science

chemistry

Topic 7 – Organic Chemistry

What is organic chemistry?

Is the study of the chemistry of carbon compounds. All living things are carbon based and there are so many carbon compounds because carbon atoms can form chains and rings.

Crude oil

Crude oil is a finite resource found in rocks and is the remains of an ancient biomass consisting mainly of plankton that was buried in mud.

Crude oil is a mixture of **hydrocarbons** – compounds containing hydrogen and carbon **ONLY**

Fractional Distillation

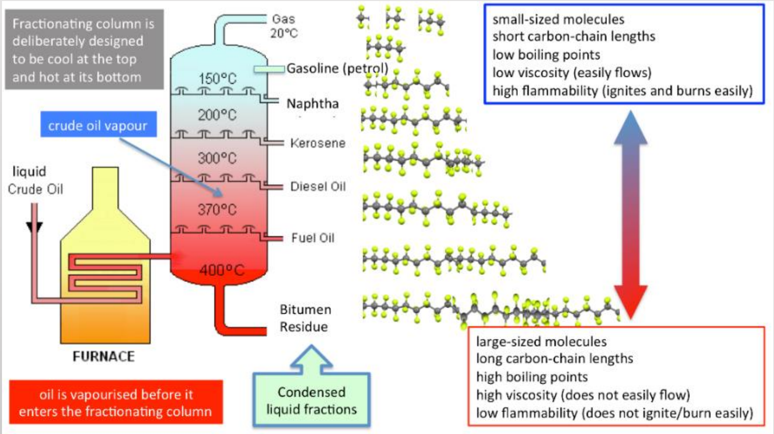
Method of separating mixtures based on their boiling points.

Heat the crude oil until is becomes a **vapour**

Put into tower with temp gradient (hot at bottom, colder at top)

Allow the vapour to condense at different heights in the tower.

Smaller molecules with lower bpt will condense higher up the tower where it is colder. Larger molecules will condense lower down the tower.



Properties of fractions

Boiling point – smaller molecules have lower boiling points

Flammability – smaller molecules burn better so are better fuels

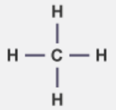
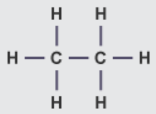
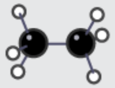
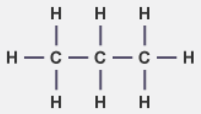
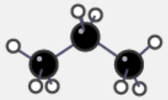
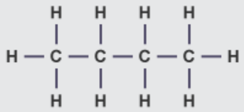
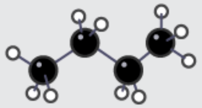
Viscosity – smaller molecules are less viscous (flow easily)

The alkanes

The main group of hydrocarbons found in crude oil are known as the alkanes.

They are a family of hydrocarbons with the same general formula C_nH_{2n+2} (n is the number of carbon atoms).

They are saturated – only contains single bonds.

Alkane	Molecular formula	Structural formula	Ball-and-stick model
Methane	CH_4		
Ethane	C_2H_6		
Propane	C_3H_8		
Butane	C_4H_{10}		

Cracking Crude Oil

Thermal decomposition reaction breaking down the long hydrocarbons into smaller ones (helps meet supply and demand)

Catalytic cracking – Hydrocarbons heated until they vaporise and then vapour passed over a hot aluminium oxide catalyst.

Steam cracking – Hydrocarbons mixed with steam and heated to about 850ºC

e.g. Heptane cracked in to 1 molecule of ethene and 1 mole of pentane $C_7H_{16} \rightarrow C_2H_4 + C_5H_{12}$

Alkenes such as ethene (C_2H_4) are also made which can be turned in to polymers / plastics

Combustion

Combustion (burning) is an oxidation reaction which produces energy.

Complete combustion of hydrocarbons produces carbon dioxide and water (condition needed plenty of oxygen)

e.g. $CH_{4\,(g)} + 2O_{2\,(g)} \rightarrow CO_{2\,(g)} + 2H_2O_{(l)}$

When there is a limited supply of oxygen, **incomplete combustion** produces either water and either carbon monoxide or just carbon (soot)

e.g. $CH_{4\,(g)} + 1.5O_{2\,(g)} \rightarrow CO_{(g)} + 2H_2O_{(l)}$

e.g. $CH_{4\,(g)} + O_{2\,(g)} \rightarrow C_{(s)} + 2H_2O_{(l)}$

CO_2, H_2O and CH_4 are greenhouse gases. Short wavelength radiation passes through atmosphere to Earth's surface and then the Earth's surface radiates different wavelengths some of which (longer wavelengths) are absorbed by greenhouse gases to produce temperature increases.

Carbon monoxide (invisible, odourless gas) is toxic because it joins with the haemoglobin in red blood cells and prevents them carrying oxygen.

Carbon / soot or soot (which blocks pipes, looks unsightly and can cause breathing problems).

Impurities such as sulfur react with oxygen to produce sulfur dioxide which dissolves in rainwater to form acid rain.

Amount of CO_2 in the atmosphere can be reduced by:

Iron seeding of the oceans (this promotes the growth of algae which use up carbon dioxide by photosynthesis)

Turning carbon dioxide back into hydrocarbon fuels.

Alkenes

Cracking produces shorter alkanes which make better fuels and also alkenes. We can test for alkenes using bromine water which goes from orange to colourless if alkenes are present.

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Topic 7 – Organic Chemistry (single chemistry)

Alkenes

These are formed from the cracking of alkanes (see previous sheet). They are unsaturated hydrocarbons as they contain a carbon to carbon double bond and have the same general formula C_nH_{2n}.

Alkenes react with oxygen in combustion reactions like alkanes but tend to produce slightly smokier flames due to incomplete combustion.

$C_2H_{4\,(g)} + 3O_{2\,(g)} \rightarrow 2CO_{2\,(g)} + 2H_2O_{(l)}$

Alkenes react with hydrogen gas at 60°C in the presence of a nickel catalyst. This is called hydrogenation and is used in the hardening of vegetable oils when making margarine

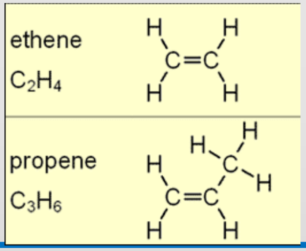
$C_5H_{10} + H_2 \rightarrow C_5H_{12}$

Alkenes react with water / steam at high temp and pressure over a phosphoric acid catalyst to produce alcohols.

$C_2H_4 + H_2O \rightarrow C_2H_5OH$

Alkenes react with halogens (this is the test for alkene – they decolourise bromine water)

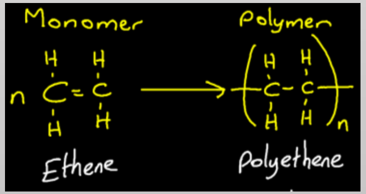
$C_2H_4 + Br_2 \rightarrow C_2H_4Br_2$



Polymers

Alkenes undergo addition polymerisation (adding lots of small molecules together to make a big one).

e.g. $nC_2H_4 \rightarrow (\text{-}CH_2CH_2\text{-})_n$

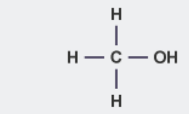
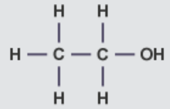
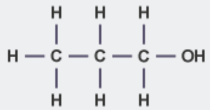
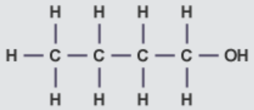


Condensation polymerisation involves monomers with two functional groups . When these types of monomers react they join together and usually lose small molecules, such as water. This is why they are called condensation reactions.

Alcohols

- Made when an aqueous solution of sugar is fermented using yeast at 35°C in the absence of oxygen. $C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$
- Alcohols react with oxygen and also undergo combustion
  $C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$
- Alkenes react with sodium to produce sodium ethoxide & hydrogen (word)
- Alcohols undergo oxidation with an oxidising agent such as acidified potassium dichromate (VI) to make carboxylic acids
  $C_2H_5OH + 2[O] \rightarrow CH_3COOH + H_2O$

This is a similar reaction to what happens when wine is left open for too long, the microbes in the air oxidise the alcohol and it smells like vinegar.

Name	Molecular formula	Full structural formula
Methanol	CH_3OH	
Ethanol	C_2H_5OH	
Propan-1-ol	C_3H_7OH	
Butan-1-ol	C_4H_9OH	

Carboxylic acids and esters

Carboxylic acids form acid solution when they dissolve in water, hence the term acid. As met in topic 4, acids will react with bases:

Ethanoic acid + sodium carbonate → sodium ethanoate + water + carbon dioxide

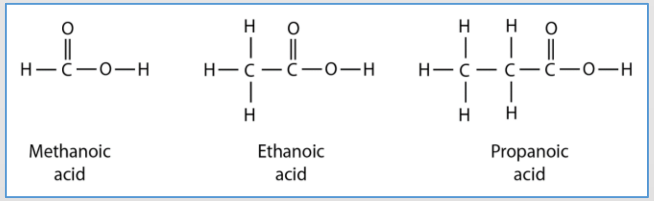
$2CH_3COOH + Na_2CO_3 \rightarrow 2CH_3COONa + H_2O + CO_2$

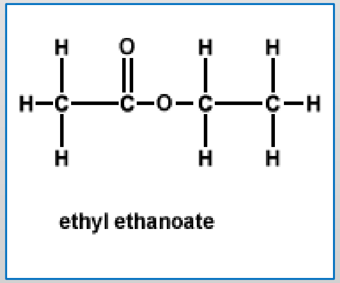
Carboxylic acids will react with alcohols to form esters:

Ethanoic acid + ethanol → ethyl ethanoate + water

$CH_3COOH + C_2H_5OH \rightarrow CH_3COOC_2H_5 + H_2O$

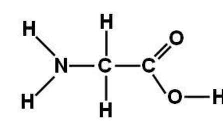
Esters often have sweet , fruity smells and are used in perfumes and food flavourings.





Amino Acids and DNA (a natural polymer)

- Amino acids have two different functional groups in a molecule
- They react by condensation polymerisation to produce polypeptides and proteins.
- DNA is a polymer made up of a sugar molecule, phosphate group and a base.



Topic 8 – Analytical Chemistry

What is a pure substance?

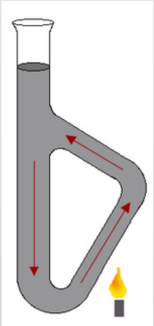
A pure substance is a single element or compound, not mixed with any other substance.
Pure elements and compounds melt and boil at specific temperatures.
Melting point and boiling point data can be used to distinguish pure substances from mixtures.

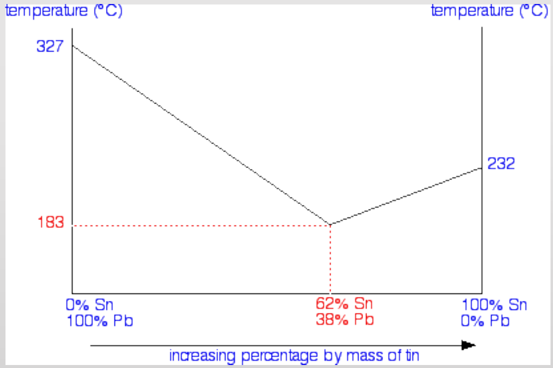
Impurities

Impurities lower the melting point and change the boiling point.
Impure substances also melt over a larger range of temperatures.
The greater the amount of an impurity, the bigger the differences from the true melting point and boiling point.

Determining melting points (known as a substance's **fixed point**)

Thiele tubes
Melting point blocks





Formulations

A formulation is a mixture that has been designed as a useful product. Many products are complex mixtures in which each chemical has a particular purpose.

Formulations are made by mixing the components in carefully measured quantities to ensure that the product has the required properties. Formulations include fuels, cleaning agents, paints, medicines, alloys, fertilisers and foods.

Gas tests

Hydrogen – Use a burning splint held at the open end of a test tube of gas and you will hear a squeaky pop.

Oxygen – Use a glowing splint inserted into a test tube of the gas. The splint relights in oxygen.

Carbon dioxide – Bubble gas through limewater (aqueous calcium hydroxide solution) and the limewater turns milky (cloudy).

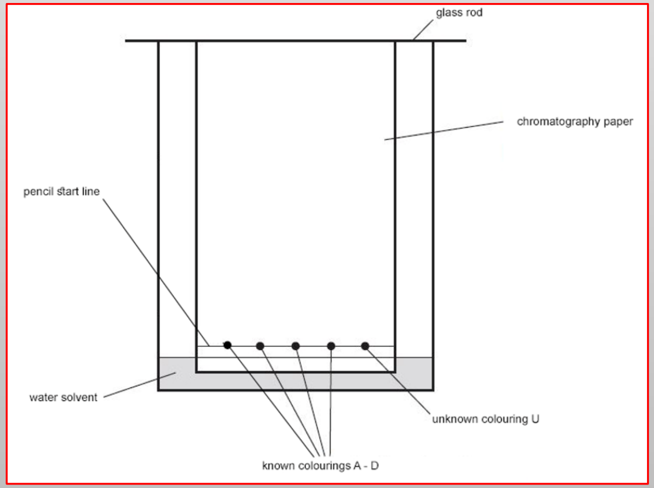
Chlorine – Damp litmus paper is put into chlorine gas the litmus paper turns pink and then is bleached and turns white.

Required Practical – Chromatography

Using a ruler, mark a line in pencil 2cm from bottom of paper.
Puts a drop of your coloured samples even spaced on the pencil line.
Place the paper in a small amount of solvent, keeping the pencil line above the solvent.
Allow the solvent and spots to rise up the paper to about 2/3 the way up and then take out and allow to dry.

Question to think about:

- Why is the line drawn in pencil?
- Why are the dots drawn 1cm apart?
- Why is it important to mark off the solvent front?



Analysing Substances

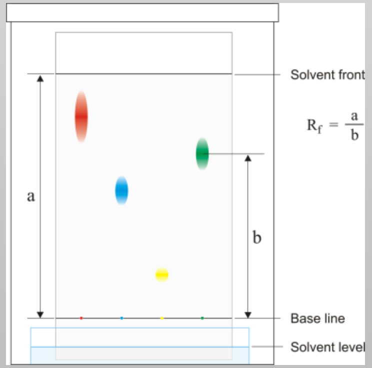
Instrumental methods provide fast, sensitive and accurate means of analysing chemicals, and are particularly useful when the amount of chemical being analysed is small.

Elements can be detected and identified using Chromatography involves a stationary phase and a mobile phase. Separation depends on the distribution of substances between the phases.

Chemical analysis can be used to identify additives in food or our water supple and can be identified by paper chromatography. Paper chromatography can be used to separate mixtures, such as food colourings. Water, or some other solvent, soaks up the paper and the dye that dissolves the best travels furthest up the paper. If there are three dots on the paper above one of the mixtures, it tells you that there are at least three dyes in that mixture (one of the dots could be two substances that happen to travel the same distance).

$$R_f = \frac{distance\ moved\ by\ substance}{distance\ moved\ by\ solvent}$$

Rf (retention factor) values can be used to compare your data from the chromatogram to a database. As long as the same temperature and solvent is used for the experiment.



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Topic 8 – Analytical Chemistry (single chemistry only)

Flame tests

Lithium compounds – crimson

Sodium compounds – yellow

Potassium compounds – lilac

Calcium compounds – orange-red

Copper compounds – green

If a sample containing a mixture of ions is used some flame colours can be masked. Some elements also have very similar colours.

Using sodium hydroxide

Sodium hydroxide can be used to identify some ions as they form coloured precipitates when mixed with sodium hydroxide (NaOH).

Aluminium, calcium and magnesium ions all produce a white precipitate but only aluminium hydroxide precipitate dissolves in excess NaOH.

e.g. using a metal chloride solution

$CaCl_{2\,(aq)} + NaOH_{(aq)} \rightarrow Ca(OH)_{2\,(s)} + NaCl_{(aq)}$

$MgCl_{2\,(aq)} + NaOH_{(aq)} \rightarrow Mg(OH)_{2\,(s)} + NaCl_{(aq)}$

Copper II compounds (Cu^{2+} ions) – blue precipitate of $Cu(OH)_2$

$CuCl_{2\,(aq)} + NaOH_{(aq)} \rightarrow Cu(OH)_{2\,(s)} + NaCl_{(aq)}$

Iron II compounds (Fe^{2+} ions) – green precipitate of $Fe(OH)_2$

$FeCl_{2\,(aq)} + NaOH_{(aq)} \rightarrow Fe(OH)_{2\,(s)} + NaCl_{(aq)}$

Iron III compounds (Fe^{3+} ions) – brown precipitate of $Fe(OH)_3$

$FeCl_{3\,(aq)} + NaOH_{(aq)} \rightarrow Fe(OH)_{3\,(s)} + NaCl_{(aq)}$

Instrumental methods

Using machines and computers to analyse unknown elements and compounds is better because they are:

- Accurate
- Sensitive (tiny mounts can be detected)
- Rapid

- However they are more expensive.

Flame emission spectroscopy

This is an example of an instrumental method of analysis.

The sample is put into a flame and the light given out is passed through a spectroscope. The line spectrum produced can be used to identify the metal ions present and their concentration.

Required Practical – Identifying ions

You should be able to describe all of these tests to identify unknown samples containing any of the ions mentioned on this page.

e.g.
To identify an unknown cation, dip a nichrome wire loop in to some of the unknown sample and pass it through a blue Bunsen burner flame and observe the colour of the flame. Take a small amount of the unknown solution and add an equal amount of sodium hydroxide solution and observe the colour of precipitate formed.

To identify an unknown anion, perform the tests on the right hand side of this page.
e.g. add $2cm^3$ of hydrochloric acid to you sample followed by $2cm^3$ of barium chloride solution and if a white precipitate forms you know the unknown sample contains sulfate ions (SO_4^{2-}).

Carbonates

Carbonates react with any dilute acid to produce carbon dioxide which can be bubbled through limewater to show it's CO_2.

$CaCO_{3\,(s)} + HCl_{(aq)} \rightarrow CaCl_{2\,(aq)} + H_2O_{(l)} + CO_{2\,(g)}$

Sulfates

When any compound containing sulfate ions is mixed with barium chloride (in the presence of hydrochloric acid), a white precipitate of barium sulfate forms.

$Na_2SO_{4\,(aq)} + BaCl_{2\,(aq)} \rightarrow BaSO_{4\,(s)} + 2NaCl_{(aq)}$

Halides

In solution halide ions produce precipitates with silver nitrate (in the presence of nitric acid).

Silver chloride is a white ppte
$NaCl_{(aq)} + AgNO_{3\,(aq)} \rightarrow AgCl_{(s)} + NaNO_{3\,(aq)}$

Silver bromide is a cream ppte
$NaBr_{(aq)} + AgNO_{3\,(aq)} \rightarrow AgBr_{(s)} + NaNO_{3\,(aq)}$

Silver iodide is a yellow ppte.
$NaI_{(aq)} + AgNO_{3\,(aq)} \rightarrow AgI_{(s)} + NaNO_{3\,(aq)}$

Precipitates

Precipitates are formed when two solutions (soluble substances) react together to produce an insoluble one which is identified in an equation as a solid product having the state symbol (s).

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Topic 9 – Chemistry of the Atmosphere

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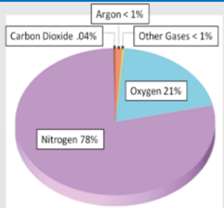
1) Early atmosphere (4.6 billion years ago)

The Earth's early atmosphere mainly contained gases that came from volcanoes.
This early atmosphere is thought to have contained:
no oxygen (or very little)
large amounts of carbon dioxide
large amounts of water vapour
small amounts of other gases such as nitrogen and ammonia

2) Present day atmosphere



78% nitrogen
21% oxygen
0.04% carbon dioxide
<1% argon and other noble gases
and water vapour.
Small changes in today's atmosphere are still happening as a result of:

- volcanoes
- human activity (such as burning fossil fuels, deforestation and farming)
- Increases in CO_2 due to burning fossil fuels leads to global warming.

3) The greenhouse effect

Short wavelength radiation passes through atmosphere to Earth's surface. Earth's surface radiates different wavelengths some of which (longer wavelengths) are absorbed by greenhouse gases to produce temperature increases.
Main greenhouse gases are CO_2, CH_4 & H_2O

4) Consequences of climate change

- Sea level rise, flooding etc
- More storms
- Changes to rainfall
- Changes in temperature
- Changes to food producing capacity
- Changes to distribution of wildlife

5) Why did the atmosphere change?

There are different sources of information about the development of the atmosphere. This makes it very difficult to be precise about how it changed. Some of the evidence from elsewhere in the solar system (such as the planet Venus or the moons of Saturn) is contradictory. Importance of peer review (evidence that is checked by other scientists)

- The early Earth was very hot. When it cooled, much of the water vapour in the atmosphere condensed to form the oceans.
- There is very little carbon dioxide in today's atmosphere so there must have been many ways in which the amount was reduced:
- Much of the carbon dioxide dissolved in the oceans. This dissolved carbon dioxide was used by sea organisms to make shells (which are mainly calcium carbonate). These shells later sank to the bottom to become part of sedimentary rocks such as limestone ("locked up" carbon refers to carbon that is in sedimentary rocks and fossil fuels).
- Primitive bacteria broke down the bonds in water to release oxygen
- When plants evolved, they used up some of the carbon dioxide in photosynthesis.
- The first plants or algae were also able to produce oxygen by photosynthesis so the amounts of oxygen in the atmosphere gradually increased.

Carbon dioxide + water → glucose + oxygen

$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$

6) Carbon footprint

Carbon footprint is the total amount of CO_2 and other greenhouse gases emitted over the full life cycle of the product / service.

Can be reduced using:

- Alternative energy supplies
- Energy conservation
- Carbon capture and storage
- Carbon taxes and licences
- Carbon off setting (e.g. tree planting)
- Carbon neutrality

7) Atmospheric pollutants

Combustion of fossil fuels (hydrocarbons) will produce water and then either carbon dioxide, carbon monoxide or carbon (soot)
$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$ (complete combustion in a plentiful supply of oxygen)

$CH_4 + 1.5O_2 \rightarrow CO + 2H_2O$ (incomplete combustion in a limited supply of oxygen)
$CH_4 + O_2 \rightarrow C + 2H_2O$ (incomplete combustion in a limited supply of oxygen)

Carbon monoxide is a colourless, odourless, toxic gas which binds to your haemoglobin preventing respiration from occurring.

Particulates / carbon (soot) can lead to global dimming and also respiratory problems.

Coal also contains sulfur which when burnt produces SO_2

At high temperatures (inside an engine) nitrogen and oxygen from the air can react together to produce nitrogen oxides (NO_x)
$N_2 + O_2 \rightarrow 2NO$

Both these oxides of sulfur and nitrogen can lead to an increase in acid rain.

Unburnt fuels and soot called particulates can also cause breathing problems

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