The Relationship Between The Number of Carbon Atoms In An Alcohol And Its Standard Enthalpy Change Of Combustion.

INTRODUCTION

Introduction and Aim:

In this experiment, I am trying to investigate the fact that if there is relationship or common pattern between the amount of carbon atoms in an alcohol and also its standard enthalpy change of combustion.

When crude oil is heated naphtha is formed, this naphtha includes alkenes. Alkenes are simple forms of alcohol as they are the alcohol that has not yet been mixed with any water, H_20. These alkenes come to form a homologous series this series is $C_nH_{2n.}$ This means that for every carbon atom there is, there are two times as many hydrogen atoms. When these alkenes are hydrated with water to form an alcohol, another homologous series is formed $C_nH_{2n+1}OH$. This is due to the fact that from water, one hydrogen atom is covalently bonded with the methane and also another hydrogen atom along with an oxygen atom is connected. The basic equation for the formation of an alcohol such as methanol is:

$$\text{Methene} + \text{Water} \longrightarrow \text{Methanol}$$

$$CH_2 + H_2O \longrightarrow CH_3OH$$

The above equation is the basis for all of the other alcohols as they are all hydrated in the same way and they also follow the same pattern of the homologous series, $C_nH_{2n+1}OH$.

The alcohols that I am using in this experiment are listed below, together with their formation and also the Relative Molecular Mass:

	Alcohol	Formation	Relative Molecular Mass	
	Methanol	CH_3OH	32	
	Ethanol	C_2H_5OH	46	
	Propan-1-ol	C_3H_7OH	60	
	Butan-1-ol	C_4H_9OH	74	
	Pentan-1-ol	$C_5H_{11}OH$	88	
	Hexan-1-ol	$C_6H_{13}OH$	102	
	Heptan-1-ol	$C_7H_{15}OH$	116	
	Octan-1-ol	$C_8H_{17}OH$	130	

**Note: It can be seen from above that the increase from One alcohol to the other is CH_2. It can also be seen that The RMM increases by 14 when the amount of carbons in the alcohol increase (1 carbon atoms + 2 hydrogen atoms = 12 + 2). **

All that I have explained above is that of the first part of the aim of this experiment, the amount of carbon atoms in an alcohol. In order to carry out this experiment, I need to know two separate pieces of information, the first is the amount of carbon atoms in the alcohol, this, I have explained above and the second is the harder piece of information to find, this is the enthalpy change of combustion. This piece of information is the difference in the amount of energy required to break bonds within, as this case shows, the alcohol and also to form new bonds.

"The Enthalpy Change of Combustion (ΔH) = Input Energy – Output Energy".

Using the above 'formula', it can be worked out if the Enthalpy Change of Combustion is an exothermic or an endothermic value. An exothermic reaction would cause a greater energy for the formation of the products than the breaking of the original reactants. An endothermic reaction will be the opposite. With this piece of information, I can firstly work out the true values through the above 'formula' but to work out these for my own experiment is a much harder task.
Below, the Enthalpy Change of Combustion is stated and shown for the first alcohol, methanol:

Methanol + Oxygen ⟶ Carbon Dioxide + Water

$$CH_3OH + 1\tfrac{1}{2} O_2 \longrightarrow CO_2 + 2H_2O$$

REACTANTS	PRODUCTS
1 O = O ½ O = O	H ----- O ----- H H ----- O ----- H 1 O = C = O

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        H
        |
H ----- C ----- O ----- H
        |
        H
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Reactants:

3	C --- H	1236 KJ
1	C --- O	360 KJ
1	O --- H	463 KJ
1	O = O	496 KJ
½	O = O	+ 248 KJ

Total Energy to break bonds: 2803 KJ

Products:

2	C = O	1468 KJ
4	O --- H	+ 1852 KJ

Total Energy to form new bonds: 3338 KJ

Enthalpy Change of Combustion (ΔH):
ΔH = Energy of Reactants – Energy of Products
ΔH = 2803 KJ – 3338 KJ
ΔH = -535
ΔH = Exothermic Reaction

Above, it can be seen that the actual ΔH figure is a negative figure; this means that the reaction is an exothermic reaction as it releases more energy meaning it releases heat; if it were to be a positive number i.e. the release of more input energy than output energy then it would be an endothermic reaction. To work out all of the ΔH values individually is a long and time consuming job, therefore, I have worked out an easier route to take in order to find the ΔH values. This route is derived from the RMM table where I have stated that there is an increase of one carbon atom and two hydrogen atoms from the previous example, for example, there is an increase of one carbon atom and two hydrogen atoms from methanol to ethanol. Therefore, if the bond energies for these extra atoms are added to the previous alcohol, the ΔH can be found out for the next alcohol. Below are the bond energies that are inputted into the previous alcohols to work out the ΔH of the next alcohol.

REACTANTS

Addition of:

H
|
C
|
H

∴ This includes the addition of:

1	**O = O**	**496 KJ**
$^1/_2$	**O = O**	**248 KJ**
2	**C --- H**	**824 KJ**
1	**C --- C**	**+ 348 KJ**
Total energy Inputted:		**1916 KJ**

PRODUCTS

There is an increase of:

2	**C = O**	**1486 KJ**
2	**O --- H**	**+ 926 KJ**
Total energy Output:		**2412 KJ**

I have worked out as shown above the extra figures that need to be added to the previous alcohol to find the new ΔH of the alcohol that comes next in the series. Overleaf is a table showing the ΔH data that I have worked out for all of the alcohols.

	Alcohol	**Formation**	**Reactants (KJ)**	**Products (KJ)**	**ΔH (KJ/Mol)**	
	Methanol	CH_3OH	2803	3338	-535	
	Ethanol	C_2H_5OH	4719	5750	-1031	
	Propan-1-ol	C_3H_7OH	6635	8162	-1527	
	Butan-1-ol	C_4H_9OH	8551	10574	-2023	
	Pentan-1-ol	$C_5H_{11}OH$	10467	12986	-2519	
	Hexan-1-ol	$C_6H_{13}OH$	12383	15398	-3015	
	Heptan-1-ol	$C_7H_{15}OH$	14299	17810	-3511	
	Octan-1-ol	$C_8H_{17}OH$	16215	20222	-4007	

Through the form of research, I have found out that there are different ΔH values for the family of alcohols; these are results that have been worked out scientifically and are known as the 'True Values'. A table showing the true values are shown below:

	Alcohol	**Formation**	**True ΔH Values (KJ/Mol)**	
	Methanol	CH_3OH	-726.3	
	Ethanol	C_2H_5OH	-1366.7	
	Propan-1-ol	C_3H_7OH	-2017.3	
	Butan-1-ol	C_4H_9OH	-2674.9	
	Pentan-1-ol	$C_5H_{11}OH$	-3322.9	
	Hexan-1-ol	$C_6H_{13}OH$	-3976.1	
	Heptan-1-ol	$C_7H_{15}OH$	-4622.9	
	Octan-1-ol	$C_8H_{17}OH$	-5280.2	

The above table therefore means that when I plot a graph to show my results I can compare them with the True Values and the Worked out values.

PLANNING

Equipment
In this experiment, I am going to find out the ΔH for each of the alcohols to see if they have a correlation with the amount of carbon atoms. In order for me to carry on with this experiment, I shall need the use of various equipment, these equipment pieces are:

- Alcohol burners + lid
- Water (300ml)
- Scales
- Drought excluder (tin can)
- Water tin
- Thermometer
- Bunsen Burner

Independent Variable
This is the item that I am going to change for each alcohol, in this experiment only one factor will be changed, this is the alcohol used. There will be eight alcohols used.

Dependant Variable
These are the items that I will keep the same, in this experiment; the items are all of the rest of the factors will stay the same, such as equipment, amount of water, same scales.

Fair Test
In order to keep this experiment fair, and as accurate as possible, I shall have to make sure that all of the equipment used is the same for all of the alcohols. This includes items such as the same scales, the same thermometer, the same amount of water and so on. It would be much better if I were able to use the same size burner. If time permits, I shall repeat each of the experiments.

Prediction
My prediction is the fact that there will be a strong, if not definite correlation between the amounts of carbon atoms there are in the alcohol and its enthalpy change of combustion.

Hypothesis
I stated in my prediction above that I think there will be a correlation between the amount of carbon atoms in an alcohol and its enthalpy change of combustion due to the fact that as we travel further down the family of alcohols, like for methanol, the reactant bond energies are greater than the products. I think that this will carry on through the whole of the family of alcohols. Also, due to the fact that carbon burns easily and more intensely, so therefore the more carbon atoms there are the higher the ΔH value would be. Furthermore, the product ΔH value will be greater each time as there are more bond energies to be formed in the products section.

Diagram
The diagram below shows the set-up for the equipment in the experiment:

Safety
In this experiment, safety plays a big role as inhalation or the swallowing of the alcohols can have dreadful side effects. Also, there is the use of fire and also hot water, improper uses of these may lead to burning or scalding. Safety goggles and a laboratory coats must be worn.

Method
1. Pick one of the eight alcohols.
2. Weigh the alcohol burner including the lid and record the weight reading.
3. Measure 300ml of water and put it into a tin can.
4. Measure the temperature of the water.
5. Put the alcohol burner in a drought excluder.
6. Take of the lid and light the alcohol burner wick.
7. Balance the water tin can on the drought excluder.
8. Wait until the temperature of the water has risen by 15° to 18°.
9. Take off the water can from the drought excluder and replace lid quickly.

10. Re-weigh burner and the lid and record the weight.
11. Repeat the experiment.
12. Find out the ΔH value by the two equations shown below:

- $4.2 * \Delta°c * \text{Mass of } H_2O = \frac{XJ}{1000} = \mathbf{X}\ KJ$
- $\text{Moles} = \frac{\text{Mass burnt}}{\text{RMM of alcohol}} = \mathbf{Y}$
- $\Delta H = \frac{\mathbf{X}\ KJ}{\mathbf{Y}}$ KJ/Mol^{-1}
- Multiply Result by –1 to give total in KJ/Mol

OBTAINING EVIDENCE

Obtaining Evidence

Below is the table I am going to use in order to record my results while carrying out the experiment.

Alcohol	Formula	Mass of Water	Weight at Start	Weight at End	Temp at Start	Temp at End

ANALYSIS

The table below shows the results of my experiment through the calculations.

Alcohol	Formation	RMM	Water	Temp at Start	Temp at End	Temp. Change	Start Mass	End Mass	Mass Burnt	Heat Out	Moles Burnt	Enthalpy (ΔH)
				(In degrees)	(In degrees)	(In degrees)	(In grams)	(In grams)	(In grams)	(KJ)		(KJ/Mol)
Methanol	CH_3OH	32	300 ml	19	34	15	169.17	167.23	1.94	18.90	0.060625000	-311.75257732
Ethanol	C_2H_5OH	46	300 ml	22	41	19	216.34	215.06	1.28	23.94	0.027826087	-860.34375000
Ethanol	C_2H_5OH	46	300 ml	18	35	17	215.06	213.97	1.09	21.42	0.023695652	-903.96330275
Propan-1-ol	C_3H_7OH	60	300 ml	19	35	16	159.22	158.20	1.02	20.16	0.017000000	-1185.88235294
Propan-1-ol	C_3H_7OH	60	300 ml	19	36	17	158.20	157.19	1.01	21.42	0.016833333	-1272.47524752
Butan-1-ol	C_4H_9OH	74	300 ml	19	34	15	206.62	205.15	1.47	18.90	0.019864865	-951.42857143
Pentan-1-ol	$C_5H_{11}OH$	88	300 ml	19	32	13	204.33	203.92	0.41	16.38	0.004659091	-3515.70731707
Hexan-1-ol	$C_6H_{13}OH$	102	300 ml	19	28	9	153.47	152.93	0.54	11.34	0.005294118	-2142.00000000
Heptan-1-ol	$C_7H_{15}OH$	116	300 ml	19	34	15	200.30	199.20	1.10	18.90	0.009482759	-1993.09090909
Heptan-1-ol	$C_7H_{15}OH$	116	300 ml	18	31	13	199.20	198.43	0.77	16.38	0.006637931	-2467.63636364
Octan-1-ol	$C_8H_{17}OH$	130	300 ml	19	35	16	198.18	197.42	0.76	20.16	0.005846154	-3448.42105263

**Note: Due to the fact that there are two results for some of the experiments as shown above. Having two different results in a graph for the same alcohol would prove difficult. Therefore, I am going to use the average for the two results as shown in the table below. **

Alcohol	Average ΔH Results Experimental Results
Ethanol	882.153526375
Propan-1-ol	1229.17880023
Heptan-1-ol	2230.363636365

GRAPHS

***Note: It is evident that the graphs should be slanted on a downwards slope, but for the ease of analysing, the figures for ΔH has been multiplied by –1 in order to give a positive figure. ***

CONCLUSION

The aim of this experiment was to try and discover if there was a correlation or any common pattern between the amount of carbon atoms in an alcohol and its standard enthalpy change of combustion (ΔH). According to the aim and title, I have been able to successfully carry out the experiment and have gained satisfying results. As can be seen from the previous graphs, Graphs 1, 2, 3and especially on graph 4, there seems to be a good correlation between the amount of carbon atoms and the ΔH of the alcohol. The general trend is the fact that when the amount of carbons increases, then generally the ΔH of that alcohol also increases (meaning the negative ΔH number increases). This means that the more carbons there are in the alcohol the greater the output energy of that alcohol is. Hence, the more carbons, the more of an exothermic output the reaction is.

The lowest ΔH values were that of Methanol at 311.75257732. The highest value was with Octan-1-ol where the ΔH value was 3448.421053. This shows the relationship from only these two figures, it can be seen that Octan-1-ol has eight carbons and Methanol has one carbon atom so therefore a small correlation can be seen from the basic output.

At the starting stages of the experiment, I made the prediction that there would be a correlation between the two factors, the amount of carbon atoms and the ΔH of the family of alcohols. This prediction that I stated is now confirmed through completing the experiment and I am able to use the experiment to support my first prediction. However, the hypothesis is correct only to a certain extent. I stated that the enthalpy of the products would decrease but in fact, they increase. The fact that I stated carbon burns easily is a true fact and has been shown by the experiment.

The basic fact for this experiment is the fact that the creation of the products for each of the alcohols in increasing number of carbon atoms is harder to bond together and more energy is needed for the manufacture of the products as they have high bond energy figures. The bond energies for the reactants are proportionate to the amount of carbon atoms in the alcohol.

Overall, I am able to use the experiment to support my prediction as both of them underline the same phrase:

'An increase in the amount carbon atoms in an alcohol means an increase in the ΔH of the alcohol.'

Even though this experiment could be derived from looking at figure books, the act of doing the experiment helps to understand the reason why there is a correlation between the ΔH and the amount of Carbon atoms in the alcohol.

EVALUATION

Due to the fact that the experiment was carried out in a school laboratory, the entire experiment was only a rough estimate to what the actual results would be. The coursework experiment was in my view done very well. I think that for the standard of equipment I had, the experiment was completed very well indeed. The reason why I would say that this experiment was successful is because of the fact that the two requirements for the experiment i.e. the enthalpy change of combustion and also the number of carbon atoms in the alcohol have been available and satisfying rational results have been produced from the experiment. However, there were some faults with the experiment, the most obvious fault is that of the one shown on Graph 3, the result for the ΔH value for Butan-1-ol. This result is out of place with the rest of the results and is probably caused by a fault in the apparatus. However, even though this experiment gave results, I do not think that the evidence gained is enough for a firm conclusion as there are anomalous results within the experiment.

This brings the section onto limitations and problems. There were very many limitations to this experiment mainly due to the fact that the experiment was not as much of a fair test as it should have been. The first problem is the fact there were different burners for different alcohols. This meant that the same burner could not be used for the experiment for the different alcohols. Furthermore, the burners were all different sizes so therefore the test was unfair. This also meant that different sized drought excluders had to be used having a knock on effect to mean different sized water containers had to be used. This means that even though the same water volume is used, there are different amounts of surface area meaning one can lose heat more quickly than the other. Another problem was the fact that different sized wicks were also evident meaning again an unfair experiment. Within the experiment there were two losses of heat, these were at the points of the period when the burner is alighted and is transferred to under the drought excluder and also at the point where it has been covered by the water that is being heated, there are gaps in the drought excluder. There is also a loss of weight at the point where the lid is being taken off from the burner and the wick is being a flamed.

As I have said before, I think that I have successfully completed the coursework for the conditions that I was working under. If I did this experiment under stricter conditions with better equipment, I would be able to produce better and more accurate results. The best improvements for this experiment would be to change the experiment in order to satisfy the faults or limitations that I have expressed above.