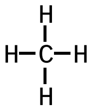
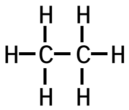
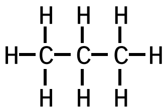
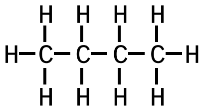
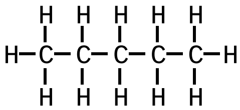
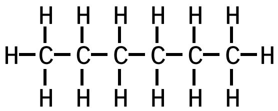
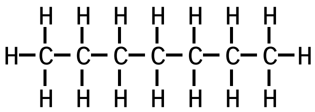
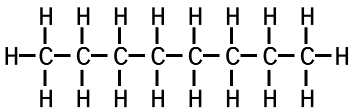
Organic Chemistry

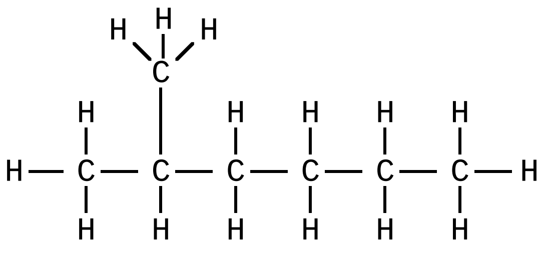
Organic compounds are compounds containing Carbon. They can be grouped into families or **homologous series**. All members of each family have the same general formula and similar chemical reactions.

ALKANES General formula C_xH_{2x+2}

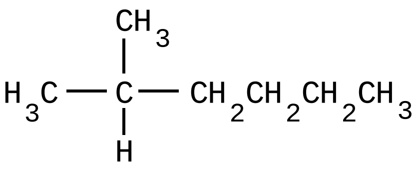
Alkanes are hydrocarbons. Their names end in 'ane'.
Here are the first eight in the series:

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}

These are all **straight-chain** alkanes. There are many more **branched-chain** alkanes e.g. 2-Methylhexane



Also written->



$H_3C-\overset{CH_3}{\underset{H}{C}}-CH_2CH_2CH_2CH_3$

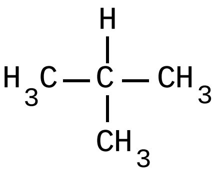
The molecular formula of 2-Methylhexane is C_8H_{18} - the same as Octane!! Substances with the same molecular formula but a different structural formula are known as **isomers**. 2-Methylhexane and Octane are isomers.

The name is derived by selecting the longest Carbon chain and numbering from the end nearest the branch.

In the above example, the longest Carbon chain is a 6-membered (Hexane) chain and there is a methyl group CH_3- on position 2. Branching groups are named after the parent alkane:

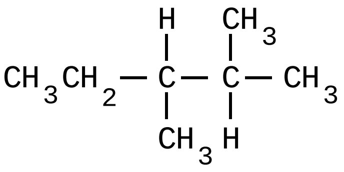
Methyl	CH_3-		
Ethyl	C_2H_5-	also written->	CH_3CH_2-
Propyl	C_3H_7-	also written->	$CH_3CH_2CH_2$-

FURTHER EXAMPLES OF NAMING ALKANES



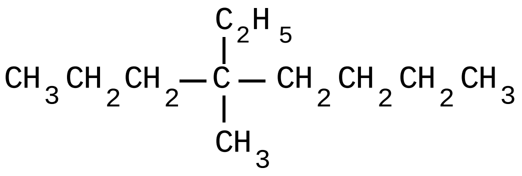
$H_3C-\underset{CH_3}{\overset{H}{C}}-CH_3$

2-Methylpropane



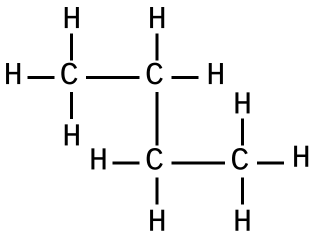
$CH_3CH_2-\underset{CH_3}{\overset{H}{C}}-\underset{H}{\overset{CH_3}{C}}-CH_3$

2,3-Dimethylpentane



$CH_3CH_2CH_2-\underset{CH_3}{\overset{C_2H_5}{C}}-CH_2CH_2CH_2CH_3$

4-Ethyl 4-Methyloctane



Butane

REACTIONS OF ALKANES

Alkanes are saturated - they contain only C-C single bonds.

They undergo a slow, substitution reaction with Bromine but only in the presence of ultra violet light e.g. Ethane

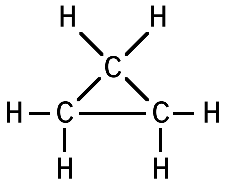
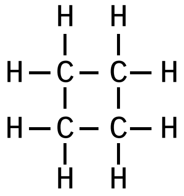
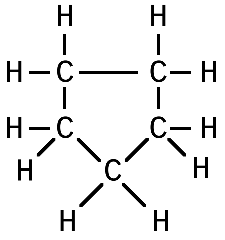
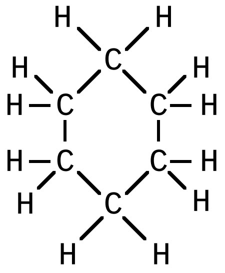
$$C_2H_6 + Br_2 \rightarrow C_2H_5Br + HBr$$

The brown colour of the Bromine slowly becomes colourless.

CYCLOALKANES General formula C_xH_{2x}

Cycloalkanes are hydrocarbons. Their names begin with 'Cyclo-'

Here are the first four in the series:

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

REACTIONS OF CYCLOALKANES

Cycloalkanes are saturated.

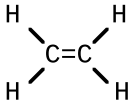
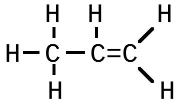
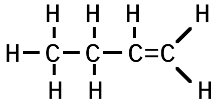
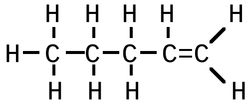
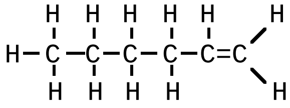
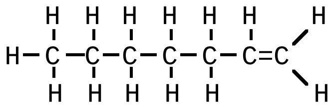
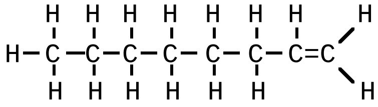
Like the alkanes, they undergo a slow, substitution reaction with Bromine but only in the presence of ultra violet light
e.g. Cyclobutane

C_4H_8 + Br_2 -> C_4H_7Br + HBr

ALKENES General formula C_xH_{2x}

Alkenes are hydrocarbons. Their names end in 'ene'.

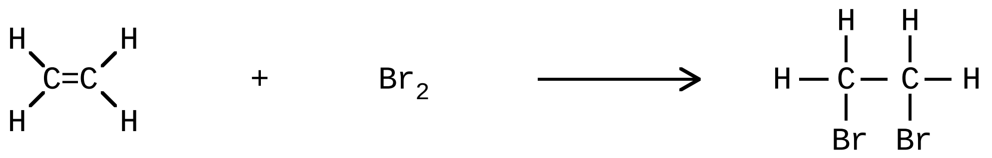
Here are the first seven in the series:

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}
Heptene		$CH_3CH_2CH_2CH_2CH_2CHCH_2$	C_7H_{14}
Octene		$CH_3CH_2CH_2CH_2CH_2CH_2CHCH_2$	C_8H_{16}

REACTIONS OF ALKENES

Alkenes are unsaturated - they contain C=C double bonds.

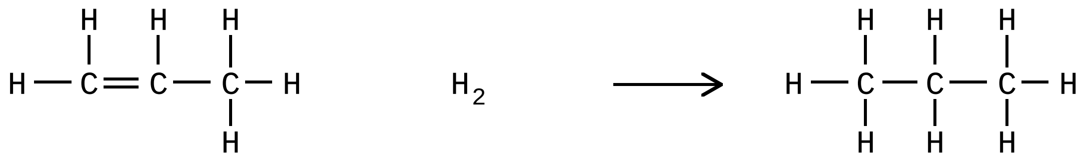
They undergo a fast, **addition** reaction with Bromine e.g. Ethene



The brown colour of the Bromine rapidly becomes colourless.

This reaction enables us to distinguish between saturated and unsaturated hydrocarbons: saturated hydrocarbons decolourise Bromine slowly and only in the presence of UV light; unsaturated hydrocarbons decolourise Bromine quickly and without UV.

Alkenes undergo an addition reaction with Hydrogen to form the corresponding alkane e.g.



Propene Propane

PREPARATION OF ALKENES

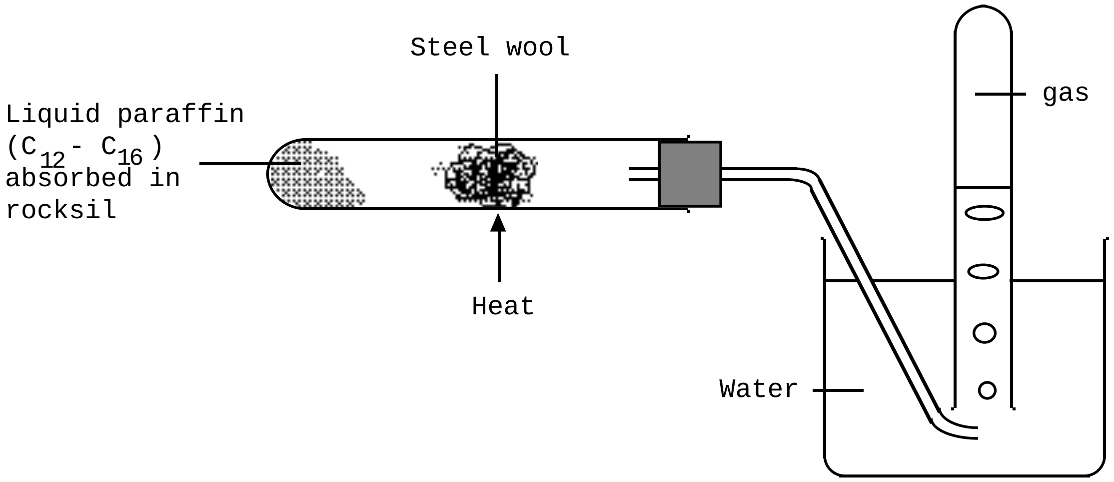
Fractional distillation of crude oil yields more long-chain hydrocarbons than are useful for present day purposes. When these large molecules are heated to very high temperatures they break down to form smaller ones, some of which are alkenes. This process is called **cracking**. The higher the temperature the more extensive the break down.

The cracking of Hexadecane at 700 - 900 ^{0}C produces mainly Ethene:

$C_{16}H_{34}$ -> 7 C_2H_4 + C_2H_6

This 'high-temperature' cracking is known as 'thermal cracking'.

EXPERIMENT: Thermal cracking of liquid paraffin:



If lower temperatures (450 - 550 ^{0}C) are used the cracking is not so extensive and larger molecules are produced. The use of lower temperatures, however, slows the reaction down. A catalyst (Aluminium silicate) must be used to speed things up. This type of cracking is known as 'catalytic cracking'.

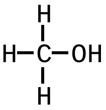
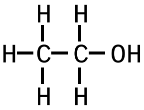
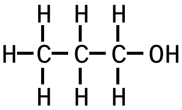
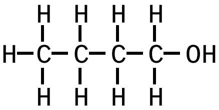
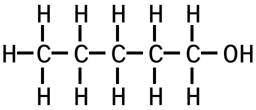
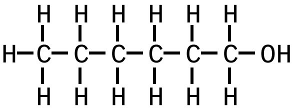
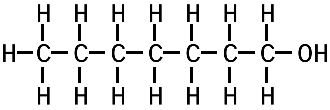
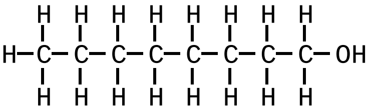
e.g. the cracking of Hexadecane at 450 - 550 ^{0}C produces Pentene and Hexane:

$$C_{16}H_{34} \quad \rightarrow \quad 2\ C_5H_{10} \quad + \quad C_6H_{14}$$

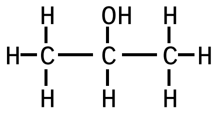
ALCOHOLS General formula $C_xH_{2x+1}OH$

Alcohols, also known as 'alkanols', contain the hydroxyl OH functional group - the group in the molecule which reacts. Their names end with '-ol'

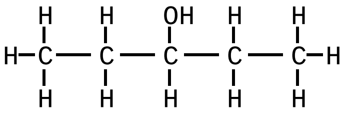
Here are the first eight in the series:

Name	**Full structural formula**	**Shortened structural formula**	**Molecular formula**
Methanol	 $H-\overset{H}{\underset{H}{C}}-OH$	CH_3OH	CH_3OH
Ethanol	 $H-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-OH$	CH_3CH_2OH	C_2H_5OH
Propan-1-ol	 $H-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-OH$	$CH_3CH_2CH_2OH$	C_3H_7OH
Butan-1-ol	 $H-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-OH$	$CH_3CH_2CH_2CH_2OH$	C_4H_9OH
Pentan-1-ol	 $H-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-OH$	$CH_3CH_2CH_2CH_2CH_2OH$	$C_5H_{11}OH$
Hexan-1-ol	 $H-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-OH$	$CH_3CH_2CH_2CH_2CH_2CH_2OH$	$C_6H_{13}OH$
Heptan-1-ol	 $H-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-OH$	$CH_3CH_2CH_2CH_2CH_2CH_2CH_2OH$	$C_7H_{15}OH$
Octan-1-ol	 $H-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-OH$	$CH_3CH_2CH_2CH_2CH_2CH_2CH_2CH_2OH$	$C_8H_{17}OH$

Other isomers with the hydroxyl group in a different position are possible e.g.



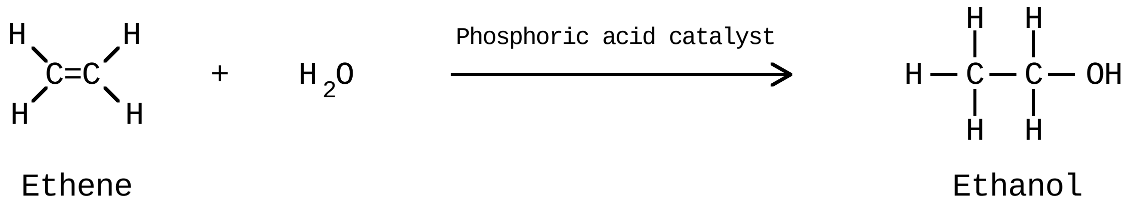
Propan-2-ol



Pentan-3-ol

PREPARATION OF ALCOHOLS

Alcohols are made by the addition reaction of alkenes with Water (hydration) in the presence of a catalyst e.g.



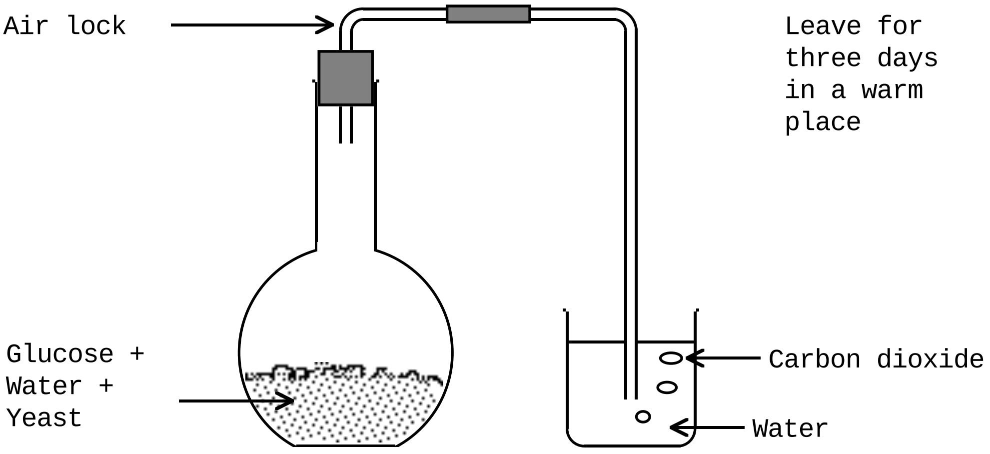
The Ethanol, thus obtained, is widely used as a solvent e.g. for hair lacquer, after shave, paint etc.

Ethanol can also be made by **fermentation** of Glucose obtained from fruits or vegetables e.g. wine is made from grapes, whisky is made from barley

$$C_6H_{12}O_6 \quad -> \quad C_2H_5OH \quad + \quad CO_2$$

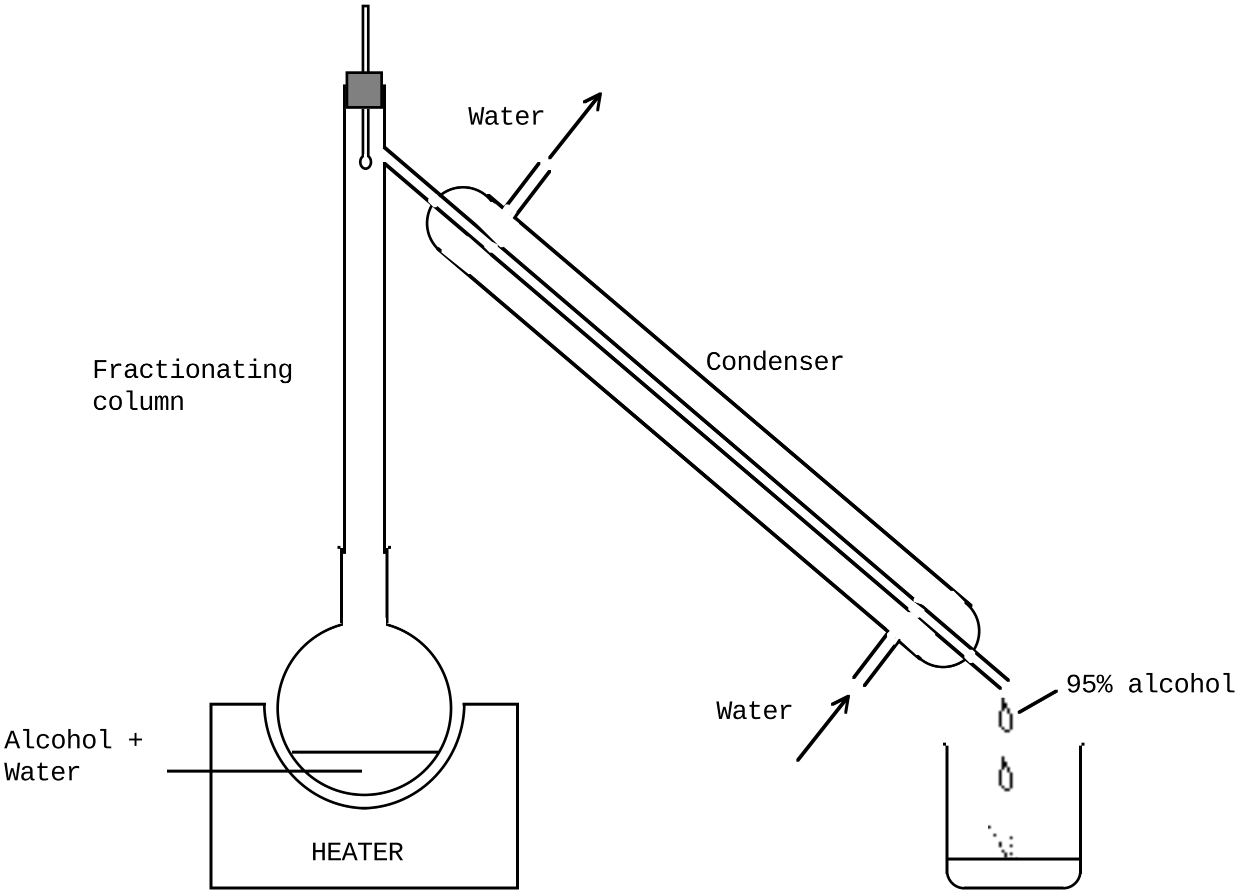
Zymase enzymes in yeast catalyse the reaction.

The fermentation of Glucose can be carried out in the laboratory :



The air lock is necessary to keep out Oxygen (Alcohol reacts with Oxygen to form vinegar, a dilute solution of Ethanoic acid)

The fermentation stops when the alcohol concentration reaches about 7%. This is because, at this concentration, the alcohol kills the yeast. The solution we obtain is therefore mostly Water !
Wines and beers are made this way.
If we want to make spirits (whisky, gin, vodka) we must increase the concentration of the alcohol. This is done by distillation :



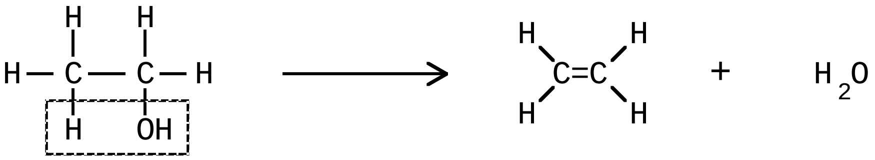
As the mixture boils, both alcohol and Water vapourise. The vapour contains more alcohol than Water since alcohol has the lower boiling point (78 ^{0}C). As the two fractions begins to rise up the fractionating column and begin to cool, the Water, with the highest boiling point (100 ^{0}C), condenses first and drops back into the flask. As the vapour moves further up the column it becomes more and more enriched in alcohol. When it reaches the top, the vapour is 95% alcohol. It then enters the condenser, cools and becomes a liquid. The thermometer reads 78 ^{0}C until all the alcohol has been distilled then begins to rise.

Apart from its use in making spirits, the distilled Ethanol can be mixed with petrol and used as a fuel in cars. When the crude oil runs out so will the petrol. Could we use Ethanol instead? It can be made from a renewable source of Glucose - sugar cane!

Ethanol is a drug which depresses the nervous system. It reduces awareness and slows down reaction times. It is illegal to drive with more than 80 milligrams of Ethanol per 100 cm^3 of blood.
In addition, Ethanol can damage the liver.

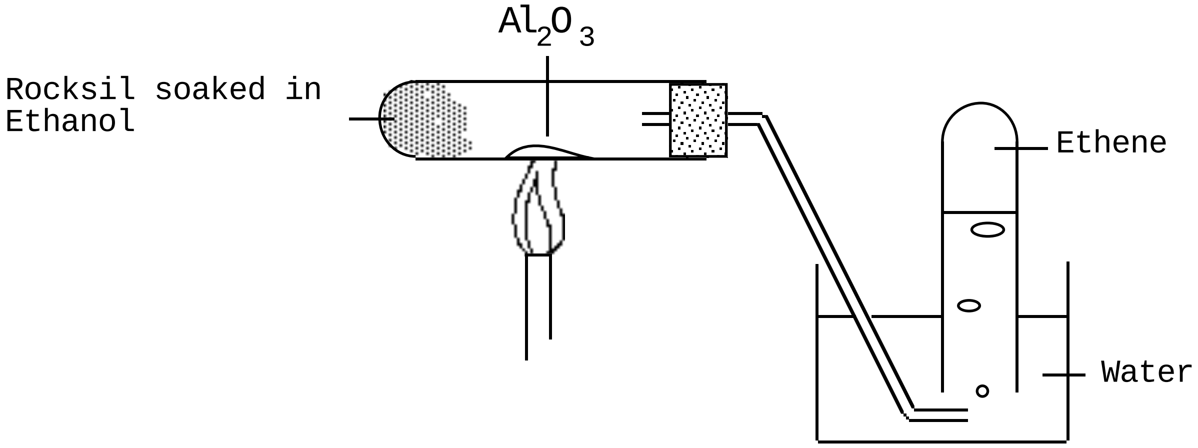
Dehydration of Ethanol

Alcohols can be converted to alkenes by passing the vapour over heated Aluminium oxide catalyst. The reaction is called 'dehydration' since loss of Water occurs.



Ethanol Ethene

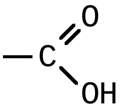
Experiment: Dehydration of Ethanol



ALKANOIC ACIDS

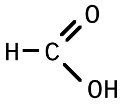
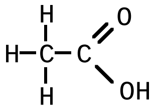
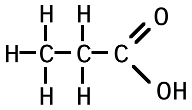
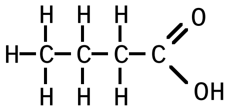
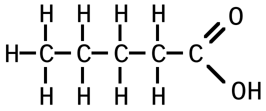
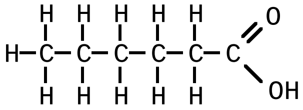
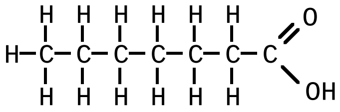
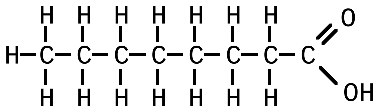
General formula $C_xH_{2x+1}COOH$

Alkanoic acids, also known as 'Carboxylic acids', contain the carboxyl COOH functional group:



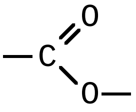
Their names end with '-oic acid'

Here are the first eight in the series:

Name	Full structural formula	Shortened structural formula	Molecular formula
Methanoic acid		$HCOOH$	$HCOOH$
Ethanoic acid		CH_3COOH	CH_3COOH
Propanoic acid		CH_3CH_2COOH	C_2H_5COOH
Butanoic acid		$CH_3CH_2CH_2COOH$	C_3H_7COOH
Pentanoic acid		$CH_3CH_2CH_2CH_2COOH$	C_4H_9COOH
Hexanoic acid		$CH_3CH_2CH_2CH_2CH_2COOH$	$C_5H_{11}COOH$
Heptanoic acid		$CH_3CH_2CH_2CH_2CH_2CH_2COOH$	$C_6H_{13}COOH$
Octanoic acid		$CH_3CH_2CH_2CH_2CH_2CH_2CH_2COOH$	$C_7H_{15}COOH$

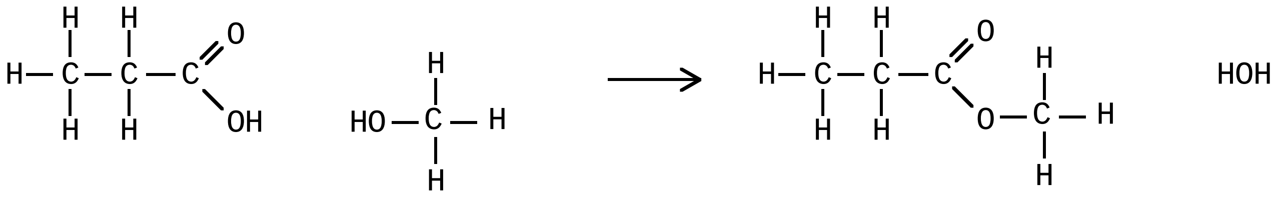
ESTERS

Esters contain the ester COO functional group:



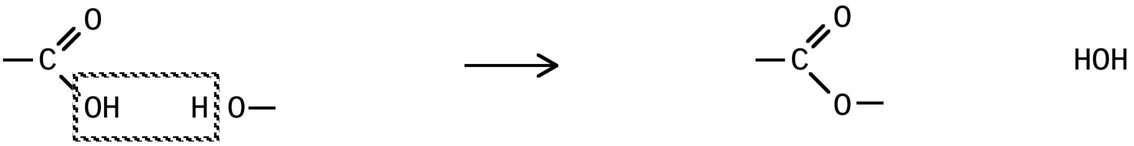
Their names end with '-oate'

Esters are made by the reaction of an alkanoic acid with an alcohol e.g.



Propanoic acid Methanol Methyl propanoate Water

The OH group breaks off the carboxylic acid. The H breaks off the alcohol. The OH and the H then join to give Water.



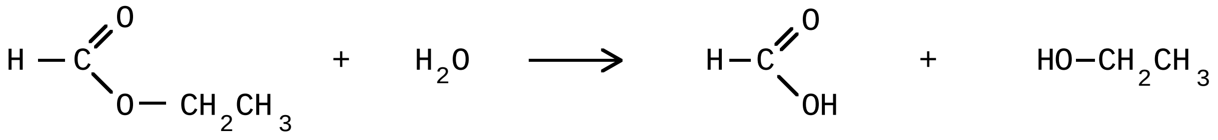
This is therefore a **condensation reaction**.

N.B. Methyl propanoate's formula may also be written, in shortened form, as $CH_3CH_2COOCH_3$.

Names are derived from the parent carboxylic acid and alcohol.

The formation of an ester can be reversed by reacting the ester with Water, a reaction known as **hydrolysis.**

e.g. the hydrolysis of Ethyl methanoate



Ethyl methanoate Water Methanoic acid Ethanol

Esters are used as flavourings, perfumes and solvents.