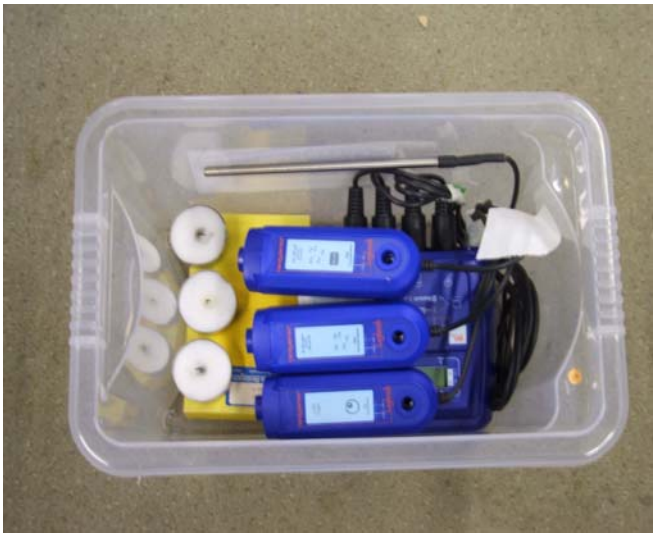
Incomplete Combustion

Introduction: For an ideal combustion reaction of a pure hydrocarbon in oxygen, two gases would be produced, carbon dioxide and water vapour. However this situation rarely occurs; hydrocarbons normally contain impurities and there is normally not enough oxygen for a complete reaction to take place. When there is not enough oxygen, carbon monoxide is also produced.

Traditionally the burning of a candle has been investigated by floating a candle in a bowl of water, lighting it and placing a glass jar over it. As the candle burns the water rises, the candle is extinguished at the point when the water has risen by approximately 20%. This has therefore been used to demonstrate that the candle is extinguished at the point when all the oxygen in the air has been used up. Using an oxygen, carbon dioxide and carbon monoxide sensor this method can be investigated.

Equipment:

- Datalogger
- CO_2 Sensor
- CO sensor
- Oxygen sensor
- Temperature sensor
- Clear box
- Metal block
- Candles
- Oil burner
- Methanol burner



Method:

In this set-up, 3 candles are used, however this does not influence the results significantly. This experiment can either be carried out using a wireless logger connected to a computer or any logger using the remote recording function. The advantage of the wireless logger is that that it will allow the students to see the data from the investigation live.

1) Plug the sensors into the logger and put the logger, the sensors and the candles into a clear box.
2) If using a plastic box, suspend a piece of metal, such as a heat sink, above the candle to prevent the heat from the candle damaging the box.

Using an ML

a) If using an ML set up a remote recording; turn the logger on by pressing the “tick” button.

b) The readings should be displayed on the logger as soon as the sensors are connected. To set the carbon dioxide sensor hold down the “set 400” button on the sensor, until the reading on the logger is appropriate.

c) To start the recording, press the “tick” button again.

Using the WL

a) If using a Logbook WL, wirelessly, open Datadisc Pt and connect the Datalogger, as normal. Select Measure/Meter and click “ok” on the first menu that appears. The meter will then be displayed.

b) Hold down the “set 400” button on the carbon dioxide sensor, until the meter reading is appropriate.

c) Start an Auto Time recording from the toolbar or from the “Measure” menu followed by “Auto time”.

d) To start the recording click on the green “record” icon in the toolbar.

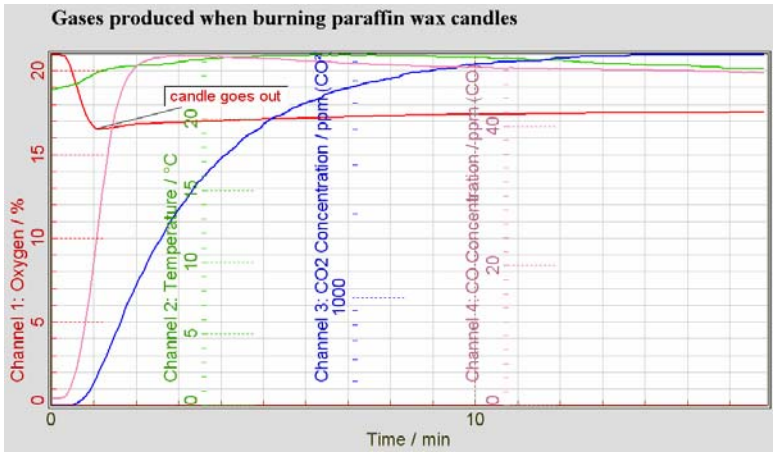
3) As soon as the recording is started, quickly light the candle(s) and close the lid of the box.
4) The carbon dioxide and carbon monoxide sensors do not respond immediately to changes in the levels and so it is necessary to continue the recording after the candle has gone out. In this case each experiment took approximately 10 minutes.
5) Stop the recording either in Datadisc or on the logger.
6) Repeat for each type of burner.

Please note before carrying out any of these activities, particularly in a school laboratory, a suitable risk assessment will need to be carried out appropriate to your working environment.

Analysing the results:

Paraffin wax candle

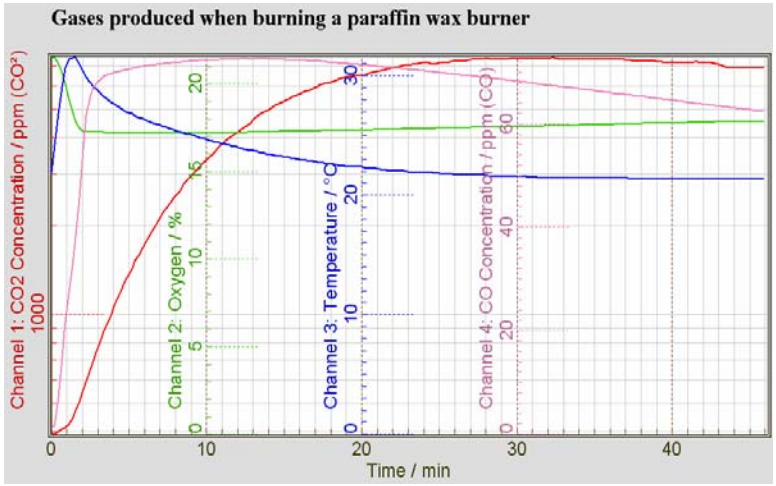
The following graph was produced for the paraffin wax candles:



N.B. It is important to note that the carbon monoxide level and the carbon dioxide level only appear to increase after the candle has gone out due to the time it takes for the sensor to respond to the change. The oxygen sensor, however, responds very quickly.

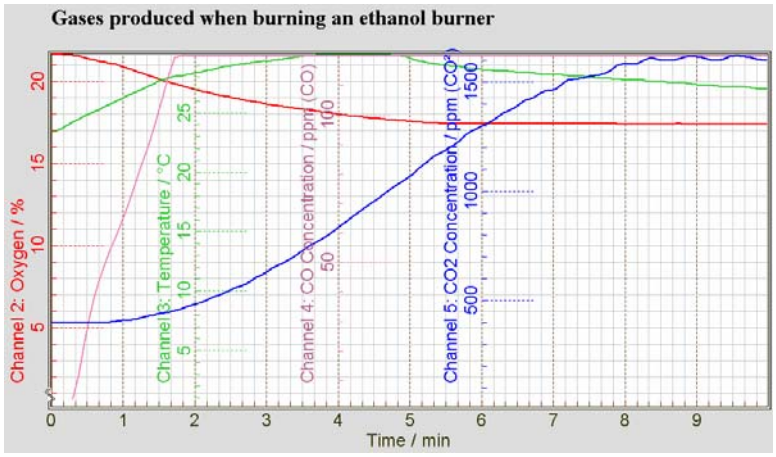
◄ To find any point on the graph use the cursor under Graph/Cursor/Spot. The oxygen level at which the candle went out was 16.5%. This indicates that the traditional approach is erroneous, as the candle requires a level higher than 16.5% oxygen to burn and is extinguished well before all of the oxygen is used up. What's more, both carbon monoxide and carbon dioxide are produced and so the volume could not be decreasing due to oxygen production since much is converted into other gases. Another aspect to consider is the production of carbon monoxide. This is a good demonstration of incomplete combustion taking place. In this case about 1 in 1080 molecular reactions are incomplete.

Paraffin oil burner



◄ The experiment was then repeated using the oil burner. Using the cursor to find the exact values, it can be seen that the burner is extinguished at 17% oxygen; the total production of carbon monoxide is higher compared with the candles and the total production of carbon dioxide is roughly comparable. However, this effect could be due to the different mechanism for burning the wax as opposed to a being caused by a different form of fuel.

Ethanol burner



◄ As can clearly be seen from this graph, when the methanol burner was burned a much larger quantity of carbon monoxide was produced (the total quantity went over-range) and considerably less carbon dioxide was produced (1600ppm compared with 7450ppm for the oil burner and 7400ppm for the candle). This indicates that a lot more incomplete combustion took place when burning ethanol. The oxygen level at which the flame was extinguished, was also slightly higher, 17.5%. However due to the high production of carbon monoxide and therefore the lower rate at which oxygen was used up, the candle burned for much longer. It is expected that the methanol would produce less CO_2, as there is only one carbon atom per molecule.

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