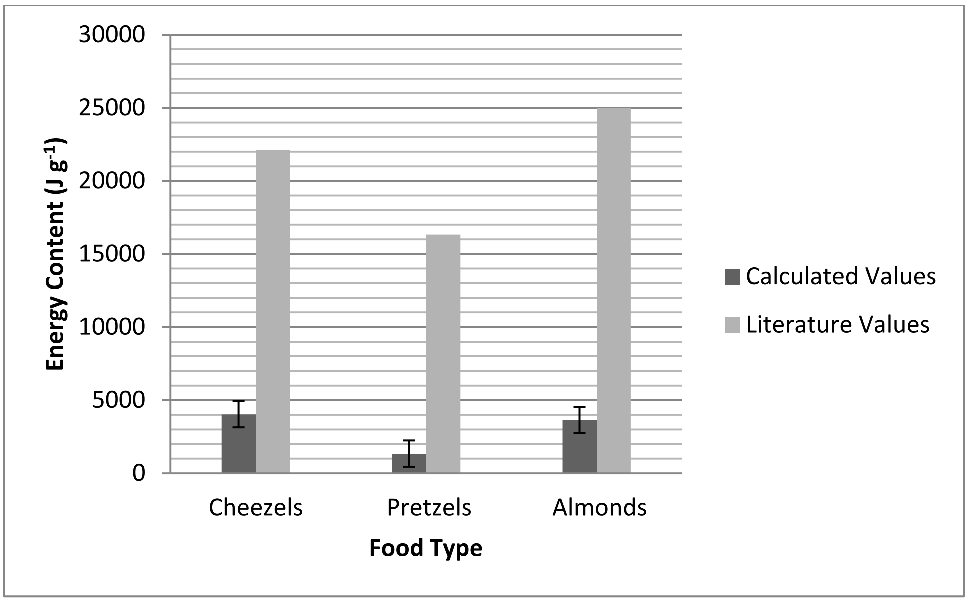
These values have relatively large uncertainties, indicating significant inaccuracies in the results.

To establish how accurate the experimental results are, these energy content values can be compared to literature values. These are:

Table 5.0 - Table to show the literature values for the energy content of each food type

Food Type	Energy Content (J g^{-1})
Cheezels	22130
Pretzel	16333
Almond	25000

Graph 5.1 - Graph to compare the calculated energy content of the three foods to the literature values



This graph clearly demonstrates that the calculated values for the energy content per gram of each food were significantly smaller than the literature values. The errors in the experiment discussed in the evaluation account for these differences. It is important to note that the literature values do not fall within the range of the calculated uncertainty values, which shows that this difference is not due to random uncertainty.

The experimental results still show a similar trend to the literature values, in that the pretzels are seen to have the lowest energy content per gram. In both cases, the Cheezels and almonds have close values, although the experimental data shows the Cheezels to have a slightly higher energy content, whilst the literature values show the opposite.

The magnitude of the difference can be shown by calculating the percentage uncertainty.

Table 5.2 - Table to show the percentage difference of the calculated and literature values

Food Type	Percentage Difference
Cheezels	81.82%
Pretzel	91.86%
Almond	85.52%

Figure 5.3 - Example calculation of the percentage difference of the calculated and literature values for the Cheezels

%Difference = $\frac{4023.9-22130}{22130} \times 100$

= 81.82%

All these percentage difference values are very high, further showing that the calculated values were inaccurate compared to the theoretical values.

Conclusion

In conclusion, the calorific content of foods varies depending on the constituent molecules. The combustion of the different varieties of food allows for this energy content to be determined. In this experiment, it was found that the pretzels have the lowest energy content per gram, whilst Cheezels have the largest energy content per gram.

However, when compared to the theoretical values, it was apparent that the experimental data was not accurate. The data collected was fairly precise, and repetitions were done for each food to reduce the effect of random error. However, the literature values fell outside the range of the uncertainties, which showed that the difference was not due to the random uncertainties. In addition, the percentage difference for all the values was very large, further illustrating that the results were inaccurate. Therefore, the systematic error in this experiment was much greater than the random error.

Graph 5.1 also highlight the discrepancy between the values. Also, it is clear that the almonds should theoretically have the highest energy per gram, yet the results show the Cheezels to have the highest energy content. Nevertheless, the theoretical and experimental results are in accordance in showing the pretzels to have the lowest energy content per gram out of the three foods.

The observations allow for this discrepancy to be partially explained. The almonds did not undergo complete combustion, burning only on the outside and leaving part of the centre unaffected. This material would still contain energy, but would not have been released during combustion. This was a systematic error, since all the foods should have been allowed to burn completely before the trial was stopped. On the other hand, the Cheezels burned completely, releasing almost all the energy contained in the molecules. This explains why the experimental data shows the Cheezels as having the most energy per gram. Also, the Cheezels had the lowest percentage difference from the theoretical values, indicating that the data from these trials was the most accurate. Nevertheless, the difference was still very large, demonstrating that there was still large amounts of error in the experiment.

Whilst the incomplete burning explains why the Cheezels appeared to have a larger calorific value than almonds, the significant difference between all the values is explained by the large amount of heat lost to the air during the experiment. The foods were not burnt in a sealed-off space, but were set up so that much of the energy released during combustion was absorbed by the air. This heat would not have been absorbed by the can or the water, and could not be included in the calculations.

Although this experiment shows that foods vary in their energy content per gram, the large systematic errors in the experiment prevented accurate data from being obtained, and the actual values were not able to be calculated.

Evaluation

The effect of random errors would be reduced due to the repetition of the trials for each food type.

Factor	Effect on Experiment	Improvement
Heat lost to environment	The temperature change of the water and can do not accurately reflect the actual amount of heat released in the combustion of the food because a significant proportion of the heat escaped to the air.	Conduct the experiment in a bomb calorimeter, and factor the heat absorption into the results. Using this method would prevent any heat being lost to the air so that all the energy released would be absorbed.
Incomplete burning of foods	Since the almonds and some of the pretzels means that not all of the heat contained in the food was released to be absorbed by the water and can.	Ensure that the foods burn through entirely so that all the heat is released. For the almonds, use half of the nut so that a larger surface area is exposed and can burn completely.
Surface area of can	The calculation of the heat absorbed by the can would be inaccurate because most of the heat would be absorbed by the base of the can, whilst the top would have very little. During the calculations, the assumption was made that the heat was evenly distributed, affecting the accuracy of the calculations.	Using a bomb calorimeter, the heat would be more evenly distributed across the surface area of the bomb.
Build-up of black residue on the can	After a number of trials, black residue began to build up on the bottom of the can. This may have partially absorbed the heat released, but was not taken into account during the calculations. This may have contributed to the discrepancy between the experimental results and theoretical data.	After each trial, wash the can clean of any residue so that there is no variation between the absorption of heat across the trials.

Works Cited

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