Topic 6 : Structures and Reactions of Hydrocarbons

Revised April 1995

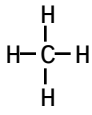
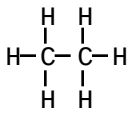
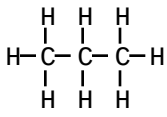
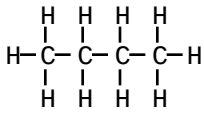
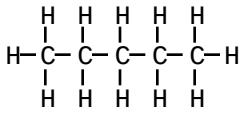
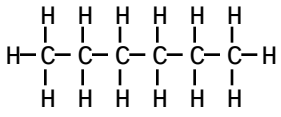
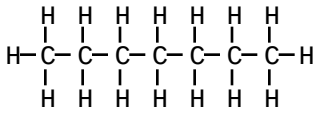
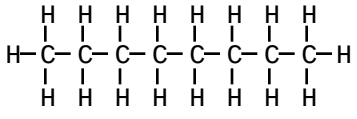
Hydrocarbons all contain Carbon and Hydrogen only. There are various families of hydrocarbons (subsets of the set of hydrocarbons) known as homologous series. Within each family the compounds have similar chemical properties.

Each member differs from the next by the group CH_2.

We shall consider three of these families :

1. Alkanes (General formula : C_xH_{2x+2})

All names end in - ANE

Name	Full structural formula	Shortened structural formula	Molecular formula
Methane		CH_4	CH_4
Ethane		CH_3CH_3	C_2H_6
Propane		$CH_3CH_2CH_3$	C_3H_8
Butane		$CH_3CH_2CH_2CH_3$	C_4H_{10}
Pentane		$CH_3CH_2CH_2CH_2CH_3$	C_5H_{12}
Hexane		$CH_3CH_2CH_2CH_2CH_2CH_3$	C_6H_{14}
Heptane		$CH_3CH_2CH_2CH_2CH_2CH_2CH_3$	C_7H_{16}
Octane		$CH_3CH_2CH_2CH_2CH_2CH_2CH_2CH_3$	C_8H_{18}

etc

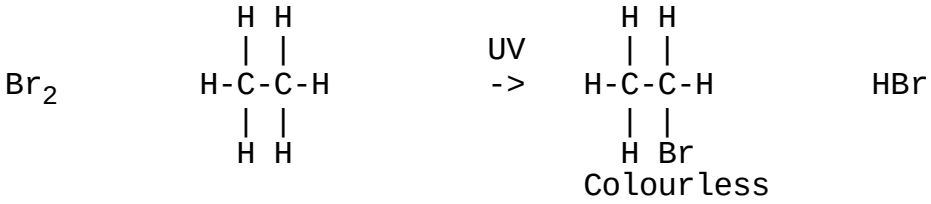
Methane is used in natural gas ; Butane is used in lighter fuel ; Octane is used in petrol.

Note that as molecular size increases so the boiling points increase. This is reflected in the physical state at room temperature (20 ^{0}C)

C_1 - C_4	gases
C_5 - C_{16}	liquids
> C_{16}	solids

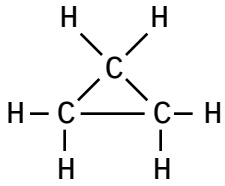
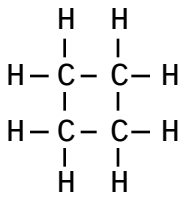
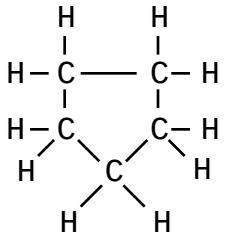
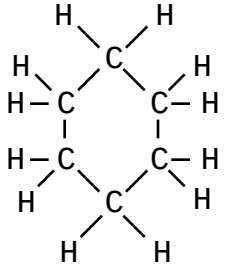
The alkanes are all **saturated** : each Carbon atom forms **four** bonds to **four** other atoms.

Reactions of Alkanes (e.g. Ethane) with Bromine



This is a substitution reaction (Br substitutes H). It is slow. The brown colour of the Bromine gradually becomes colourless. The acidic gas, Hydrogen bromide HBr, is given off. The reaction only occurs in ultra violet light (UV breaks the Br-Br bond).

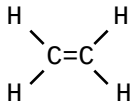
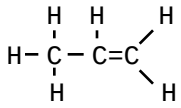
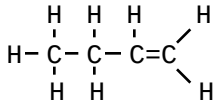
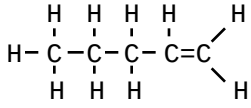
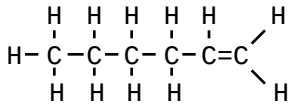
2. Cycloalkanes (General formula : C_xH_{2x})

Name	Structural formula	Molecular formula
Cyclopropane		C_3H_6
Cyclobutane		C_4H_8
Cyclopentane		C_5H_{10}
Cyclohexane		C_6H_{12}
etc		

The cycloalkanes are all saturated.

3. **Alkenes** (General formula : C_xH_{2x})

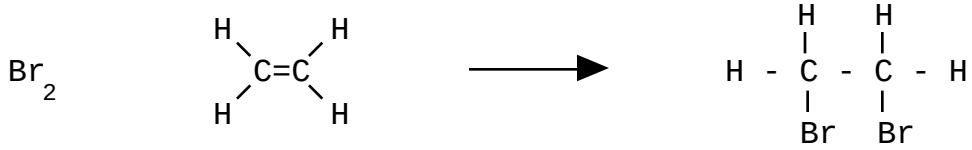
All names end in - ENE

Name	Full structural formula	Shortened structural formula	Molecular formula
Ethene		CH_2CH_2	C_2H_4
Propene		CH_3CHCH_2	C_3H_6
Butene		$CH_3CH_2CHCH_2$	C_4H_8
Pentene		$CH_3CH_2CH_2CHCH_2$	C_5H_{10}
Hexene		$CH_3CH_2CH_2CH_2CHCH_2$	C_6H_{12}

etc.

The Alkenes are all **unsaturated** : some of the Carbon atoms form FOUR bonds to less than four other atoms. Unsaturated compounds contain C=C ; saturated compounds contain only C-C.

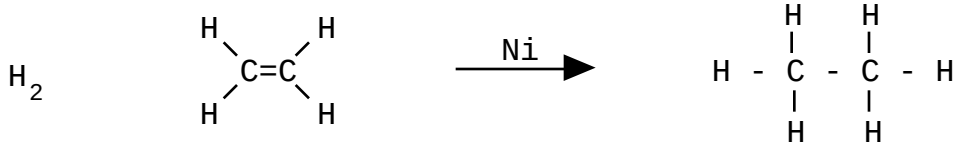
The Reaction of Alkenes (e.g. Ethene) with Bromine



colourless

The reaction is fast and does **not** require UV light. The Bromine turns from brown to colourless immediately. This reaction can be used to distinguish between saturated (C-C) and unsaturated (C=C) compounds (Saturated compounds decolourise Bromine slowly and only in UV light).

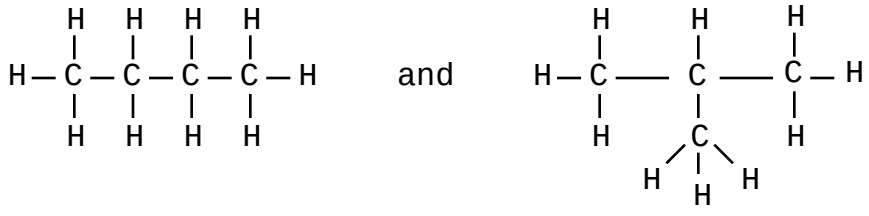
The Reaction of Alkenes (e.g. Ethene) with Hydrogen



Reaction of an Alkene (e.g. Ethene) with Hydrogen, known as hydrogenation, gives the corresponding alkane (e.g. Ethane). Powdered Nickel catalyst is required.
Both the reaction of Bromine and Hydrogen with Alkenes are described as **addition reactions** : they involve the addition of one molecule across a C=C double bond.

Isomers

Isomers are compounds which have the same molecular formula but a different structural formula. Propene and Cyclopropane are isomers. Here are another two :

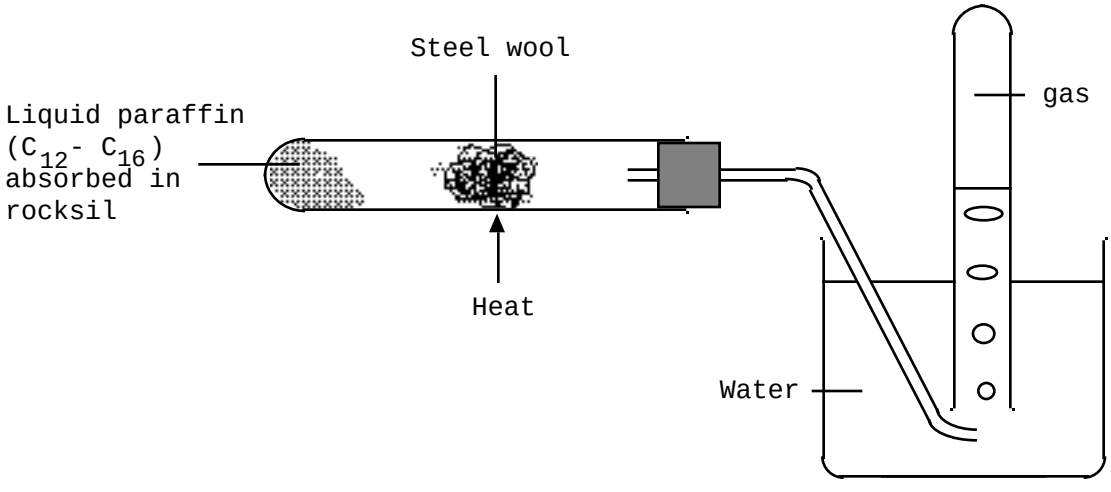


Cracking

There are not enough of the shorter chain hydrocarbons (C_5 - C_{10}) in crude oil to meet the world demand for petrol. Crude oil has, however, plenty long chain hydrocarbons. In cracking, the crude oil is heated. This makes the big molecules vibrate so violently that they break apart forming smaller molecules. Since bond breaking is random, the products are mixed and variable ; some are saturated ; others are unsaturated. There are two methods of cracking :

1. Thermal cracking

This is achieved by a high temperature using heat alone.



The following reaction may be one **of many** which occur :

$$C_{16}H_{34} \xrightarrow{\text{heat}} 6\,C_2H_4 + C_3H_8 + H_2 + C$$

The gas obtained is mainly Ethene. It burns with a yellow flame and decolourises Bromine water.

2. Catalytic Cracking

A LOW temperature, high pressure and catalyst (Aluminium silicate) are used. A lower temperature is used to avoid the complete break up to Ethene found with thermal cracking. At lower temperatures, though, the reaction is much slower. A catalyst is therefore required to speed up the reaction. Larger molecules, more suitable for use in petrol, are formed. The following reaction may be one **of many** which occur :

$$C_{16}H_{34} \xrightarrow{\text{heat}} C_8H_{18} + C_8H_{16}$$