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To Determine the Enthalpy of combustion of different alcohols.

Skill Area P: Planning

Prediction:

I predict that as the number of carbon atoms in the alcohols increases, the enthalpy (or heat content) increases at a fairly equal rate.

Detailed Scientific Knowledge:

For any reaction to take place bonds must be broken and made, bond breaking requires energy while bond making releases energy. Bonds between different atoms require or release different amounts of energy when broken or made because the bonds are different in strength. The energy that is stored in chemical bonds is called enthalpy and given the symbol H. By looking at the equation for the reaction and more importantly looking at the bonds that are being broken and made, it is possible to work out an estimate for the amount of energy that will be released in the reaction. This is called the change in enthalpy. The enthalpy of a reaction is the change in energy going from reactants to products. For exothermic reactions, the enthalpy is negative while for endothermic reactions, the enthalpy is positive. A negative value for the enthalpy, or ΔH denotes that energy has been released into its surroundings, bonds have been made and therefore there is an increase in temperature. A positive value of ΔH shows that energy has been taken in from its surroundings and bonds have been broken, as there is now more energy and also a decrease in temperature.

The reactions that I am going to be looking at are all combustion reactions and are all exothermic reactions. This means that energy will be released during the reaction and more bonds will be formed than broken. It is possible to show a reaction and its ΔH value in terms of a reaction path graph. Let us take the example of methane reacting with oxygen – a reaction not too dissimilar to the one that I will be carrying out. By looking at the symbol equation, shown below, it is possible to predict that ΔH will be negative as more bonds are being formed.

$$\mathbf{CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O}$$

By working out ΔH for this reaction, I will be able to draw a reaction path. However as I am not doing this experiment, I will use the average bond energies to work out ΔH. Although this will achieve quite an accurate result, it is not perfect because these are only **general** bond energies, so the actual bond energies may differ slightly. To find ΔH, I have to know the following bond energies:

E (C-H) = 412 KJ/mol^{-1}

E (O=O) = 496 KJ/mol^{-1}

E (C=O) = 743 KJ/mol^{-1}

E (O-H) = 463 KJ/mol^{-1}

For the reactants the bonds being broken are 4 * (C-H), and 2 * (O=O). Therefore the energy being taken in is 1648 KJ + 992 KJ = 2640 KJ.

For the products, the bonds being formed are 2 * (C=O), and 4 * (O-H). Therefore the energy being given out is 1486 KJ + 1852 = **-**3338 KJ. The energy diagram is therefore shown below:

This method of finding ΔH can be applied to my investigation but I will also compare it to the result of ΔH that I achieved from my experiment. This can be found using two equations. For the first one, I need the mass of the water, the temperature rise of the water and the specific heat capacity of the water to find the energy given out using the equation:

$$\mathbf{E = m * C * \Delta t.}$$

After having the energy given out, I need to find the amount of energy given out by one mole of the alcohol. To do this I need to use the equation given below:

*ΔH = Energy in the water * (Molar mass of alcohol / Change in mass of burner)*

In order to provide evidence to support or undermine my conclusion, I will need to process my results. After finding the change in enthalpy using the methods that I have shown above, I will record them in a table. I will then find the difference between each one of them. If the difference remains relatively constant for all the alcohols, then I will be able to say that there is a constant change in enthalpy, and so support my prediction in my conclusion.

Now I need to look at **why** the enthalpy will increase as the number of carbon and hydrogen atoms increases. If we look at the reactions that occur when the alcohols are reacted in oxygen, we obtain the following symbol equations:

$$CH_3OH + 1.5O_2 = CO_2 + 2H_2O$$

$$C_2H_5OH + 3O_2 = 2CO_2 + 3H_2O$$

$$C_3H_7OH + 4.5O_2 = 3CO_2 + 4H_2O$$

$$C_4H_9OH + 6O_2 = 4CO_2 + 5H_2O$$

$$C_5H_{11}OH + 7.5O_2 = 5CO_2 + 6H_2O$$

As you can see in the equations above, the alcohol is reacting with oxygen forming carbon dioxide and water. This is a normal combustion reaction. However a lot of attention must be paid to the changes to the number of moles of each of the other products – they increase by 1. This means that more and more bonds are being formed. Bond forming releases energy to the outside environment, making the temperature rise. This is a negative value of the enthalpy. As the bonds being broken only increases by a smaller amount, then the change in enthalpy will be larger. There is a constant increase in enthalpy because if we find the difference between the equations, we can write it as:

$$CH_2 + 1.5O_2 = CO_2 + H_2O$$

I can tell from that equation that there are more bonds being formed than being broken therefore the change in enthalpy will increase at a constant rate.

Safety Precautions:

For this investigation, there are many safety precautions that I will have to be aware of. The alcohols that I will be using are obviously flammable, and so need I will need to take care when handling them to avoid spillages and they should only be used out of the way of other flames. My experiment will produce heat so the apparatus will need to be handled with care during and after the experiment.

Apparatus:

- Retort Stand, Boss Head and Clamp
- Copper calorimeter
- Various alcohol burners
- Thermometer
- Stirrer
- Electronic measuring balance
- Measuring cylinder

Diagram:

Planned Procedure:

The set up of the apparatus, as you can see from the diagram, is relatively simple. The metal calorimeter is held in place by the retort stand. I would then pour into the copper calorimeter the set amount of water of 200 cm^3, using a smaller measuring cylinder meaning that it would be more precise so that it would remain a fair test. Next before lighting the burner, I will weigh it and make a note of the reading, as this is necessary in determining the amount of alcohol used. I will then place the burner under the calorimeter and adjust its height so that it is exactly 5 cm away from the top of the burner. I will take the temperature of the water and make a record of this, as this is necessary in calculating the temperature rise. After lighting the wick of the burner away from the calorimeter, the burner should be placed under the calorimeter quickly to stop unnecessary burning.

I will stir the water at regular intervals of about every 5 seconds so that the temperature of the water remains constant everywhere in the beaker. Every 5 seconds or so I will check the thermometer to see whether the temperature is 40 ^{o}C higher than the initial temperature. When the temperature reaches that designated temperature, then I will stop the alcohol burner. Very carefully as the copper calorimeter would still be very hot, I would slide the burner from underneath and place it on the measuring balance. I would record this mass so that I would know the amount of alcohol used.

The next thing that I would do would be to repeat this experiment again with the same alcohol for at least another 2 times, or until the results are very similar. After having done that, I would do the same experimental method but only with another different alcohol, for example if I used methanol, I would now use ethanol. After doing the repeats like the previous experiment, I would move onto another alcohol, for example propanol. I would do this twice more with another two alcohols to obtain at least 10 results for the mass change, and the temperature rise.

Preliminary experiment and Strategy:

Before this experiment, I undertook various other preliminary experiments to confirm my variables and also so that my planned procedure would be effective, and I would obtain as reliable and precise results as possible. It became apparent that I needed to prevent heat loss throughout the experiment as I soon found that I obtained very inaccurate results if I had the calorimeter more than 10 cm away from the top of the burner. When I lowered the height of the calorimeter to about 5 cm away form the top of the burner, I soon found that my results were much more accurate than before. This is why I decided to set the height of the calorimeter to 5 cm above the top of the burner.

I decided to use a calorimeter because I found that in my preliminary experiments that when using a glass beaker, a lot of energy was absorbed by the glass while less energy was absorbed by the metal calorimeter. The results that I obtained from using a glass beaker were that the energy I obtained was 11700 J; while with the metal calorimeter using exactly the same variables (the same mass of water, temperature rise and the specific heat capacity of water), the energy that I obtained was 10920 Joules. This clearly shows that the glass beaker absorbs much more energy making my results less precise and reliable.

I have also decided to base my range of variables on my preliminary experiment as I think that there will be a constant change in ΔH as I am using a homologous series. In order to make my experiment a fair test, I will have to control various things that would otherwise affect the results and make sure that I only change one variable at a time. I will need to keep the mass, or volume, of water the same, as this is one of the things that I need to work out the amount of energy given off by the burner. I already know that 1 cm^3 is the same as 1 g, so the amount of water should remain at 200 cm^3, or 200g. I will also need to keep the temperature rise constant because then I will be able to directly compare the results without having to work out the energy produced. I will need to keep the distance that the calorimeter is away from the beaker so my results will be as reliable as possible. However, one factor that I will not be able to control is the size of the wick on the burner. If one alcohol burner has a much greater size of a wick then it will mean that there is more surface area and more heat could be produced. Having said that, the experiments will be taking place in a laboratory and so the environment that each experiment takes place is relatively constant.

Variables:

Independent	The different alcohols
Dependant	The mass of the alcohol burner
Controlled	The temperature rise The amount of water The distance from the burner to the calorimeter
Uncontrolled	Drafts from people opening doors or windows nearby The size of the wick of the burner

Range of Variables:

I will use five different alcohols in my investigation so that I obtain a clear view of how this variable affects my results. These are as follows:

1. Methanol: CH_3OH

2. Ethanol: C_2H_5OH

3. Propanol: C_3H_7OH

4. Butanol: C_4H_9OH

5. Pentanol: $C_5H_{11}OH$

I have decided to use five different alcohols as this will give me the clearest view of how the enthalpy changes with each alcohol that have different molar masses. If I was just dealing with two different alcohols, then if the enthalpy does change then I will not be able to make a conclusion as it is just looking at two alcohols. However if I look at five different alcohols, then a clear pattern will emerge about the change in enthalpy in alcohols and I will have obtained enough evidence from my results to make a conclusion. This is why I have chosen the range of values that I will use to be as large as possible in order that I can obtain a clear view of how this factor will affect my results.

Reliable and precise evidence:

In order to obtain reliable and precise evidence, I will set about doing a number of tasks. I will use a small measuring cylinder that could measure up to the nearest 0.1 cm^3 so that I will be able to pour 200 cm^3 of water into the calorimeter which would be much more accurate if I just used a beaker to measure it.

I will use an electronic measuring balance so that I would be able to very accurately record the mass of the alcohol burner to at least 2 decimal places. This would mean that my results would be very accurate as opposed to using other measuring scales. As I have already mentioned, I will make this experiment a fair test so that I will obtain as accurate and reliable evidence as possible.

There are some aspects of the experiment that may go wrong therefore I will need to especially careful when attempting them. When reading the temperatures of the thermometer, I will need to be very careful that I look directly at the reading not at any angle as this may affect the readings that I obtain. Also I should be very careful in measuring the distance from the top of the burner to the calorimeter as this would also affect the results and the energy produced. After lighting the burner, I will need to put it very quickly under the water as if I don't do this then some of the burner may be used up without heating the water. This is another thing that may go wrong. I will need to make sure that the metal calorimeter has completely cooled down so that there would be no energy stored in it at the start of the next experiment. However as I am repeating all the experiments I believe that this will not be so much of a problem. Hopefully however, I think that the experiment will run relatively smoothly throughout.