Topic 5 : Fuels

Revised April 1995

Fuels are chemicals which burn giving out energy. For example, coal, oil and natural gas are all fuels. When a substance burns it reacts with Oxygen. This reaction is called **combustion**.

Example 1 : A glowing splint relights and burns in Oxygen. This is the test for Oxygen.

Example 2 : Combustion of Methane (Natural gas)

$$CH_4 + 2\ O_2 \rightarrow CO_2 + 2\ H_2O + \text{energy}$$

Coal, oil and natural gas are all **fossil fuels** i.e. they were formed by decay of animal and plant remains over millions of years. They are a ' finite ' resource - they will not last forever. Unless renewable forms of energy are developed there will be an energy crisis when the fossil fuels begin to run out.

The Formation of Coal

Coal was formed when sediment was deposited, usually by a river at its mouth, on top of dead vegetation. The intense pressure converted the vegetation into coal.

The Formation of Oil and Natural Gas

Oil was formed when sediment was deposited by a river on top of the remains of small animals and plants lying on the sea bed. The intense pressure converted these remains into oil and natural gas. The oil soaked up into porous rocks like sandstone but was trapped below non-porous rocks like clay. The gas forms a pocket above the oil. Oil is brought to the surface by drilling.
The thick, black oil (known as Crude) must be transported with care. It does not dissolve in water ; it floats on the surface of water. If spilled at sea it therefore forms slicks which are washed up and pollute beaches killing sea birds and other marine life.

Fractional Distillation of Crude Oil

Crude oil is a mixture of compounds. It is refined to separate this mixture. The main substances in crude oil are hydrocarbons - compounds which contain Hydrogen and Carbon only. Fractional distillation is the process used to separate the hydrocarbons into groups (fractions) of similar size. It makes use of the fact that 'The larger the molecule the higher the boiling point'. Larger molecules have a bigger surface area, stick together more and are therefore more difficult to separate and turn into a gas (a 'change of state')

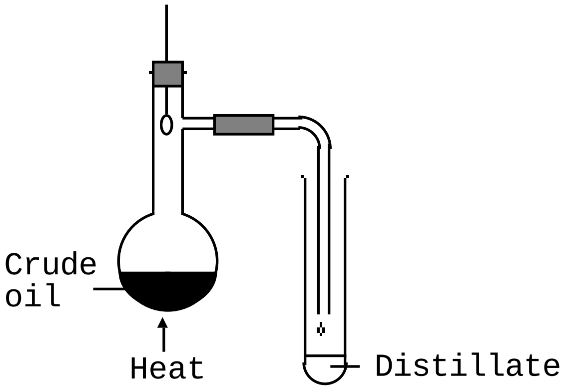
Example : Hexane C_6H_{14} B.P. 69 ^{0}C

Decane $C_{10}H_{22}$ B.P. 174 ^{0}C

Six fractions are separated :

Fraction	No. of Carbon atoms per molecule	Boiling range ^0C	Uses
Gases	C_1 - C_4	below 20	Calor gas
Petrol	C_5 - C_{10}	20 - 170	Cars
Paraffin	C_{10} - C_{18}	170 - 300	Stoves, aeroplanes
Diesel	C_{15} - C_{25}	270 - 370	Trains, lorries
Lubricating oil	C_{20} - C_{70}	above 370	Machinery
Bitumen	above 70 C	solid residue	Roads

In the laboratory we can use a simple apparatus to distil crude oil:



The fractions boil off in the order : gases, petrol etc.
The amounts of each fraction depend on the original source of the crude oil. Oil from the Gulf is more viscous and contains more of the heavier fractions than oil from the North Sea.

We note three main differences in the different fractions :

1. **<u>Ease of evaporation</u>**

   The heavier fractions (e.g. lubricating oil) evaporate less quickly than the lighter fractions (e.g. petrol). Large molecules stick together more and are more difficult to separate and turn into a gas.

2. **<u>Flammability (ease of catching fire)</u>**

   The lighter fractions catch fire more easily than the heavier fractions. It is the mixture of hydrocarbon vapour and Oxygen above the liquid which ignites. Since they evaporate more quickly, the lighter fractions have more vapour above the liquid and so catch fire more easily than the heavier fractions.

3. **<u>Viscosity (thickness)</u>**

   The heavier fractions are more viscous (less runny) than the lighter fractions. The larger the molecules the more they stick together. This makes movement difficult and therefore reduces the flow of the liquid.

The Combustion of Hydrocarbons

If there is plenty of Oxygen available hydrocarbons burn to produce Water and Carbon dioxide ; if the Oxygen supply is restricted (in small rooms or car cylinders) the products are Water and the poisonous gas Carbon monoxide. It is dangerous to burn paraffin stoves in an unventilated room.

Example : Ethane

Plenty Oxygen gives '**complete combustion**'

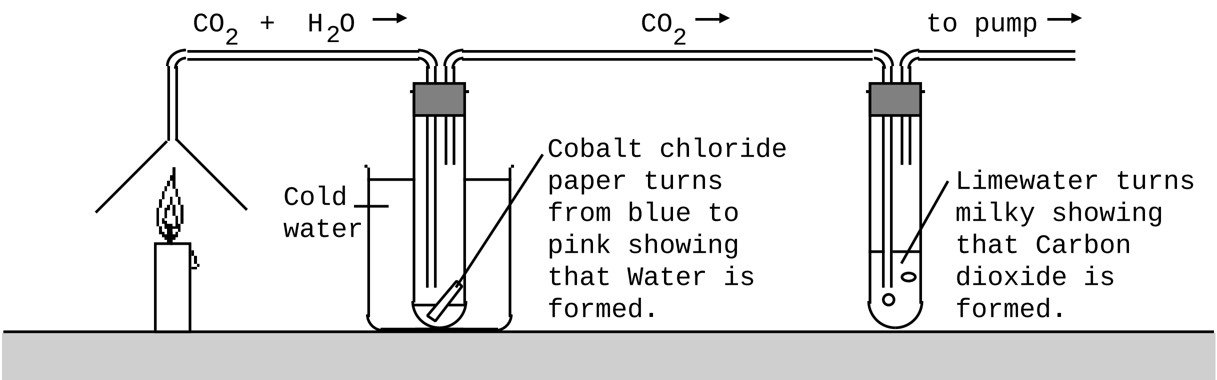
C_2H_6 + O_2 -> CO_2 + H_2O

Oxygen deficiency leads to '**incomplete combustion**'

C_2H_6 + O_2 -> CO + H_2O

[N.B. Practice balancing the above reactions!]

We can demonstrate the burning of hydrocarbons in a good supply of Oxygen (air) by burning candle wax (hydrocarbon) in the following apparatus :



Notice that this experiment shows that hydrocarbons must contain Hydrogen : the Hydrogen in the Water formed can only have come form the hydrocarbon. Similarly the experiment shows that hydrocarbons must contain Carbon : the Carbon in the Carbon dioxide can only have come from the hydrocarbon.

Air Pollution

Oil, natural gas and coal contain a small amount of Sulphur compounds. When these fuels are burned, the Sulphur combines with Oxygen forming Sulphur dioxide which is released into the atmosphere. Sulphur dioxide is an acidic gas causing acid rain and severe bronchial troubles. The Sulphur can be removed from the oil and natural gas and used to make Sulphuric acid. This reduces air pollution.

Burning petrol in a car engine causes major pollution :-

(a) The petrol/air mixture is ignited by passing a spark through the mixture. Unfortunately this spark also provides the energy required to get Nitrogen and Oxygen in the air to react together to form Nitrogen monoxide NO and Nitrogen dioxide NO_2, an acidic gas causing acid rain and throat cancer.

(b) Lead compounds, added to petrol to slow down combustion, burn forming Lead oxide which causes brain damage in small children.

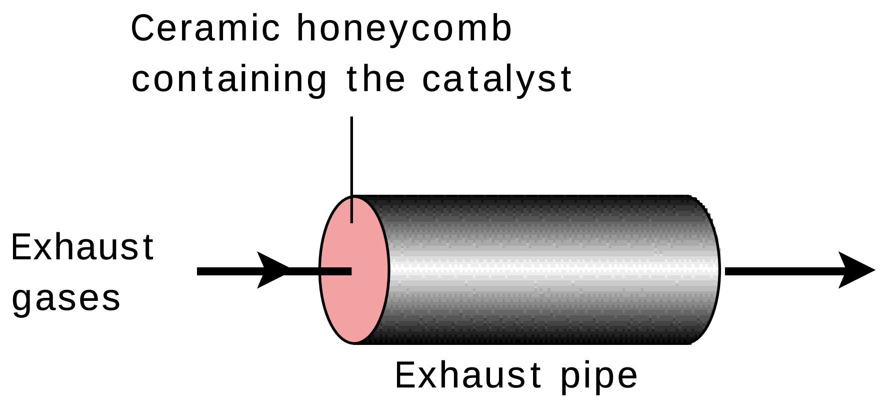
(c) The small amount of Oxygen available results in poor combustion. Unburned Carbon and hydrocarbons C_xH_y are formed.
Carbon monoxide CO, produced as a result of the small amount of Oxygen available, is also formed. CO causes heart disease. The amount of CO produced can be reduced by increasing the amount of Oxygen available (using a 'lean-burn' engine) so that Carbon dioxide is formed instead.

Catalytic Convertors in Cars

The toxic gases in car exhaust react with each other forming non-toxic products:

$$NO + CO + NO_2 + C_xH_y \rightarrow N_2 + CO_2 + H_2O$$

Unfortunately this reaction is very slow. A Platinum/Rhodium catalyst, placed in the exhaust, speeds up the reaction:



Drawbacks :

(a) 'Leaded petrol' cannot be used with a catalytic convertor because the Lead sticks to the catalyst, 'poisons' it and prevents it from working. New 'un-leaded' petrol contains no Lead but contains other additives which may cause cancer.

(b) Increases the price of the car by about £500.

(c) Does not remove but actually increases, by 15%, the amount of Carbon dioxide in car exhaust.
[Carbon dioxide is a 'greenhouse' gas]

(d) Only works when the catalyst begins to get hot after the car has been running for about 20 minutes and is therefore no use for short journeys.