



## Hydrocarbons : alkanes, alkenes and alkynes

A hydrocarbon is a compound containing only carbon and hydrogen.

All organic compounds can be considered to be *hydrocarbons*, or compounds derived (i.e. 'coming') from hydrocarbons.

For example, methane ( $\text{CH}_4$ ) is a hydrocarbon, whereas carbon tetrachloride ( $\text{CCl}_4$ ) is not. However, carbon tetrachloride is derived from a hydrocarbon - replace the H-atoms of methane ( $\text{CH}_4$ ) with Cl-atoms and you get  $\text{CCl}_4$ .

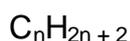
Three important groups of hydrocarbons are the alkanes, alkenes and the alkynes.

### Alkanes

Straight chained or branched chained hydrocarbons with *single bonds* are called **alkanes**.

These compounds are also known as **saturated hydrocarbons**.

The general formula of alkanes is:



$n$  = number of carbon atoms  
 $n + 2$  = is the number of hydrogen atoms in the molecular formula.

A group of compounds represented by one general formula is known as a **homologous series**.

The condensed structural formulas for the first four alkanes are:

$\text{CH}_4$   
methane

$\text{CH}_3\text{CH}_3$   
ethane

$\text{CH}_3\text{CH}_2\text{CH}_3$   
propane

$\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_3$   
butane

### Physical Properties

The first four alkanes ( $\text{C}_1$  to  $\text{C}_4$ ) are all gases at room temperature. Natural gas is mostly methane.

Compounds from  $\text{C}_5$  to  $\text{C}_{17}$  are oily liquids. Petroleum contains a wide variety of alkanes.

Natural gas and petroleum alkanes are used mainly for fuels.

Compounds greater than  $\text{C}_{17}$  are solids at room temperature and pressure.

As the number of carbon atoms increases, the molecules become larger and heavier.

This also means that their melting points and boiling points increase.

Liquid alkanes are insoluble in water, another property of liquid alkanes is that they are less dense than water. Alkanes are soluble in non-polar solvents such as toluene and tetrachloromethane.

### Reactions of alkanes

Although they are relatively unreactive, alkanes do undergo two important kinds of reactions: reactions with oxygen (combustion) and substitution of hydrogen atoms with chlorine and other halogens.



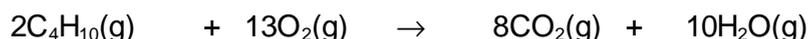
## Combustion (oxidation) reactions

All the alkanes burn in air.

In burning, the alkanes react with the oxygen in air to produce carbon dioxide and water. For example, methane burns in an excess of oxygen as follows:



The *balanced reaction* for the combustion of butane is:

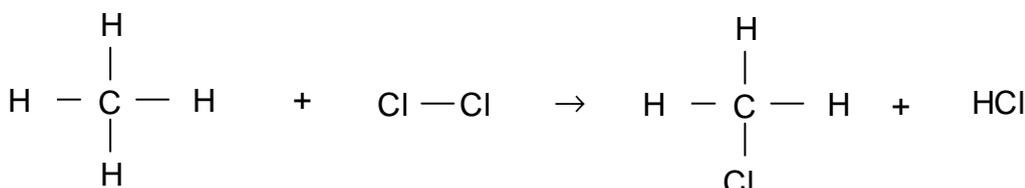


## Substitution reactions

Methane and other alkanes react with chlorine in sunlight or at high temperature in a **substitution reaction**.

A substitution reaction is a reaction in which one atom (or group of atoms) substitutes for another atom (or group of atoms) in a molecule.

The reaction of methane with chlorine is a reaction in which one or more chlorine atoms substitute for hydrogen atoms of the methane molecule:



chloromethane

If there is an excess of chlorine ( $\text{Cl}_2$ ), more atoms of hydrogen are replaced by chlorine atoms. When this happens, the final product is tetrachloromethane ( $\text{CCl}_4$ ).

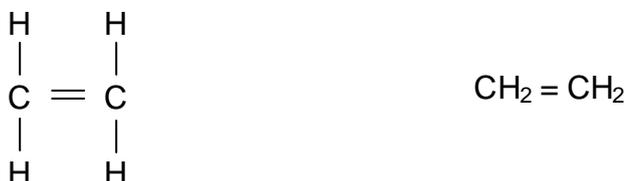
The reaction of an alkane with other halogens (such as bromine) results in a range of substitution products called **haloalkanes**. Chloromethane is an example of a haloalkane.

## **Alkenes & Alkynes**

An **alkene** is a hydrocarbon containing a carbon-carbon **double bond** and having the general molecular formula:

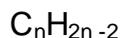


Ethene (or ethylene as it is sometimes called) is the simplest alkene:

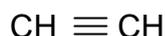




An **alkyne** is a hydrocarbon containing a carbon-carbon **triple bond** and having the general molecular formula:

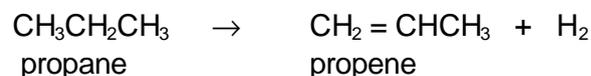


Ethyne (or acetylene as it is sometimes called) is the simplest alkyne:



### Sources and uses of alkenes & alkynes

Ethene (ethylene) and propene (propylene) are present in small quantities in natural gas and petroleum. The chemical industry prepares enormous quantities of these compounds by heating ethane and propane:



In these reactions, carbon-hydrogen bonds are broken in the alkanes to produce the corresponding alkenes.

Ethylene and propylene are used to manufacture plastics and a number of organic chemicals, including ethanol (alcohol), acetic acid, and ethylene glycol (antifreeze).

Acetylene,  $\text{CHCH}$ , is prepared by heating methane at high temperatures:



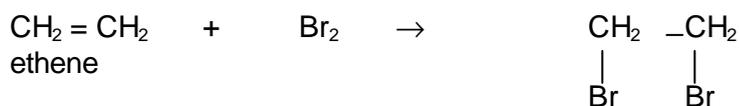
Acetylene was at one time the starting material for many industrial chemicals, most of which are now prepared from ethylene. Acetylene is widely used in the oxy-acetylene welding torch because it burns in oxygen with a hot flame.

### The reactions of the alkenes & alkynes

The alkenes and alkynes are generally more reactive than the alkanes. The reactions they undergo are mostly **addition reactions**.

An addition reaction is a reaction in which parts of a reactant molecule are added to each carbon atom of a carbon-carbon double or triple bond.

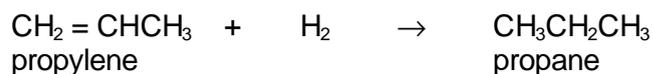
The reaction of ethene with bromine is a simple example of an addition reaction:



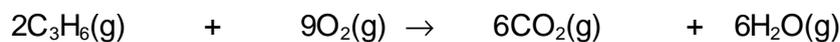
The product is 1,2-dibromoethane



An example of **hydrogenation** is the reaction of propylene with hydrogen:



Alkenes also undergo **combustion** reactions. For example, propene burns in a supply of air to give carbon dioxide and water:



If there is not enough oxygen available, propene will burn with a yellow flame and produce soot (carbon) and carbon monoxide (CO).

Ethyne burns in air with a luminous flame and produces a lot of soot. If a good supply of oxygen is available, ethyne burns with a colourless flame. This reaction is:

