Determination of the
Molar Enthalpy of Combustion of Paraffin Wax
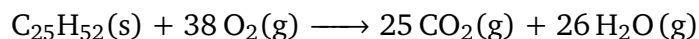# IB Chemistry HL

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1   Purpose

The purpose of this lab was to determine the molar enthalpy of the combustion of Paraffin Wax ($C_{25}H_{52}(s)$) in the following reaction:

$$C_{25}H_{52}(s) + 38\,O_2(g) \longrightarrow 25\,CO_2(g) + 26\,H_2O\,(g)$$

2   Evidence

2.1   Qualitative Observations

The Paraffin Wax candle appears white and opaque, with the colour fading into orange nearing the bottom. Upon touch, the Paraffin Wax feels slightly slippery, and after putting the candle down, the slippery sensation transfers to your hands. The Paraffin Wax candle was able to be attached to the watchglass by exposing the bottom of the candle to a flame, in which the melted paraffin wax at the bottom was able to stick onto the watchglass. This indicates that melted paraffin wax exhibits adhesive properties.
The container surrounding the base of the Paraffin Wax candle does not leave

any openings for air to escape other than the opening at the top. These observations are shown in Figure 1.

Figure 1: Appearance of the Paraffin Wax candle attached to watchglass within container.

The can containing the water has a proportionally greater height than diameter. The opening at the top of the can is significantly wider than the diameter of the thermometer, indicating that the space within the can is not entirely closed and isolated. The two holes allowing for the rod to pass through does wrap around the rod tightly, however because it is a manually created hole, it still allows for passage of air within the can and outside the can. These observations are shown in Figure 2.

Figure 2: Appearance of can used to contain the water from a top view

The Aluminium Foil surrounding the can leaves an opening at the top between the ring and the diameter of the can, as seen in Figure 2.

The process of conducting a trial involved raising the ring along the Ring Stand, lighting the candle, and lowering the ring. This means that there is an interval of time from lighting the candle where combustion was not taking place within the calorimeter. Additionally, after lowering the ring to a reasonable height where the bottom of the aluminium foil surrounding the can meets the top of the container surrounding the candle, the two ends of the aluminium foil become separated due to the significantly larger diameter of the container at the bottom. This leaves a few openings at the side of the aluminium foil cylinder.

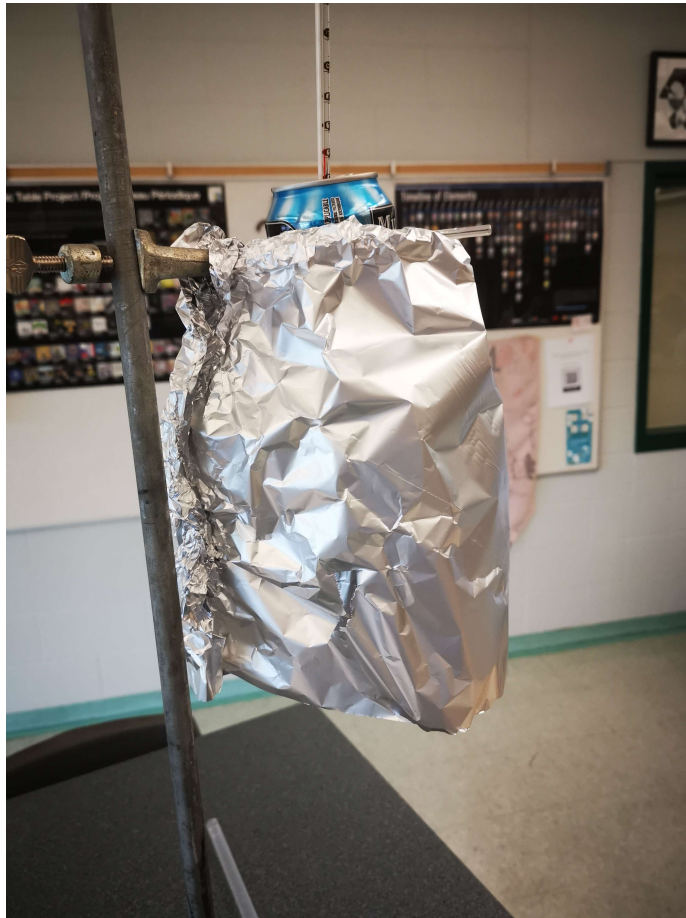Some of these observations can be seen in Figure 3.

Figure 3: View of aluminium foil attached around elevated ring on ring stand

As seen in Figure 4, there is a black stain on the bottom of the can containing the bottom. This is presumably solid carbon produced by incomplete combustion from previous calorimetry experiments.

Figure 4: Appearance of black stain on the bottom of the can containing water

2.2 Quantitative Data

The raw data recorded from the experiment is recorded in Table 1. Note that when measuring the mass of the water, the lab scale was tared with the can, then water was added into the can. Therefore, the mass recorded doesn't need to be subtracted by the mass of the can.

Trial Number	1	2	3
Mass of can /g (±0.003g)	13.039	15.769	15.080
Mass of water /g (±0.003g)	50.141	50.112	50.105
Initial mass of candle and watch glass /g (±0.003g)	106.907	106.209	105.691
Final mass of candle and watch glass /g (±0.003g)	106.209	105.691	105.240
Initial Temperature of water /°C (±0.3 °C)	23.8	25.0	25.0
Final Temperature of water /°C (±0.3 °C)	60.7	51.2	52.6

Table 1: Raw data recorded from each trial during the experiment

Something else to keep in mind is that the final temperature of the water was determined by setting a timer for 5 minutes and recording the temperature afterwards. However, for the first trial, we forgot to consider after what period of time would we record the final temperature. Therefore, that trial simply involved noting the temperature after twenty 15 second intervals which was manually counted. This demonstrates a reason why the final temperature of the water for the first trial was significantly different than the two other trials.

3 Analysis

3.1 Calculation of theoretical molar enthalpy of combustion

The theoretical molar enthalpy of combustion for Paraffin Wax ($C_{25}H_{52}(s)$) will be calculated using Hess' Law.

With $\Delta H°_f$ being the molar enthalpy of formation for some compound, the following values will be used.

$C_{25}H_{52}(s)$: $\Delta H°_f = -1424.3 \ kJmol^{-1}$
$CO_2(g)$: $\Delta H°_f = -393.5 \ kJmol^{-1}$
$H_2O(g)$: $\Delta H°_f = -241.8 \ kJmol^{-1}$

These values can then be used to calculated to theoretical molar enthalpy of combustion for Paraffin Wax.

$$let \ \Delta H°_{comb} = \text{the molar enthalpy of combustion for Paraffin Wax} \ /kJ$$

$$let \ n = \text{the amount of a compound} \ /mol$$

$$let \ \Delta H°_f = \text{the molar enthalpy of formation for a compound} \ /kJmol^{-1}$$

$$\Delta H°_{comb} = \Sigma nH°_f products - \Sigma nH°_f reactants$$

$$\Delta H°_{comb} = \Big((25mol)(-393.5kJmol^{-1}) + (26mol)(-241.8kJmol^{-1})\Big)$$

$$- (1mol)(-1424.3kJmol^{-1})$$

$$\Delta H°_{comb} = -14700kJ$$

$$\Delta H°_{comb} = -14.7MJ$$

3.2   Calculation of experimental molar enthalpy of combustion

The system of the calorimetry experiment will be the combustion of the Paraffin Wax, and the surroundings will be the water and the can. We will make the assumption that the can is made out of aluminium ("Drink can", 2023).
The systems and surroundings are presented in Table 2 along with what they entail. Note that q equals to the total heat in J.

System	Surroundings
Combustion of Paraffin Wax ΔE_p $q_1 = nH°_{comb}$	Water + Aluminium Can ΔE_k $q_2 = m_{water}c_{water}\Delta T_{water}$ $q_3 = m_{Al}c_{Al}\Delta T_{Al}$

Table 2: System and surroundings of the calorimeter.

Given that $q_1 = q_2 + q_3$, the value of $nH°_{comb}$ can then be calculated. A sample calculation is shown below for Trial 1.

$$q_1 = q_2 + q_3$$
$$nH°_{comb} = m_{water}c_{water}\Delta T_{water} + m_{Al}c_{Al}\Delta T_{Al}$$
$$H°_{comb} = \frac{m_{water}c_{water}\Delta T_{water} + m_{Al}c_{Al}\Delta T_{Al}}{n}$$

$m_{water}c_{water}\Delta T_{water} + m_{Al}c_{Al}\Delta T_{Al}$
$$= (50.141g \pm 0.003g)(4.19Jg^{-1°}C^{-1})(60.7°C \pm 0.3°C - 23.8°C \pm 0.3°C)$$
$$+ (13.039g \pm 0.003g)(0.897Jg^{-1°}C^{-1})(60.7°C \pm 0.3°C - 23.8°C \pm 0.3°C)$$

$m_{water}c_{water}\Delta T_{water} + m_{Al}c_{Al}\Delta T_{Al}$
$$= (50.141g \pm 0.006\%)(4.19Jg^{-1°}C^{-1})(36.9°C \pm 2\%)$$
$$+ (13.039g \pm 0.02\%)(0.897Jg^{-1°}C^{-1})(36.9°C \pm 2\%)$$

$$m_{water}c_{water}\Delta T_{water} + m_{Al}c_{Al}\Delta T_{Al} = 8.18 \times 10^3 J \pm 4\%$$

$$n = (106.907 \pm 0.003g - 106.209g \pm 0.003g)(\frac{1mol}{352.77g})$$
$$n = (0.698g \pm 0.9\%)(\frac{1mol}{352.77g})$$
$$n = 1.98 \times 10^{-3}mol \pm 0.9\%$$

$$H°_{comb} = \frac{8.18 \times 10^3 J \pm 4\%}{1.98 \times 10^{-3}mol \pm 0.9\%}$$
$$H°_{comb} = -4.1MJmol^{-1} \pm 0.2MJmol^{-1}$$
$$H°_{comb} = -4.1MJ \pm 0.2MJ$$

Table 3 presents the calculated experimental molar enthalpies of combustion for each trial.

Trial Number	Experimental molar enthalpy of combustion /MJ ($\pm 0.2MJ$)
1	-4.1
2	-4.2
3	-4.8

Table 3: Calculated experimental molar enthalpy of combustion for each trial

The average experimental molar enthalpy of combustion for Paraffin Wax can then be calculated, as shown below.

$$\overline{\Delta H^\circ_{comb}} = \frac{\Sigma \Delta H^\circ_{comb}}{N}$$

where $\overline{\Delta H^\circ_{comb}} = $ average experimental molar enthalpy /MJ

$\Delta H^\circ_{comb} = $ calculated experimental molar enthalpy for a trial /MJ

$N = $ number of trials conducted

$$\overline{\Delta H^\circ_{comb}} = \frac{(-4.1MJ \pm 0.2MJ) + (-4.2 \pm 0.2MJ) + (-4.8 \pm 0.2MJ)}{3}$$

$$= -4.4MJ \pm 0.2MJ$$

Finally, the percent error can be calculated using this averaged value as the experimental molar enthalpy of combustion.

$$\%_{err} = \left| \frac{experimental - theoretical}{theoretical} \times 100\% \right|$$

$$= \left| \frac{-4.4MJ - (-14.7MJ)}{-14.7MJ} \times 100\% \right|$$

$$= 70.3\%$$

4   Conclusion

4.1   Summary

4.2   Evaluation

4.3   Suggested Improvements

References

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