Candidate 1 evidence

Enthalpy of Combustion

Aim

To investigate the change that happens to the enthalpy of combustion of an alcohol when the chain of carbons is increased.

Underlying Chemistry

The enthalpy of combustion of a substance is the heat energy given out when one mole of the substance completely burns in oxygen. All combustion reactions are exothermic so the value for the enthalpy change is always negative.

There are 2 types of combustion:
- complete combustion
- incomplete combustion

Complete combustion requires a plentiful supply of oxygen so that the elements in the fuel react fully. When the fuel burns completely:

- carbon oxidises to carbon dioxide
- hydrogen oxidises to water

The equation, generally, looks like this:

hydrocarbon + oxygen → carbon dioxide + water

with the hydrocarbon being the alcohol

Incomplete combustion takes place when the oxygen supply is not enough for the fuel to completely burn.

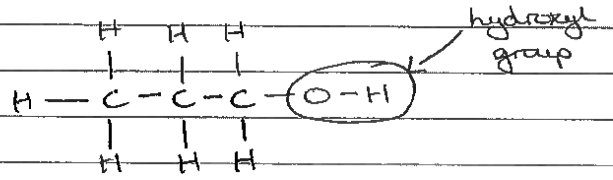
General equation for incomplete combustion:

hydrocarbon + oxygen → carbon monoxide + carbon + water

Carbon monoxide is a poisonous gas and the carbon is released as soot which is why incomplete combustion does not take place very often.

LDF's and Hydrogen Bonding

An example: Propan-1-ol:



All alcohols have hydrogen bonding present due to the hydroxyl group. This is an intermolecular force so it occurs between molecules.

Alcohols also have London Dispersion forces present and dipole-dipole interactions. The boiling points rise when the chain of carbons increases in an alcohol due to the dispersion forces increasing. The attractions get stronger which increases the size of the temporary dipoles set up.

Calculating Enthalpies

The formula used to calculate enthalpy of combustion is:

$$E_H = cm\Delta T$$

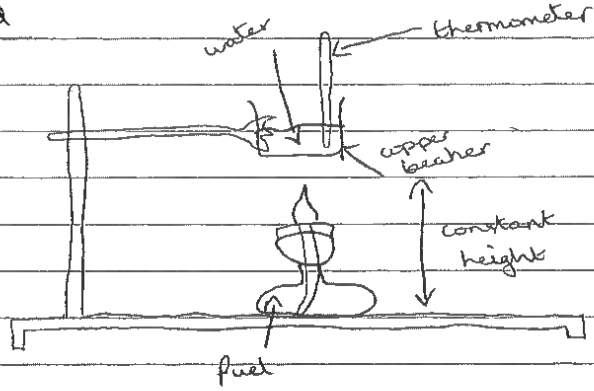
'E_H' is the enthalpy change in kJ or kJ/mol

'c' is the specific heat capacity of water which is a constant, and is found in the data booklet to be 4·18 $kJ\ kg^{-1}\ °C^{-1}$.

'm' is the mass of water in kilograms.

'ΔT' is the change in temperature the water undergoes in °C.

Method



We set up the apparatus as shown above. We measured the mass of the alcohol before the experiment and after to calculate the mass burned. We let the thermometer rise up by 10° then blew out the flame. We repeated this 6 times with 3 different alcohols.

Raw Data

Methanol

① Water: start temp. = 20°C
end temp. = 30°C

Methanol: start mass = 187.87g
end mass = 187.07g

② Water start temp. = 20°C
end temp. = 30°C

Methanol: start mass = 179.07g
end mass = 178.49g

Ethanol

① Water: start temp = 20°C
end temp = 30°C

Ethanol start mass = 197.02g
end mass = 196.78g

② Water: start temp = 20°C
end temp = 30°C

Ethanol start mass = 196.79g
end mass = 196.52g

Propanol

① Water: start temp. = 20°C
end temp. = 30°C

Propanol: start mass = 171.35g
end mass = 171.12g

② Water: start temp. = 20°C
end temp. = 30°C

Propanol start mass = 177.44g
end mass = 177.27g

Mean Data

Alcohol	Mean Enthalpy of Combustion calculated ($kJmol^{-1}$)
Methanol	-198.9
Ethanol	-756.7
Propanol	-1282.8

Methanol:

① Alcohol burned = $\frac{187.87 - 187.07}{2}$ = 0.8g

② Alcohol burned = 0.58g

$E_H = cm\Delta T$
$= 4.18 \times 0.1 \times 10$
$= 4.18 kJ/mol$

$E_H = cm\Delta T$
$= 4.18 \times 0.1 \times 10$
$= 4.18 kJ/mol$

0.8g → 4.18kJ/mol
32g → -167.2kJ/mol

0.58g → 4.18kJ/mol
32g → -230.6kJ/mol

Mean enthalpy = $\frac{167.2 + 230.6}{2}$

= -198.9 kJ/mol

Ethanol

① Alcohol burned = 0.24g

0.24g → 4.18kJ/mol
46g → -801.2kJ/mol

② Alcohol burned = 0.27g

0.27g → 4.18kJ/mol
46g → -712.1kJ/mol

Mean enthalpy = -756.7kJ/mol

Propanol

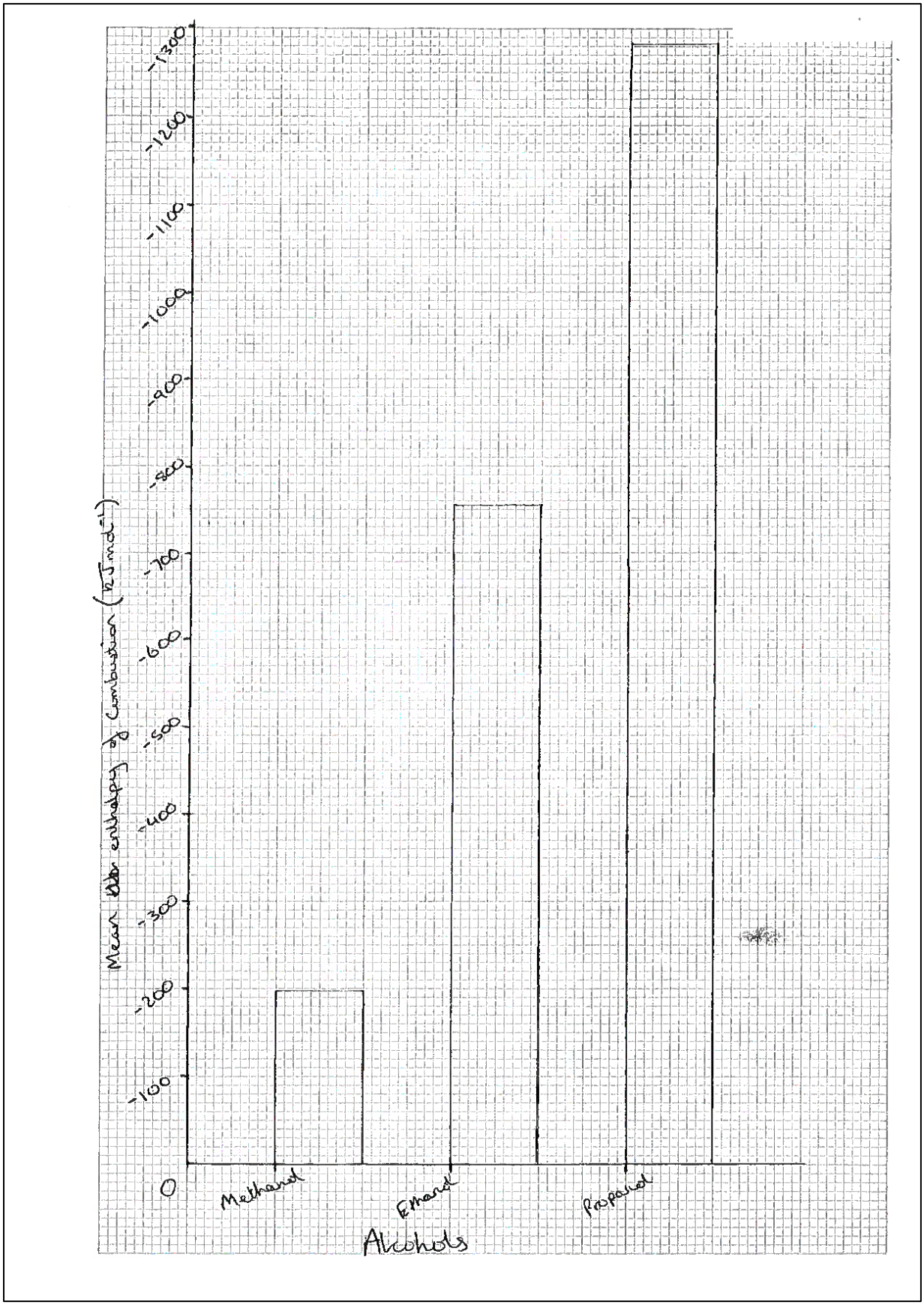
① Alcohol burned = 0.23g

0.23g → 4.18kJ/mol
60g → -1090.4kJ/mol

② Alcohol burned = 0.17g

0.17g → 4.18kJ/mol
60g → -1475.3kJ/mol

Mean enthalpy = -1282.8kJ/mol


Mean Bond enthalpy of Combustion (kJ mol⁻¹)
-1300
-1200
-1100
-1000
-900
-800
-700
-600
-500
-400
-300
-200
-100
0
Methanol
Ethanol
Propanol
Alcohols

Enthalpies of Formation and Combustion of Selected Substances

Substance	Standard enthalpy of formation /kJ mol^{-1}	Standard enthalpy of combustion/kJ mol^{-1}
hydrogen	–	−286
carbon (graphite)	–	−394
sulfur (rhombic)	–	−297
methane	−75	−891
ethane	−84	−1561
propane	−104	−2219
butane	−126	−2878
benzene	49	−3268
ethene	52	−1411
ethyne	227	−1301
methanol	~~−239~~	−726
ethanol	~~−278~~	−1367
propan-1-ol	~~−303~~	−2021
methanoic acid	−425	−255
ethanoic acid	−484	−874

Selected Bond and Mean Bond Enthalpies

https://www.sqa.org.uk/sqa/files_ccc/ChemistryDataBooklet_NewH_AH-Sep2016.pdf (13/03/2019)

Analysis

My results and the internet source agree with each other as, the enthalpy of combustion increases when the chain of carbons increase. In both cases, propan-1-ol has the highest enthalpy of combustion for both sources.

Conclusion

To conclude, when the chain of carbons is increased in an alcohol, the enthalpy of combustion increases.

Evaluation

Due to the reaction being exothermic, heat escaped from my experiment as my values for combustion were not the same as the data booklet. To minimise this, I could have used draught shields to keep the heat in as much as possible for more accurate results.

Also, the apparatus we used to set up this experiment was basic and simplistic which shows as my internet source's enthalpy of combustion was far more significant than what I calculated. To improve this, we could have used better equipment like a bomb calorimeter which would have given more accurate results.

Source 2 comes from the dates booklet used by higher students and academic people across Scotland. This increases the reliability of the comparison between the two sources and also the trends and conclusion made.

Bibliography

https://www.sqa.org.uk/sqa/files_ccc/ChemistryDataBooklet_NewH_AH-Sep2016.pdf (13/03/2019)

Second Source

https://www.bbc.com/bitesize/guides/z8p72hv/revision/2 (12/03/2019)