Chemistry Coursework

To Investigate Whether There is a Link Between the Number of Carbon Atoms in Alcohol and its Standard Enthalpy of Combustion

Anil Sood 11G

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Introduction

Alcohol is the common family name for the hydrocarbon group Alkanols. The generic formula of these organic compounds is:

$$C_n.H_{(2n+1).}OH$$

The first example from the alkanol family is:

Methanol - $C.H_{3.}OH$

From the generic formula we can see that different types of alcohols will have different number of carbon atoms.

In this project I intend to investigate whether there is a link between the number of carbon atoms in alcohol and its standard enthalpy of combustion Δ**H**.

Planning

Different members of the alcohol family have different numbers of carbon atoms and should therefore have different enthalpy $\Delta\mathbf{H}$ values. The complete combustion of an alcohol is when it reacts with oxygen in the air to form water and carbon dioxide.
In this process energy is required to break the existing chemical bonds (endothermic reaction) and energy is given out by the creation of new chemical bonds (exothermic reaction).
If the heat of combustion is a $-\Delta\mathbf{H}$ the reaction is exothermic as the products of combustion are at a lower energy level than the reactants. The energy is given out when forming the bonds between the new water and the carbon dioxide molecules.
Here are the balanced equations for the alcohols that I will be using:

Methanol – $CH_3OH + 1^1/_2O_2 \rightarrow CO_2 + 2H_2O$
Ethanol – $C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$
Propanol – $C_3H_7OH + 4^1/_2O_2 \rightarrow 3\ CO_2 + 4H_2O$
Butanol – $C_4H_9OH + 6O_2 \rightarrow 4CO_2 + 5H_2O$
Pentanol – $C_5H_{11}OH + 7^1/_2O_2 \rightarrow 5CO_2 + 6H_2O$
Hexanol – $C_6H_{13}OH + 9O_2 \rightarrow 6CO_2 + 7H_2O$
Heptanol – $C_7H_{15}OH + 10^1/_2O_2 \rightarrow 7CO_2 + 8H_2O$
Octanol – $C_8H_{17}OH + 12O_2 \rightarrow 8CO_2 + 9H_2O$

Firstly to ensure that there is a link between the number of carbon atoms in alcohols and the enthalpy of combustion I shall carry out a preliminary test before I initiate the actual investigation. This will consist of burning two different alcohols. The heat produced from this process will be used to heat up a measured quantity of water in a beaker.

The two alcohols I have chosen for my preliminary investigation are:

1. Butanol – $C_4H_9OH + 6O_2 \rightarrow CO_2 + 5H_2O$

2. Octanol – $C_8H_{17}OH + 12O_2 \rightarrow CO_2 + 9H_2O$

<u>Apparatus List:</u>

- Range of alcohols (listed above)
- Draught proof tin
- Heat proof mat
- Water Beaker
- Thermometer
- Balance
- Measuring cylinder
- Tripod
- Measured amounts of 200 cm_3 of water
- Bunsen Burner (So a splint can be lit to light alcohol)

Method:

- Firstly weigh the mass of the alcohol bottle and record the reading.
- Then set up the apparatus as shown in the diagram below.
- Then take the alcohol required for the first test, which in this case is Butanol, and put a draught proof tin over it.
- Then measure 200 cm_3 of water using the measuring cylinder and pour it into the water beaker.
- Then a thermometer is used to measure the initial temperature of the water, which should also be recorded.
- A lit splint (using the Bunsen burner) is used to light the wick of the alcohol bottle.
- The water beaker, containing the water, is to be instantly placed over the burning alcohol on the draught proof tin
- Once the temperature of the water reaches approximately 40 degrees Celsius the wick is blown out.
- Finally the alcohol bottle is to be removed and re-weighed, and the new mass recorded.

Diagram:

Safety

- Wear safety glasses.
- Tie back long hair, tuck in school ties, and button up cuffs.
- Ensure there are no naked flames near alcohol being stored or measured.
- Clean up any alcohol spills immediately.
- Take care not to handle hot apparatus, allow cooling before dismantling and cleaning.
- Wear an apron.
- If spilt on skin or clothing remove affected clothing to prevent fire risk and wash affected area.

Several things should be taken into account to make it a fair test:

- Trying to keep the conditions around the alcohol burner the same in each test, i.e. the amount of draft.
- To try and ensure heat loss is the same for each alcohol when burnt.
- When measuring the alcohol container to make sure everything is measured including the lids for the containers.
- To use the same balance to measure the weight of all the alcohols used.

Outcome of the preliminary test

The results showed that there was a pattern between the number of carbon atoms and the enthalpy of the alcohol, so I therefore continued my main investigation. Therefore I can now make a prediction for the results of my investigation.

Prediction

From the preliminary results I can predict that as the number of carbon atoms increases in the alcohol the enthalpy of combustion increases. This can be qualified by the following equations for the complete combustion of Ethanol:

$C_2H_5OH + 3O_2 \rightarrow CO_2 + 3H_2O$.

Δ**H =** Energy of the products of combustion + Energy of the reactants of combustion

For the reactants you have:

Five C-H bonds, one C-C bond, one C-O bond, one O-H bond and three O=O. Energy is required to break these bonds. The table below shows the required energy values for this process.

Bond	Bond Energy Values (kJ/mol)
H-H	436
O=O	496
C-C	348
C=C	612
C-H	412
C-O	360
C=O	805
H-O	276

Table 1 – Bond Energy Values

By using the bond energy values from the table above it is possible to calculate the enthalpy of combustion for a given alcohol:

Energy required for breaking reactant bonds:
5*H-C = 2060
1*O-H = 463
1*C-O = 360
3*0=0 = 1488
1*C-C = 348
Total = 4719
Energy required for creating product bonds:
4*C=O = -2972
6* O-H = -2778
Total = -5750
Δ**H** = -1031kJ/mol for combustion of ethanol.

This can be used to calculate the theoretical enthalpy of combustion for the alcohols of this investigation. Below is a list showing the theoretical enthalpy of combustion for these alcohols.

Methanol = - 659
Ethanol = -1031
Butanol = - 2023
Pentanol = - 2301
Heptanol = - 3511
Octanol = - 4007

As you can see a longer molecule takes more energy to break its bonds, compared to a smaller molecule. However, as the carbon length increases the greater the number of carbon dioxide and water molecules produced as a result of the combustion of the alcohol. This is because the energy released due to the creation of the increasing

number of C=O bonds are far greater than the bonds being broken. Hence the net result is exothermic process.

Therefore I expect there to be a trend going upwards on my graph. Methanol will have the lowest reading, and as the number of carbons increase in the different alcohols their readings will increase. Therefore I expect the results to be close to my prediction, having considered the theory bond energy.