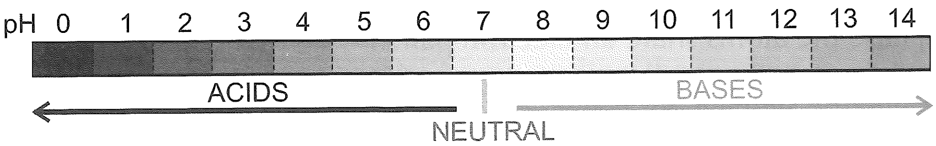
Acids and Bases

The pH Scale

1) The **pH** scale goes from **0** to **14** and measures how **acidic** or **basic** something is. **Acids** have a pH **less** than 7, while **bases** have a pH **greater** than 7. The **more acidic** something is, the **lower** the pH, so strong acids have a pH of between **0** and **1**. By contrast, the more **basic** something is, the **higher** its pH will be. **Strong bases** have a pH of **14**.
2) **Neutral** substances (such as water) have a pH of **7**. They are neither acidic nor basic.



Acids are Proton Donors and Bases are Proton Acceptors

1) Acids are **proton donors**. They **release hydrogen ions** (H^+) when mixed with water.

$$HCl_{(g)} \xrightarrow{\text{water}} H^+_{(aq)} + Cl^-_{(aq)}$$

2) The reverse happens with **bases** — they're proton acceptors so they **take H^+ ions.** **Alkalis** are bases that are **soluble** in water. They release **OH^-** ions in solution.

$$NaOH_{(s)} \xrightarrow{\text{water}} Na^+_{(aq)} + OH^-_{(aq)}$$

3) When an acid reacts with an alkali, a **salt** and **water** are formed — this is called a **neutralisation** reaction.

$$\text{acid} + \text{alkali} \rightarrow \text{salt} + \text{water}$$

You can show neutralisation just in terms of H^+ and OH^- ions. The hydrogen ions (H^+) from the acid will react with hydroxide ions (OH^-) from the base to produce water.

$$H^+_{(aq)} + OH^-_{(aq)} \rightarrow H_2O_{(l)}$$

> **EXAMPLE:** Write a balanced equation for the reaction between hydrochloric acid (HCl) and sodium hydroxide (NaOH).
>
> This reaction is a **neutralisation reaction** — a hydrogen ion from HCl combines with a hydroxide ion from NaOH to form water. The remaining ions combine to form the salt:
>
> $$HCl_{(aq)} + NaOH_{(aq)} \rightarrow H_2O_{(l)} + NaCl_{(aq)}$$

Some Common Acids and Bases

Acid	Formula
Hydrochloric acid	HCl
Sulfuric acid	H_2SO_4
Nitric acid	HNO_3
Ethanoic acid	CH_3COOH

Base	Formula
Sodium hydroxide	$NaOH$
Potassium hydroxide	KOH
Ammonia	NH_3

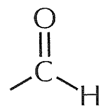
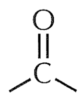
Siobhan always tells the truth, but Alka lies...

1) Write a balanced equation for the reaction between nitric acid and potassium hydroxide.
2) Write equations to show what happens when the following substances are mixed with water:
   a) sulfuric acid, b) potassium hydroxide, c) nitric acid.

Organic Molecules

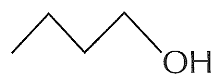
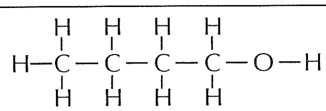
There are Lots of **Families** of Compounds in Organic Chemistry

Organic Chemistry is the study of organic compounds — these are just substances that contain **carbon**. Carbon compounds can be split up into different **groups** which have similar **properties** and **react** in similar ways. These groups are called **homologous series**. All the compounds in a homologous series contain the same **functional group** — a certain group of atoms that is responsible for the **properties** of the molecule. Here are some **common homologous series**:

HOMOLOGOUS SERIES	FUNCTIONAL GROUP	EXAMPLE
alkanes	-C–C-	propane — $CH_3CH_2CH_3$
alkenes	-C=C-	propene — $CH_3CH=CH_2$
alcohols	-OH	ethanol — CH_3CH_2OH
aldehydes		ethanal — CH_3CHO
ketones		propanone — CH_3COCH_3
carboxylic acids	-COOH	ethanoic acid — CH_3COOH

There are Different Ways of **Representing** a Molecule's **Structure**

Chemists have a few different ways of representing an organic molecule's **formula**.
Here are a few ways that you'll need to be able to interpret:

FORMULA	WHAT IT SHOWS YOU	FORMULA FOR BUTANOL (an alcohol)
General formula	This describes **any member** in a homologous series. The number of carbons is represented by 'n' and the number of hydrogens in terms of 'n'.	$C_nH_{2n+1}OH$ (this is true for all alcohols.)
Molecular formula	This shows the number of **atoms** of each **element** in a molecule.	$C_4H_{10}O$
Structural formula	This shows the molecule **carbon by carbon**, with all attached hydrogens and functional groups.	$CH_3CH_2CH_2CH_2OH$
Skeletal formula	The **bonds** of the carbon skeleton are drawn, with any **functional groups**. The carbon atoms and attached hydrogens aren't shown.	
Displayed formula	All the **atoms** and **bonds** are drawn to show how the molecule is arranged.	

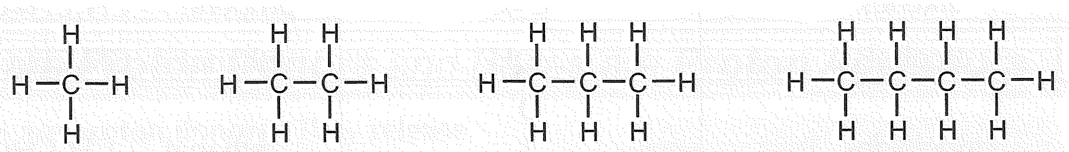
Organic Chemistry — no pesticides, no added sugars, no flavourings...

1) Draw the skeletal and displayed formulae for the molecule with the structural formula $CH_3CHOHCH_2CH_3$.
2) What is the molecular formula of the compound with the structural formula CH_3CH_2COOH?

Alkanes

Structure and Bonding in Alkanes

1) Alkanes are **hydrocarbons** — they **only** contain hydrogen and carbon atoms.
2) Alkanes contain **two types** of bond. All of the **carbon-carbon** bonds are **single covalent bonds**. All the other bonds are **carbon-hydrogen covalent bonds** (which are always single).
3) All of the available bonds have been formed, so we call alkanes **saturated** molecules.
4) **Carbon** always forms **four** covalent bonds and **hydrogen** makes **one** covalent bond.
5) The diagrams below show the structures of the first four **straight-chain alkanes**: methane, ethane, propane and butane.



methane ethane propane butane

It is important to realise that these structures are only **2D representations** of the **3D molecules**. The molecules are not rigid. There is **free rotation** around a carbon-carbon single bond. This means that the carbon chains are quite **flexible** and gives the molecules the ability to **change shape**, particularly as the chain length increases.

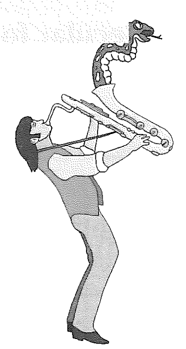
Properties of Alkanes

The **bonds** in alkanes are very **strong** and it requires a **lot of energy** to break them. This can be used to explain some of their **properties**:

1) They are very **unreactive**.
2) They are **not** able to form **polymers**.
3) They **burn cleanly**, tending to undergo **complete combustion** to form **carbon dioxide** and **water** (see page 28). The flame is usually a faint blue colour.
   For example, the combustion of ethane:
   $2C_2H_{6(g)} + 7O_{2(g)} \rightarrow 4CO_{2(g)} + 6H_2O_{(g)}$ (+ energy)

Also:

4) **Boiling point increases** as the **length** of the carbon chain increases.
5) **Viscosity** (resistance to flow) **increases** as chain length increases.
6) **Volatility** (ease of evaporation) **decreases** as chain length increases.



These last three properties are explained by the fact that the **attractive forces** between molecules get stronger as the chain length **increases** (page 9).

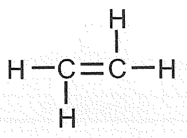
Alkanes are like the weather in the UK — completely saturated...

1) Draw out the structures of the next two alkanes, pentane (C_5H_{12}) and hexane (C_6H_{14}).
2) a) Write out the molecular formulae of the first four alkanes.
   b) We can work out a general formula for the alkanes of the form $C_nH_?$, where n is the number of carbon atoms. Work out, in terms of n, what should be in place of the ?.
3) Write a balanced equation for the complete combustion of propane in oxygen.

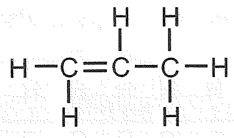
Alkenes

Structure and *Bonding* in Alkenes

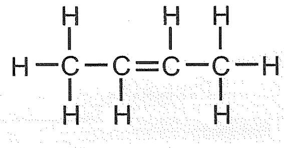
1) **Alkenes** are similar to alkanes in that they are also **hydrocarbons**. The difference is in the presence of a **carbon-carbon double covalent bond** (C=C) somewhere in the carbon chain.
2) This means **not** all possible single bonds have been made — these molecules are **unsaturated**.
3) As in all compounds the carbon atoms must have **four** bonds, and hydrogen only **one**.
4) The structures of the first three alkenes (ethene, propene and butene) are shown below:



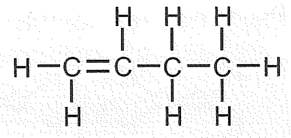
ethene



propene



butene



butene (again)

As you can see from butene, the presence of the C=C bond means that most alkenes have **more than one** possible structure. The C=C bond can be in various different **positions** along the chain.

Molecules with the same **molecular formula** but different **structures** are called **isomers**.

The C=C bond does not allow the same **free rotation** and flexibility around itself as a C–C bond. It is a **rigid** bond. But the rest of the carbon chain is the same as in an alkane molecule, so rotation is allowed around the **single** bonds.

Properties of Alkenes

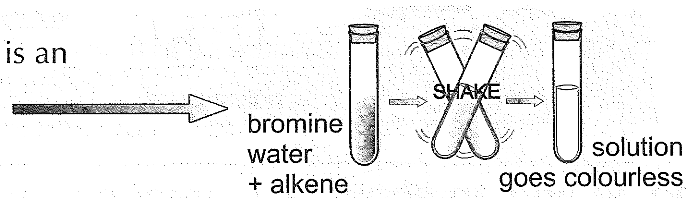
The presence of the C=C bond dictates the chemical properties of alkenes.

1) They are **reactive** compounds, undergoing many different types of chemical reaction.
2) They are used extensively to form **polymers**, e.g. poly(ethene) (see next page).
3) They **do not** burn **cleanly**, giving very **yellow** flames and lots of **soot**.

And as for alkanes, when you increase the **chain length** of an alkene:

4) The **boiling point** increases.
5) The **viscosity** increases.
6) The **volatility** decreases.

You can **test** for whether a compound is an alkene by adding it to **bromine water**. Alkenes **decolourise** bromine water, turning it from **orange** to **colourless**.



'Sleeping Butene' — coming soon to a cinema near you...

1) Draw out a structure for the next alkene: pentene (C_5H_{10}).
2) Draw out two alternative structures for hexene (C_6H_{12}).
3) Work out the general formula for the alkenes of the form $C_nH_?$.

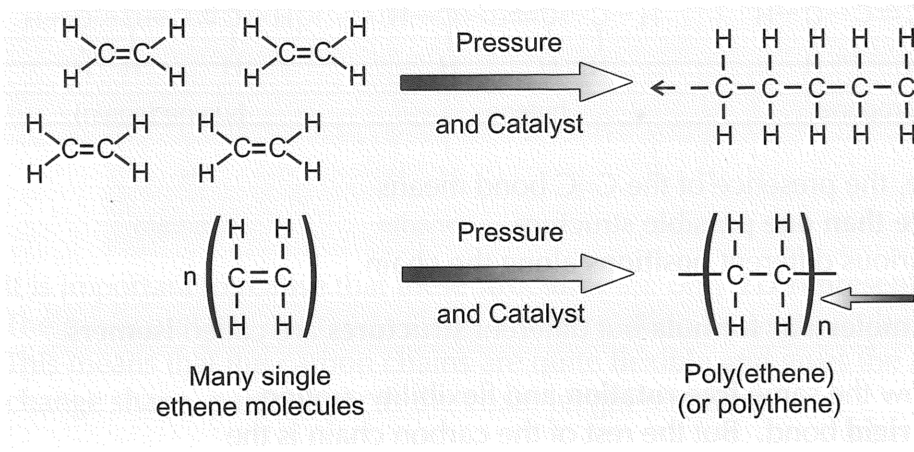
Polymerisation

Alkenes Can Form **Polymers**

The presence of the double bond in alkene molecules means that they are capable of forming **polymers**. A polymer is a long, chain-like molecule built up from lots of **repeating units**. In this case the repeating units, called **monomers**, are alkene molecules.

Under the right conditions (these depend on the alkene and the desired properties of the polymer), many small alkenes (like ethene and propene) will **open** up their double bonds and **link together** to form these long chain polymers.

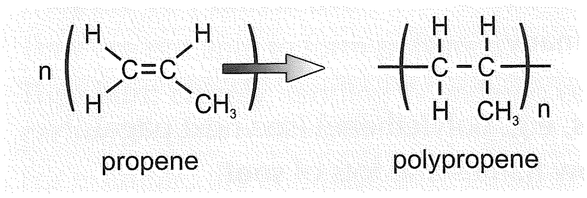
The following example shows the formation of **poly(ethene)** (or **polythene** for short):

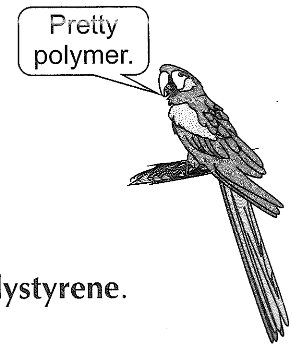


This is the standard way of representing polymers. The group of atoms inside the brackets is the **monomer** (or **repeating unit**).

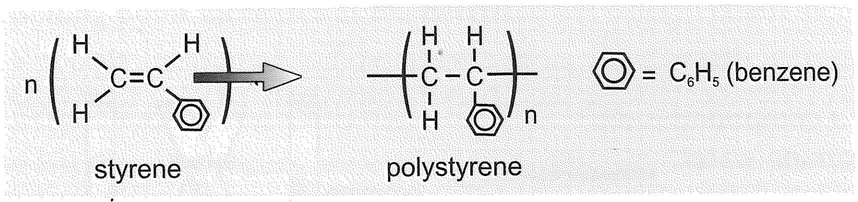
Other Small Alkenes do a **Similar Thing**

1) **Propene** polymerises to form **polypropene**.

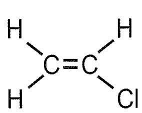
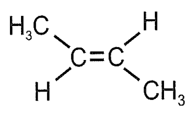




2) **Styrene**, which has a **benzene** ring in it, polymerises to form **polystyrene**. (Benzene is just a ring of six carbon atoms in which the bonding electrons are shared between all six carbons.)



I'd go on and on about how great polymers are, but it'd get repetitive...

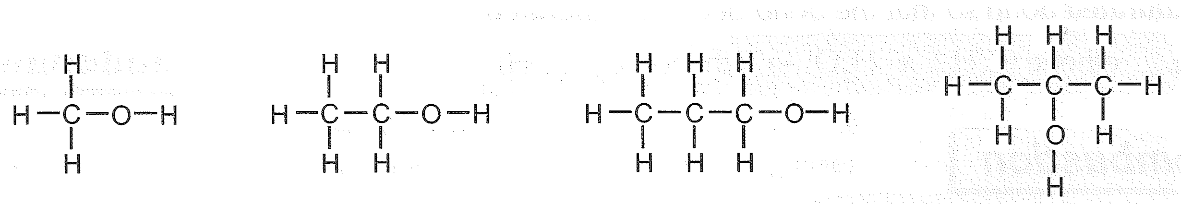
1) What property of alkenes allows them to form polymers?
2) Using the standard way of representing polymers, shown above, draw the polymers formed by the following alkenes:
   a) chloroethene:  b) this isomer of butene: 

Alcohols

Alcohols Contain an -OH Group

The **alcohols** are a group of compounds that all contain an -OH group (an oxygen atom covalently bonded to a hydrogen atom).

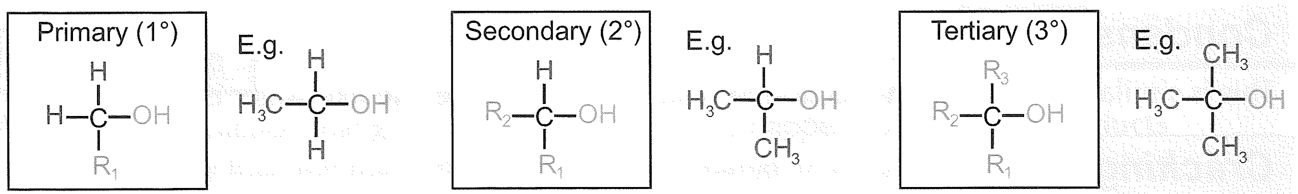
The first three alcohols are called **methanol**, **ethanol** and **propanol**. Their structures are:



methanol ethanol propanol propanol again

For many alcohols, the -OH group can be put in different **positions** along the chain, so they are able to form **isomers** — just like in the example with propanol above.

Alcohols can be called **primary**, **secondary** or **tertiary**. The type of alcohol depends on what other groups surround the carbon atom that the -OH group is attached to.

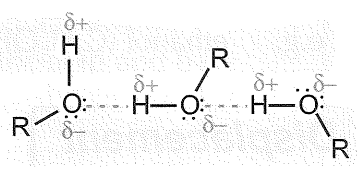


R = carbon chain

The Properties of Alcohols

Oxygen is an **electronegative** element (see page 10), so it draws the bonding electrons towards itself in the C–OH bond, meaning that alcohols are normally **polar** molecules.

The electronegative oxygen also draws electrons away from the **hydrogen atom** in the -OH group, giving the hydrogen atom a **slightly positive charge**. This charge attracts the **lone pairs** of **electrons** on oxygen atoms in other nearby alcohol molecules, which forms a **hydrogen bond** (page 10).



Hydrogen bonds have a big effect on the **properties** of alcohols.

1) Alcohols are **soluble** in water.
2) Alcohols have **high boiling** and **melting** points compared to alkanes or alkenes of a similar size. This is because hydrogen bonds are the **strongest** type of intermolecular bond, so they need lots of energy to break.

Alcohols — always wine-ing about their rum luck. I cava beer it...

1) Draw two different isomers of butanol, C_4H_9OH.
2) Work out the general formula of alcohols, using the form $C_nH_?OH$.
3) Predict, with reasoning, whether ethane or ethanol will have a higher melting point.