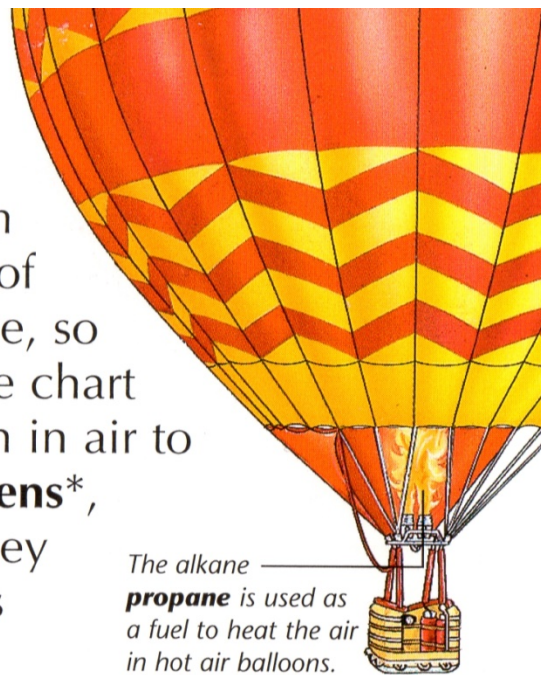


ALKANES

Alkanes, or **paraffins**, are all **saturated*** **hydrocarbons*** and **aliphatic compounds***. They form a **homologous series*** which has a **general formula*** of C_nH_{2n+2} . As the molecules in the series increase in size, so the physical properties of the compounds change (see chart below). Alkanes are **non-polar molecules***. They burn in air to form carbon dioxide and water, and react with **halogens***, otherwise they are unreactive. Excepting **methane**, they are obtained from **petroleum***. They are used as fuels and to make other organic substances, e.g. plastics.



The alkane **propane** is used as a fuel to heat the air in hot air balloons.

Some properties of alkanes

Name of compound	Molecular formula*	Structural formula*	Physical state at 25°C	Boiling point (°C)
Methane	CH ₄	CH ₄	Gas	-161.5
Ethane	C ₂ H ₆	CH ₃ CH ₃	Gas	-88.0
Propane	C ₃ H ₈	CH ₃ CH ₂ CH ₃	Gas	-42.2
Butane	C ₄ H ₁₀	CH ₃ CH ₂ CH ₂ CH ₃	Gas	-0.5
Pentane	C ₅ H ₁₂	CH ₃ CH ₂ CH ₂ CH ₂ CH ₃	Liquid	36.0
Hexane	C ₆ H ₁₄	CH ₃ CH ₂ CH ₂ CH ₂ CH ₂ CH ₃	Liquid	69.0

The first part of the name indicates the number of carbon atoms in the molecule. The -ane ending means the molecule is an alkane (see page 214).

The next molecule in the series is always one -CH₂- group longer.

Gradual change of state as molecules get longer.

The boiling points of the alkanes increase regularly as the molecules get longer. Melting points and densities follow the same trend, getting higher as the molecules increase in size.

Methane (CH₄)

The simplest alkane. It is a colourless, odourless, inflammable gas, which reacts with **halogens*** (see equation, below right) and is a source of hydrogen. **Natural gas** contains 99% methane.

Ethane (C₂H₆)

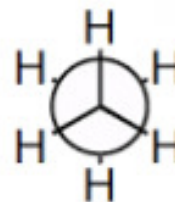
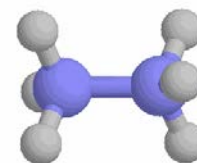
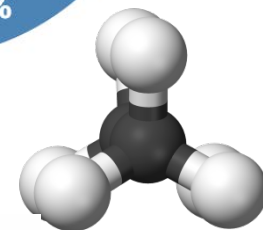
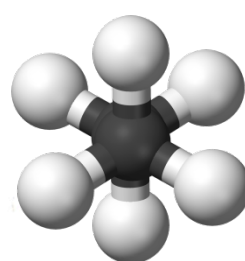
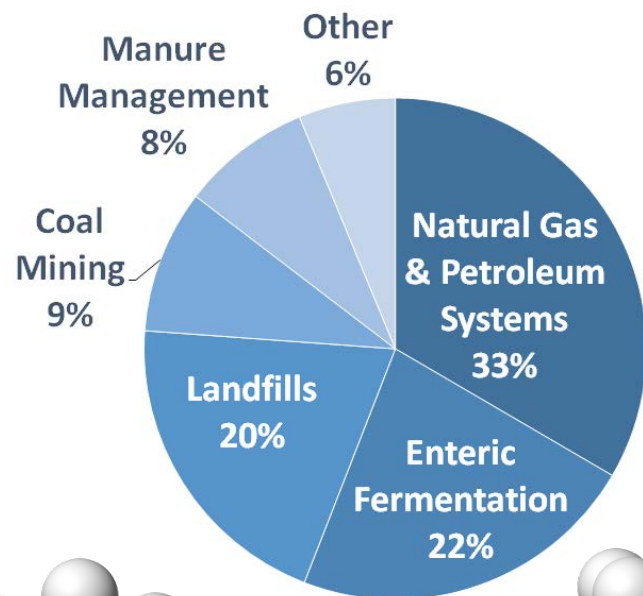
A member of the alkanes. A gas found in small amounts in **natural gas** (see **methane**), but mostly obtained from **petroleum***. Its properties are similar to those of methane. It is used to make other organic chemicals.

Propane (C₃H₈)

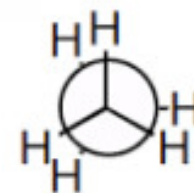
A member of the alkanes. A gas that is usually obtained from **petroleum***. Its properties are similar to **ethane**. It is bottled and sold as fuel for cooking and heating.

Alkanes are extracted from **petroleum*** and **natural gas** found deep under the ground.

U.S. Methane Emissions, By Source



staggered
 $\theta = 60^\circ$



eclipsed
 $\theta = 0^\circ$

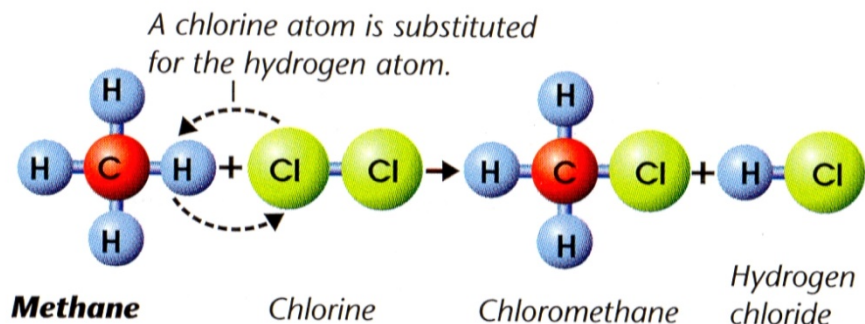
Cycloalkanes

Alkane molecules whose carbon atoms are joined in a ring, e.g. **cyclohexane** (see picture, page 190). Their properties are similar to other alkanes.

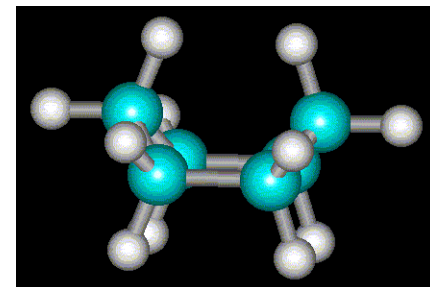
Substitution reaction

A reaction in which an atom or **functional group*** of a molecule is replaced by a different atom or functional group. The molecules of **saturated compounds***, e.g. alkanes, can undergo substitution reactions, but not **addition reactions** (see right).

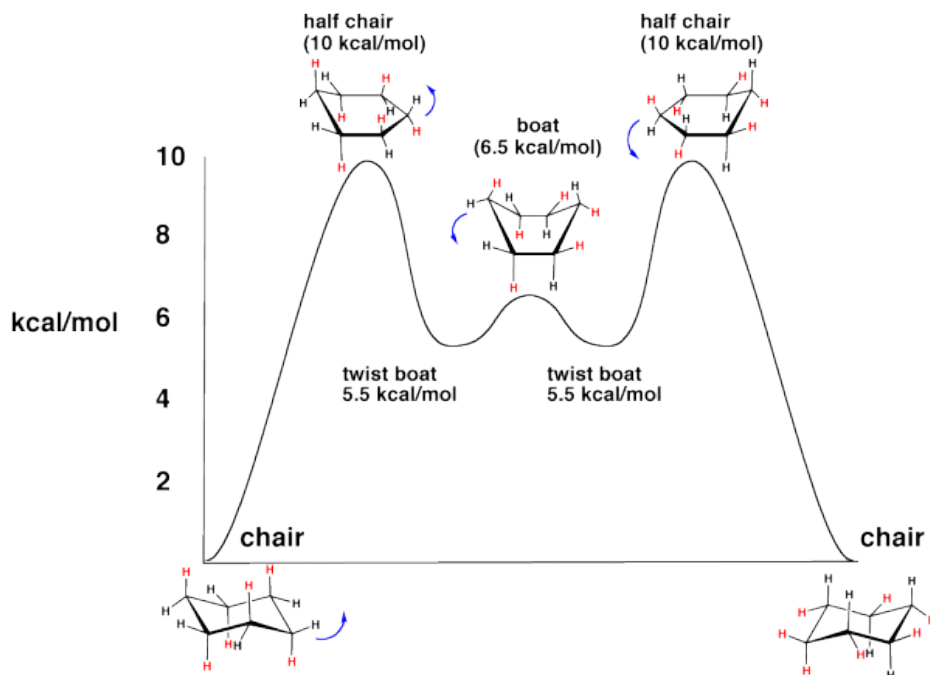
Alkanes react with **halogens*** by undergoing a **substitution reaction**. Here is an example:



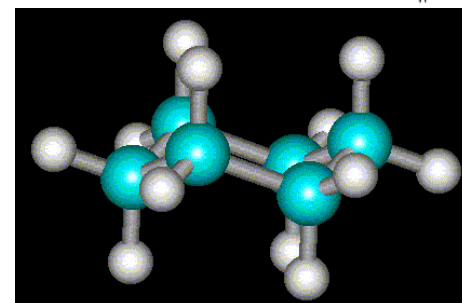
Boat form



Cyclohexane Chair Flip Energy Diagram



Chair form



ALKENES

Alkenes, or **olefins**, are **unsaturated*** **hydrocarbons*** and **aliphatic compounds***. Alkene molecules contain one or more **double bonds*** between carbon atoms. Those with only one form a **homologous series*** with the **general formula*** C_nH_{2n} . As the molecules increase in size, their physical properties change gradually (see below). Alkenes are **non-polar molecules***. They burn with a smoky flame and in excess oxygen are completely **oxidized*** to carbon dioxide and water. Alkenes are more reactive than **alkanes**, because of their double bond – they undergo **addition reactions**, and some form **polymers***. Alkenes are made by **cracking*** alkanes and are used to make many products including plastics and antifreeze.

Some properties of alkenes				
Name of compound	Molecular formula*	Structural formula*	Physical state at 25°C	Boiling point (°C)
Ethene	C_2H_4	$CH_2=CH_2$	Gas	-104.0
Propene	C_3H_6	$CH_3CH=CH_2$	Gas	-47.0
But-1-ene	C_4H_8	$CH_3CH_2CH=CH_2$	Gas	-6.0
Pent-1-ene	C_5H_{10}	$CH_3CH_2CH_2CH=CH_2$	Liquid	30.0

The number denotes the position of the **double bond*** in the molecule. **Alkenes** are named in the same way as **alkanes**, but end in -ene, not -ane (see page 214).

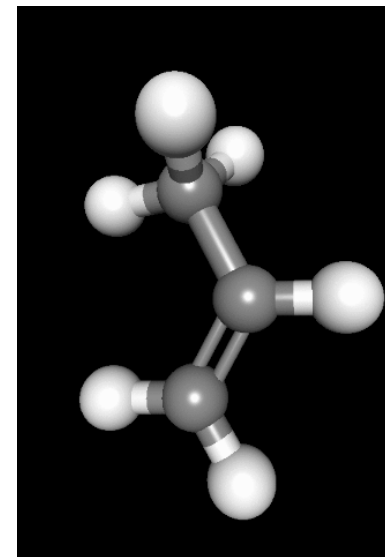
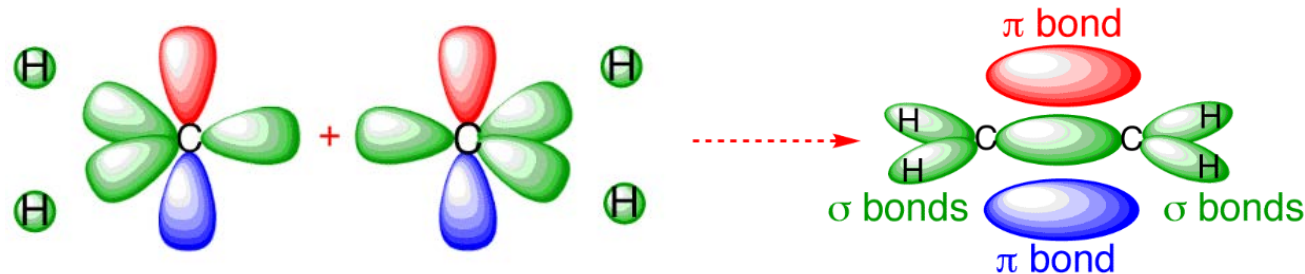
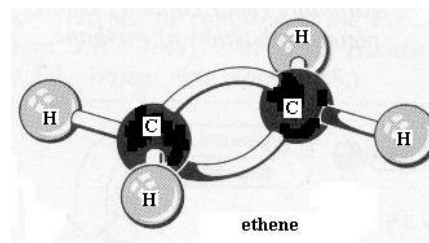
Each molecule is one $-CH_2-$ group longer. The position of the **double bond*** is shown.

Gradual change from gases to liquids to solids as the molecules get longer.

As the molecules get longer, the boiling points of the alkenes increase regularly. Melting points and densities follow the same trend.

Ethene (C₂H₄) or ethylene

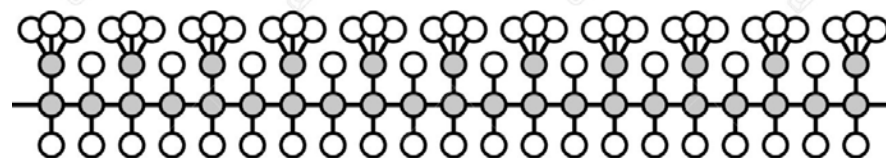
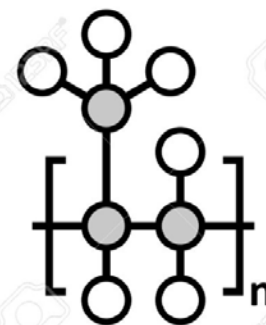
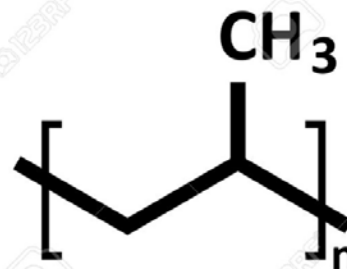
The simplest alkene (see chart above) – it is a colourless, sweet-smelling gas which undergoes **addition reactions** including **addition polymerization*** to form **poly(ethene)**, commonly known as **polythene**, (see **homopolymer**, page 200). Ethene is used to make plastics, also ethanol and many other organic chemicals.



Propene (C₃H₆) or propylene

A member of the alkenes. It is a colourless gas used to make propanone (also known as **acetone** – see **ketones**, page 194) and **poly(propene)**, also called **polypropylene**.

Some kitchen tools are made from **poly(propene)**, the **polymer*** of **propene**.

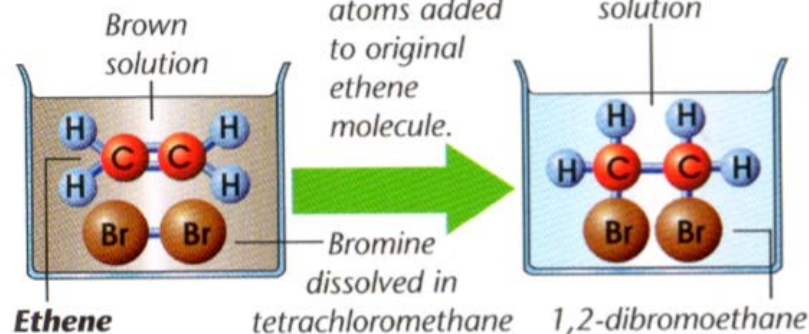


Addition reaction

A reaction in which two molecules react together to produce a single larger molecule. One of the molecules must be **unsaturated*** (have a **double** or **triple bond***).

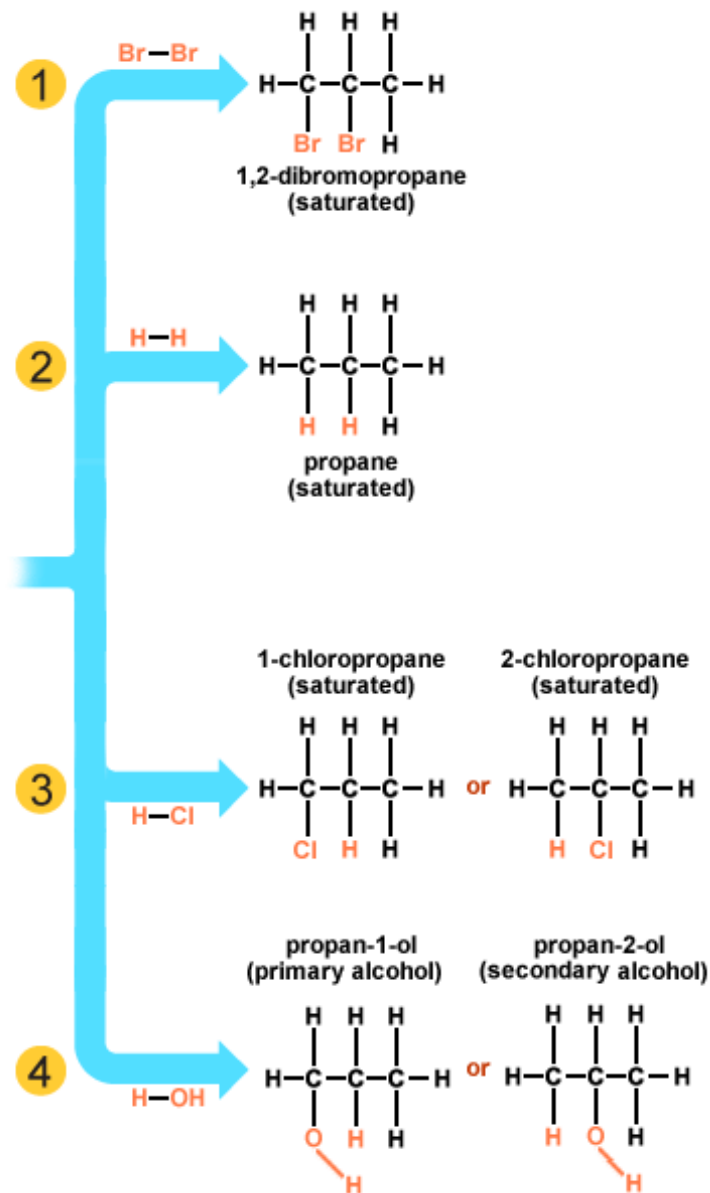
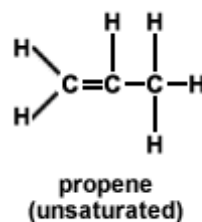
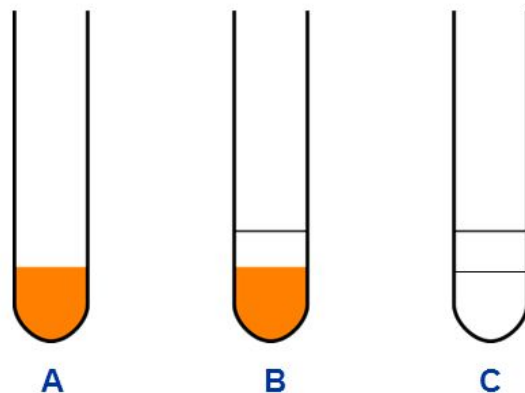
Addition reaction

Two bromine atoms added to original ethene molecule.



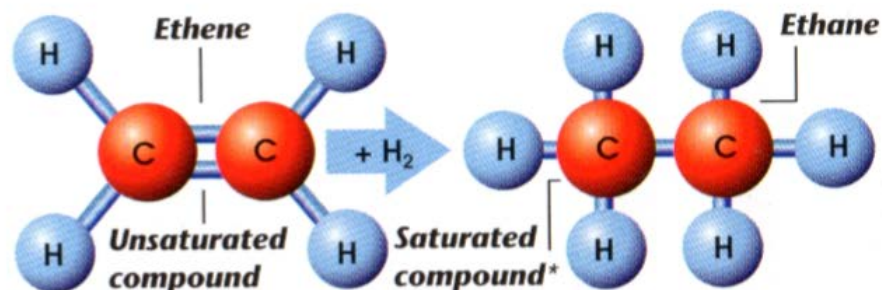
The change of colour is used as a test for **unsaturated compounds*** like alkenes.

- A** PLACE A SOLUTION OF BROMINE IN A TEST TUBE
- B** ADD THE HYDROCARBON TO BE TESTED AND SHAKE
- C** IF THE BROWN COLOUR DISAPPEARS THEN THE HYDROCARBON IS AN ALKENE

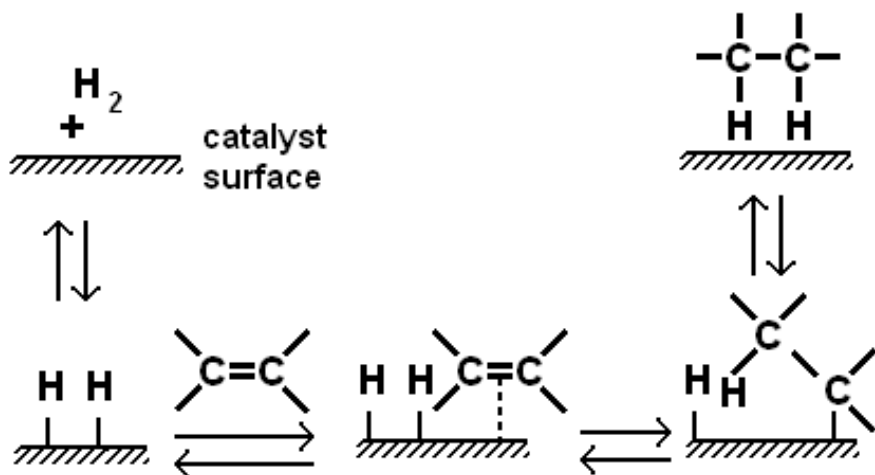


Hydrogenation

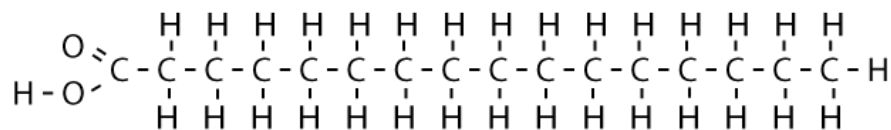
An **addition reaction** in which hydrogen atoms are added to an **unsaturated compound*** molecule.



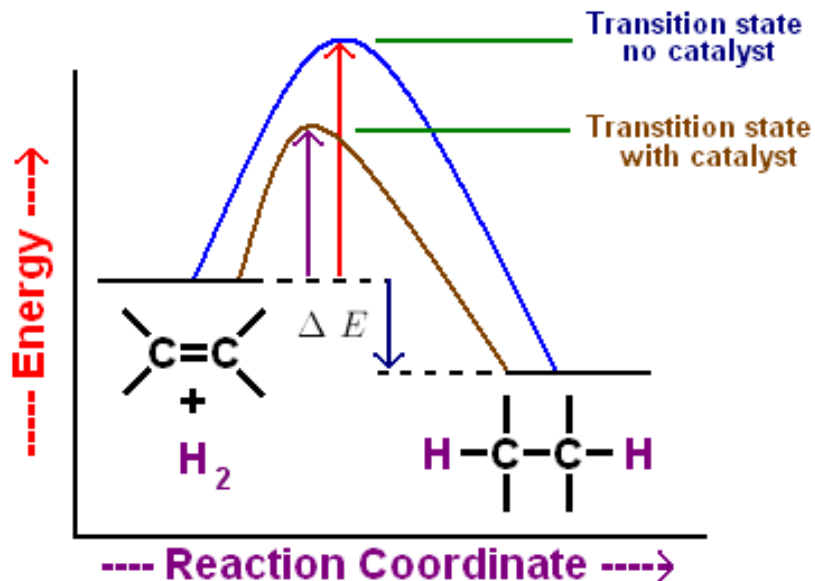
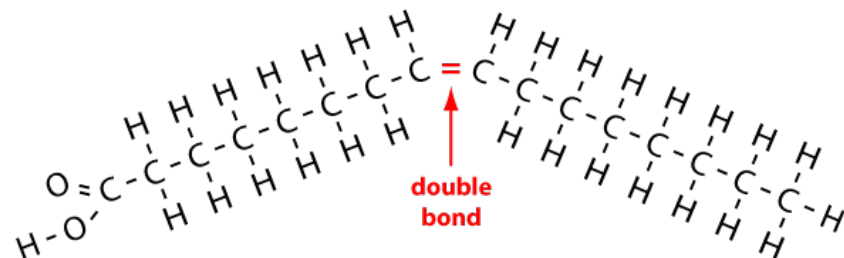
This type of reaction is used in the margarine industry to harden animal and vegetable oils. (These oils are **unsaturated compounds***, but not alkenes).



saturated fatty acid

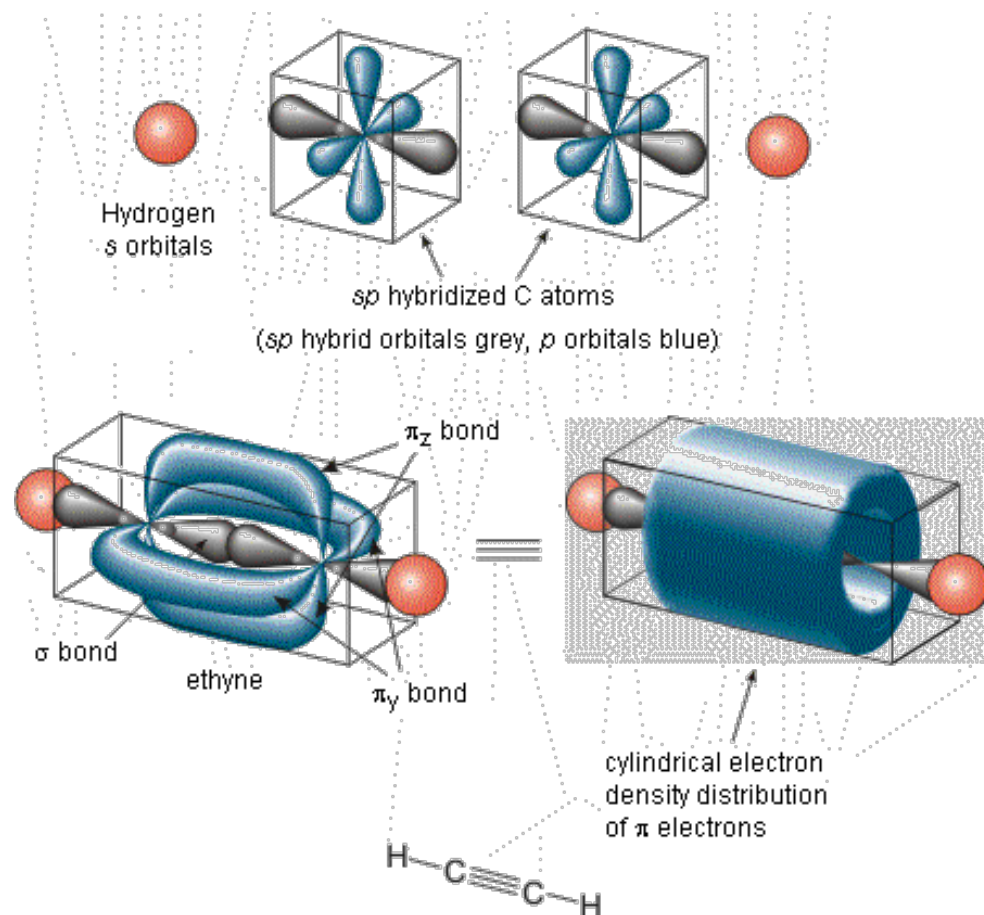


unsaturated fatty acid

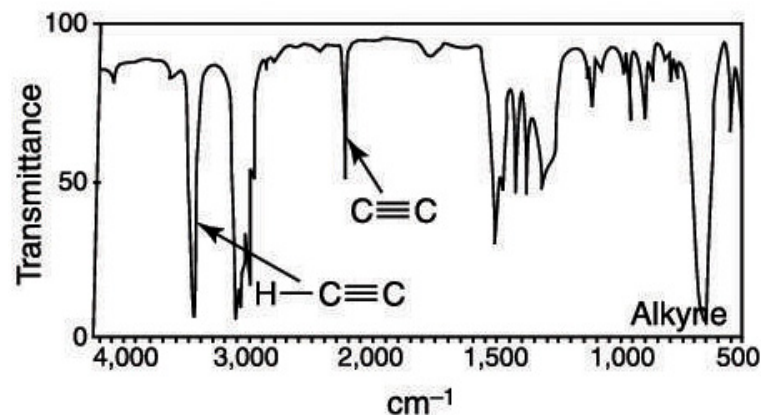


ALKYNES

Alkynes, or **acetylenes**, are **unsaturated*** (each molecule has a carbon-carbon **triple bond***) and **aliphatic compounds***. They are **hydrocarbons*** and form a **homologous series*** with a **general formula*** C_nH_{2n-2} . Alkynes are named in the same way as **alkanes***, but end in -yne, not -ane (see page 214). They are **non-polar molecules*** with chemical properties similar to **alkenes***. They burn with a sooty flame in air and a very hot flame in pure oxygen. Alkynes are produced by **cracking***. They are used to make plastics and solvents.



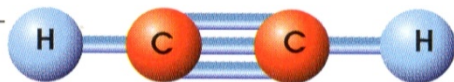
Structural formulae* of some alkynes	
Name of compound	Structural formula*
Ethyne	$CH \equiv CH$
Propyne	$CH_3C \equiv CH$
But-1-yne	$CH_3CH_2C \equiv CH$



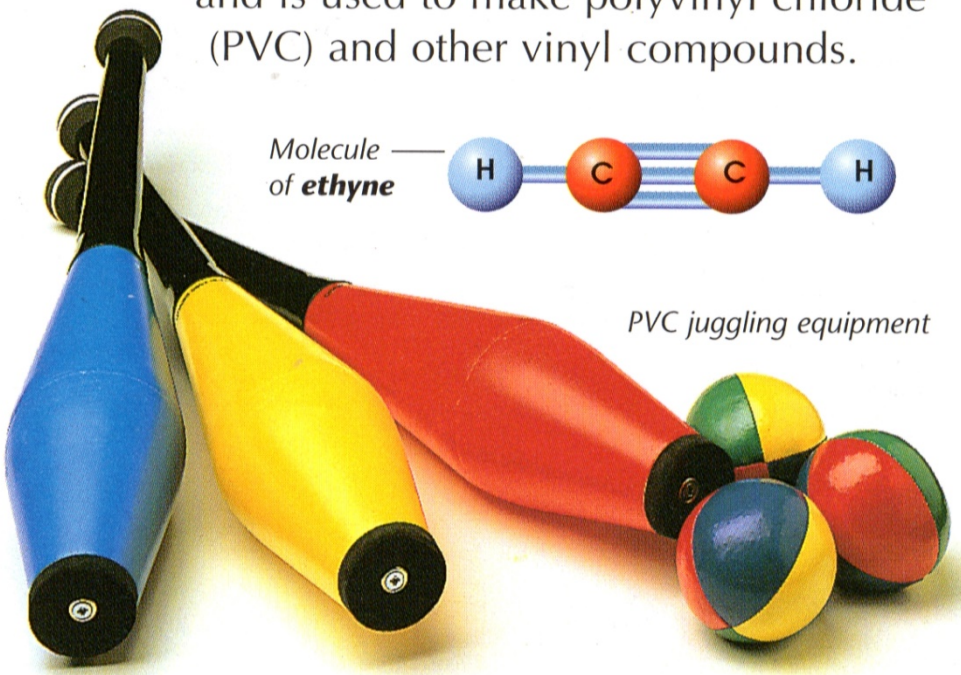
Ethyne (C_2H_2) or acetylene

The simplest member of the alkynes. A colourless gas, less dense than air and with a slightly sweet smell. It is the only common alkyne. Ethyne undergoes the same reactions as the other alkynes but more vigorously, e.g. it reacts explosively with chlorine. It is used in oxy-acetylene welding torches as it burns with a very hot flame. Ethyne is made by **cracking*** and is used to make polyvinyl chloride (PVC) and other vinyl compounds.

Molecule
of **ethyne**



PVC juggling equipment



up to $2,800^{\circ}\text{C}$





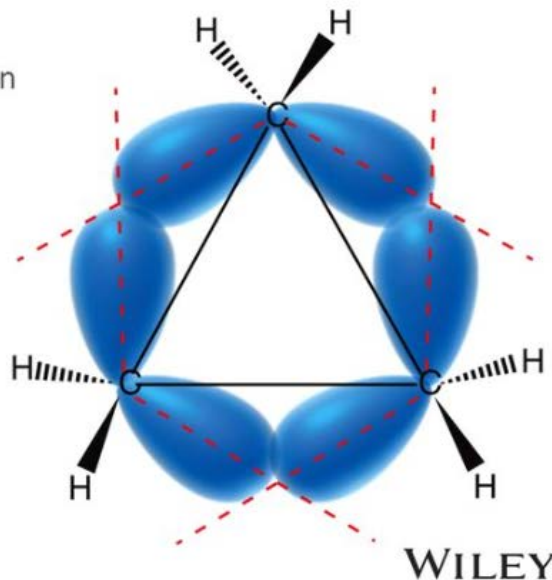
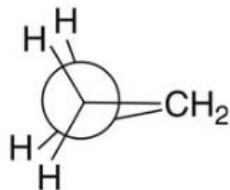
Highly Strained Aliphatic Compounds

- Cyclopropane is 44 kJ/mol less stable than cyclohexane per CH_2 group. It is highly strained and very reactive

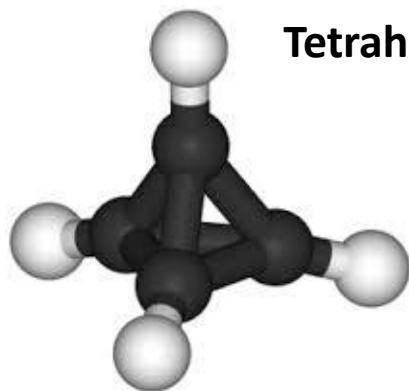
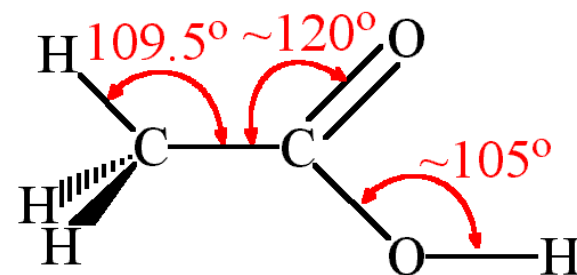
1. Angle strain

- Bond angles of 60° cause electron pair repulsion in adjacent bonds
- Inefficient sigma bond overlap

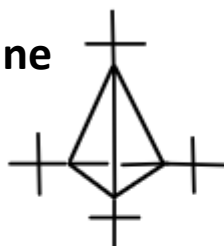
2. Torsional strain – eclipsing C-H bonds all the way around the ring – see the Newman projection



WILEY



Tetrahedrane



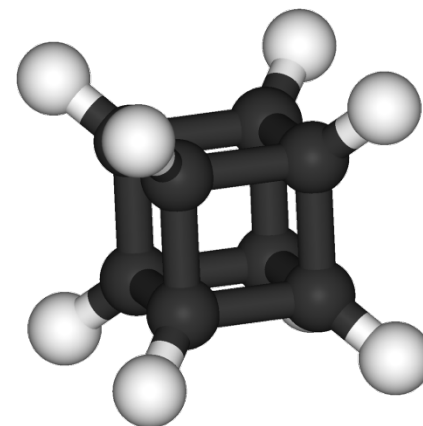
Maier, 1978,
tetra-*t*-Bu-
tetrahedrane.

m.p. 135°C !

Strain:
130 kcal
 mol^{-1}

Cubane

Eaton, 1964



m.p. $130\text{-}131^\circ\text{C}$
decomposes over 200°C