Enthalpy of Combustion of Alcohols and carbon atoms

Name

Institution

Course

Professor’s Name

Date

Introduction

Rationale

Hydrocarbons such as alcohol have been used as an alternative source of fuel for many decades. As the fossil fuel price increases, there is a need for alternative sources of energy. Alcohol is one method that is environmentally friendly and very effective. The effectiveness of a given alcohol is determined by the enthalpy of combustion. In this exploration, I will investigate carbon atoms impacts the enthalpy of combustion.

Background

The enthalpy of combustion is defined as the amount of heat energy that is given out when one mole of a substance (alcohol) burns in the presence of oxygen (Verevkin et al, 2021). The equation below shows the combustion of alcohol;

Alcohol + oxygen $\longrightarrow$ carbon (IV) oxide +water + Heat energy

When alcohol burns in the air carbon (IV) oxide, water, and heat energy is produced. During the combustion of alcohol, heat energy is produced and thus the reaction is an exothermic reaction (Weber et al, 2021). A hydrocarbon is an organic compound that contains oxygen and carbon atoms only (Carey, 2019). Examples of hydrocarbons include; butanol, ethanol, and methanol.

Various alcohol have different numbers of carbons as shown below;

Alcohol	**Number of carbon atoms**
Methanol	1
Ethanol	2
Butanol	4
Pentanol	5

Hexanol	6

Enthalpy heat of combustion increases as the number of carbon atoms within alcohol molecules. As the number of carbon atoms increases, the molecular structure increases, and thus the enthalpy increases.

Aim

The main objective of this exploration is to consider how carbon atoms in primary alcohol impact the enthalpy of combustion. In this exploration, the following alcohols will be investigated; methanol, ethanol, butanol, pentanol, and hexanol.

Hypothesis

During the combustion primary alcohols react with oxygen to produce water, carbon (IV) oxide, and energy. The combustion of alcohol entails the breaking of carbon bonds and forming new bonds with oxygen (Chen& Chen, 2020). As carbon atoms in a primary alcohol increases, the molecular size of the alcohol increases, and thus more energy will be released. Based on this information, therefore, it can be predicted that as the number of carbon atoms escalates in primary alcohols, the enthalpy of combustion will also increase.

Variables

Dependent variable

The enthalpy of combustion of various primary alcohol will be used as a dependent variable in this assessment. The enthalpy of combustion will be computed by measuring the mass of alcohol used to raise the temperature of water by 15^0C.

Independent variable

The number of carbon atoms in a carbon molecule will be computed by writing down the molecular structure of the molecule.

Control variable

Table 1: control variable table

Control variable	**Impact of the variable**	**How the variable will be manipulated**
Room temperature	The room temperature dictates the initial temperature of the water. As the room temperature increases, less heat energy will be required to raise the temperature of water by 15^0C and thus affecting the final results	-To have accurate results, the experiment will be conducted in a controlled environment where the room temperature and pressure will be kept constant.
Volume of water	As the volume of water increases, more heat energy will be required to raise the water temperature (Sarp et al, 2021). At the same time, minimal heat energy will be required when the volume of water is small. Therefore varying volumes of water will have	-In order to have accurate and reliable data, the volume of water used in this experiment will be constant (100ml). A measuring cylinder

	a negative of the final results.	
Calorimeter distance	The distance between the burner and the calorimeter does affect the heat energy supplied to the beaker.	The distance between the calorimeter and the burner will be kept constant throughout the exploration. The wick distance should also be kept constant to ensure the legitimacy of the data.
Temperature	The amount of heat energy required to raise the temperature of water by 40^0C is high compared to the amount of heat energy required to raise the temperature of water by 10^0C. Therefore varying temperatures will provide inaccurate results.	The temperature change of water will be kept constant (15^0C). A mercury thermometer will be used to record the initial and final temperature of the water.
Water quality	The quality of water will impact the enthalpy combustion of a given alcohol. When the quality	Pure distilled water will be used in this exploration.

	of water is poor, the heat capacity of water increases.	
Same apparatus	Different apparatus such as calorimeters and measuring scales have varying uncertainty. Different calorimeters will have varying heat capacitance and this affects the final results.	-in order to increase the accuracy of data, the same calorimeter and measuring scales will be used in this experiment.

Methodology

Materials

- Glass beaker ($400 \pm 0.5ml$)

-4 oil burners

-500ml distilled water

-100ml of primary alcohol (methanol, ethanol, propanol, and butanol) in burners

-1 lighter

- Mercury thermometer ($100(\pm 0.05^{0}$)

-Digital measuring scale ($\pm 0.01g$)

-copper calorimeter

-1 Measuring ruler ($30 \pm$0.1cm)

-2 Tripod Stand

-Cotton wool (for insulation purposes)

-measuring cylinder

Procedure

1. Gather all the materials listed above this will ensure easier access to equipment.
2. Place the copper calorimeter on top of the tripod stand.
3. Measure 100ml of water using a measuring cylinder. Place the water into the calorimeter and cover the colorimeter with the lid to ensure there is no heat loss.
4. Measure and record the initial mass of the burner containing methanol.
5. Place the burner below the tripod stand and adjust the distance between the lamp and the calorimeter to 5cm (this distance will be controlled throughout the entire experiment).
6. Open the lid of the lamp and light up the burner using the lighter provided. Start reading the thermometer reading until the temperature difference is 15^0C.
7. Measure the final mass of the lamp and record the data.
8. Find the amount of fuel used to raise the amount of water by 15^0C.
9. Repeat steps 2-9 two more times to ensure the accuracy and consistency of data.
10. Repeat steps 2-10 using other primary alcohols provided.
11. Compute the enthalpy of combustion of each alcohol and present the data in a graph.

Risk assessment

Safety

-There were considerable risk issues in this exploration. All the alcohols used are highly flammable and thus no direct flame should be used.

Environmental factors

During the combustion of alcohol, carbon (IV) oxide is given out. Carbon (IV) is a greenhouse gas that is causing global warming and climate change. In this exploration however, the amount of alcohol used is very small and thus the amount of carbon (IV) oxide released into the atmosphere is very small.

Ethical issues

There were no ethical considerations in this exploration since no living organism was used.

Results

Raw data

Table 2: raw data table

Alcohol	**Trial 1**		**Trial 2**		**Trial 3**	
	Initial mass (g)	**Final mass (g)**	**Initial mass (g)**	**Final mass (g)**	**Initial mass (g)**	**Final mass (g)**
Methanol	56.23	55.70	55.72	54.61	52.61	50.50
Ethanol	82.61	81.98	81.98	80.42	80.42	78.89
Butanol	87.59	88.15	88.15	86.56	86.54	85.01
Pentanol	64.09	61.97	61.97	60.68	60.68	59.61
Hexanol	75.75	75.02	75.01	74.12	74.14	73.17

Sample calculation

The mass of fuel used

To calculate the mass of the fuel (acid) used, the following method will be applied;

$$\text{mass of fuel used (g)} = \text{intial mass (g)} - \text{final mass(g)}$$

$\text{mass of fuel used (g) (methanol} = 58.23\text{(g)} - 55.70\text{(g)} = 0.53\text{g}$

The same method was applied to find the mass (g) of the fuel used to raise the temperature of water to 40^0C.

Table 3: mass of the fuel used

Alcohol	**Trial 1**	**Trial 2**	**Trial 3**
Methanol	0.53	1.11	2.11
Ethanol	0.63	1.56	1.53
Butanol	1.05	1.59	1.53
Pentanol	2.12	1.29	1.07
Hexanol	0.73	0.89	0.97

Average fuel used:

$$Mean = \frac{Trial\ (1) + Trial\ (2) + Trial\ (3)}{3}$$

$$\boldsymbol{Mean\ (methanol)} = \frac{0.53 + 1.11 + 2.11}{3} = 1.25g$$

Enthalpy

In order to compute the enthalpy of each alcohol, the following steps will be used;

Moles

To find the moles of the alcohol used;

$$Moles = \frac{mass}{molar\ mass}$$

Consider the moles of ethanol;

The molar mass can be computed by looking at the molecular structure of the alcohol;

C_2H_6O

RMM= (C, H, and O);

RMM of C (carbon) =12.01

RMM of H (hydrogen) =1.01

RMM of O (oxygen) =16.00

$RMM = 2(12.01) + 6(1.01) + 16.00 = 46.08$

Moles of ethanol;

$$Moles = \frac{1.24g}{46.08} = 0.027\ moles$$

The following method is used to find the specific heat capacity of ethanol;

$heat\ capacitor = m * c * \Delta T$

Where;

m= mass of fuel used

c= water capacitance (4.184kJ/mole)

ΔT =Change in temperature (15^0C)

$heat\ capacitor = 1.24g * 4.184 * 15 = 77.82J$

To find the enthalpy of combustion, the following method is applied;

$$enthalpy\ of\ combustion = \frac{heat\ change}{moles\ of\ ethanol\ used}$$

$$enthalpy\ of\ combustion = \frac{77.82}{0.027} = -2891.98\ j/mol$$

Since the process is an exothermic reaction (heat is given out), a negative sign is used;

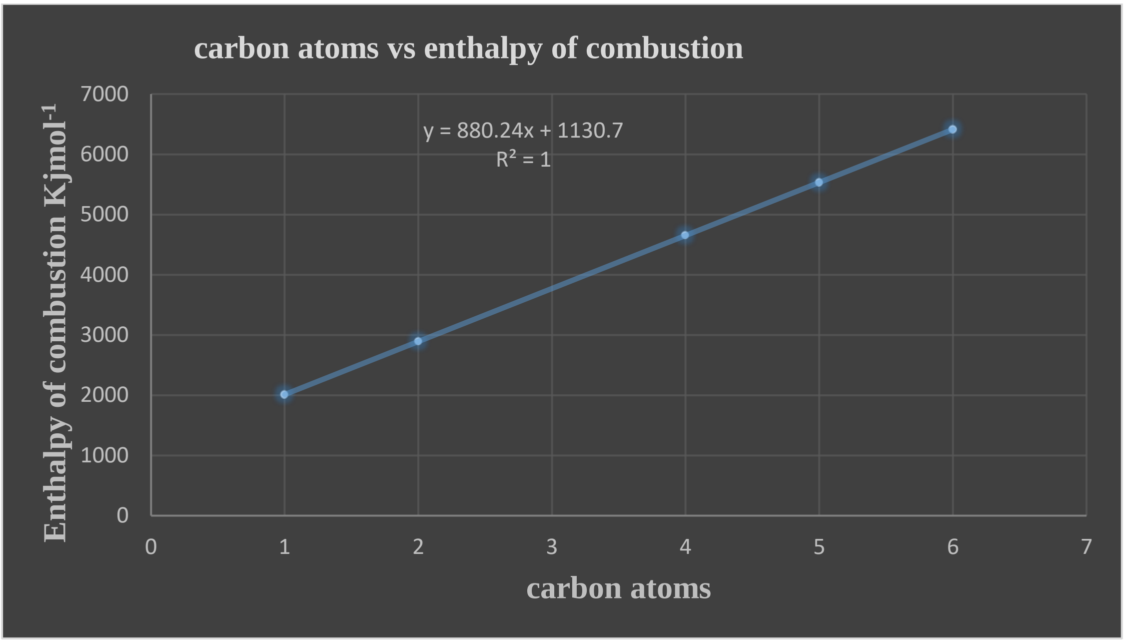
The table below summarises the processed data from this experiment;

Table 4: processed data table

Alcohol/fuel	**Carbon Chain**	**Average in mass**	**Enthalpy of combustion $Kjmol^{-1}$**
Methanol	1	1.25	2010.83
Ethanol	2	1.24	2891.98
Butanol	4	1.39	4651.83
Pentanol	5	1.49	5532.29
Hexanol	6	0.86	6411.69

Data analysis

Based on the data from the above table, it can be noted that as the number of carbon increases, the enthalpy of combustion also increases. When methanol (1 carbon atom) was used, the enthalpy of combustion was -2010.83 $Kjmol^{-1}$. As the carbon atoms increases to 4 (butanol), the enthalpy of combustion was -4651.83 $Kjmol^{-1}$. When hexanol (6 carbon atoms) was used, the enthalpy of combustion was 6411.69 $Kjmol^{-1}$. The data from the above table can be used to develop the following graph;



Based on the graph it can be noted that as the number of carbon rises, the enthalpy of combustion also rises. There is a direct link between carbon atoms and the enthalpy of combustion. The line of best fit from the chart above indicates an upward trajectory indicating that there is a direct link between the variables. The coefficient correlation indicates a perfect association thus confirming that there is a positive link existing between the carbon chain and the enthalpy of combustion. The equation from above graph is;

$y = 880.24x + 1130.7$ where gradient is positive indicating that indeed there is positive association between variables.

Conclusion

Summary

The main objective of this assessment was to investigate how the number of carbon atoms in various hydrocarbons impacts the enthalpy of combustion. It was predicted that "as the number of carbon atoms escalates in primary alcohols, the enthalpy of combustion will also increase". From the data collected in this exploration it can be noted that as the number of carbon rises, the energy produced during combustion also increases and thus confirming my hypothesis. A graph showing the number of carbon atoms and enthalpy of combustion has a linear link confirming that there is a positive link between the variables. Based on this information, therefore, it can be concluded that there is a negative link between carbon atoms and the enthalpy of combustion.

Evaluation

The exploration was successful although there were some errors incurred during the experiment. The experiment was conducted in a controlled environment where the oxygen supply was limited. As a result, the combustion was incomplete, and thus less energy was released. In order to evade this error in the future, it is vital for the experiment to be conducted in a large room that is well-ventilated.

Extension

In future experiments, it is vital to consider other hydrocarbons such as alkanoic acids. The research question should be “How does the number of carbon atoms in alkanoic acids affect the enthalpy of combustion?

Reference

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