

Alkanes and Alkenes Notes

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What is organic chemistry? It's the study of compounds that have carbon atoms bonded to other elements, mostly hydrogen, oxygen, nitrogen and the halogens (F, Cl & Br). It's called organic chemistry because quite a lot of the compounds that we work with are involved with living things or things that were once alive. Crude oil for example 😊

Crude oil: a mixture of hydrocarbons. It is made from the fossilised remains of dead plants and animals and it takes millions of years to form.

Hydrocarbons: are compounds that contain carbon and hydrogen atoms only. There are two kinds of hydrocarbons that we study for the GCSE, alkanes and alkenes.

The simplest organic compounds are hydrocarbons which contain only single bonds (ordinary covalent bonds where two electrons are shared). These are called **alkanes**.

Alkanes

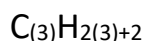
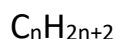
An Alkane: a saturated hydrocarbon. This means that all the covalent bonds between atoms in an alkane molecule are single bonds. All alkanes have names that end in – **ane**.

The general formula of an alkane is C_nH_{2n+2} . Please do learn this. It mostly tends to come up as a multiple-choice question.

How do we use the general formula of an alkane? Just like we would use an n^{th} term in maths. Substitute in the number of carbon atoms instead of n to find the formula. Let's have a look at one of these.

Example 1: Let's say that we want to find the molecular formula of an alkane with 3 carbons in it.

We substitute in 3 instead of ' n ' and complete the expression.



This is the molecular formula for the alkane with 3 carbon atoms in it. It's called Propane 😊.

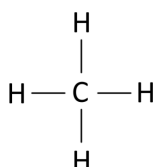
Alkanes are a homologous series. But what is a homologous series? Excellent question!

A homologous series – is a group of compounds with the same general formula, that have similar chemical properties, meaning that they react the same way as each other and that they show a gradual variation in their physical properties.

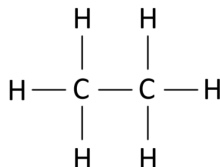
For example: the boiling point (which is a physical property) of a molecule will increase as the carbon chain gets longer.

This makes sense as the longer the chain is the more intermolecular forces of attraction that there are in the molecule. Therefore we need to break more intermolecular forces and this takes more energy. Let's look at the first 5 alkanes.

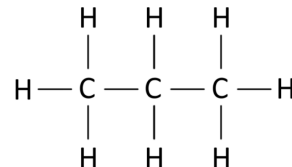
1. Methane, CH_4



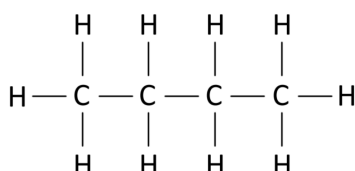
2. Ethane, C_2H_6



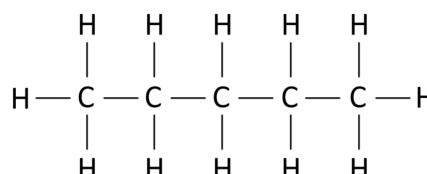
3. Propane, C_3H_8



4. Butane, C_4H_{10}



5. Pentane, C_5H_{12}



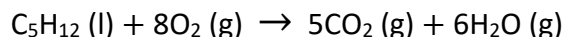
Reactions of Alkanes

We need to know about two typical reactions that alkanes undergo. Those are combustion and cracking. Cracking is sometimes called thermal cracking but it's exactly the same reaction.

Combustion

Like all hydrocarbons, alkanes burn to give CO_2 and H_2O . Take the example of the combustion of pentane below:

Pentane + Oxygen $\rightarrow$ Carbon dioxide + Water



This is complete combustion. There are two types of combustion, **complete combustion** and **incomplete combustion**.

Complete combustion – occurs when a fuel fully reacts with a sufficient supply of oxygen. It results in the formation of two main products, carbon dioxide, CO_2 and water, H_2O .

Incomplete combustion – occurs when a fuel burns in an insufficient supply of oxygen. As a result, the fuel is not fully oxidised. This leads to the formation of harmful products, such as carbon monoxide, CO and soot (carbon particles), in addition to water, H_2O .

Catalytic Cracking

What is it catalytic cracking? It's a process of strongly heating a large alkane over a catalyst in the absence of O_2 , this can crack any hydrocarbon. The word equation below shows this reaction.

Large alkane $\rightarrow$ smaller alkane + alkene

Cracking will produce a mixture of alkanes and alkenes and these can be separated by fractional distillation.

What are the conditions used for cracking?

High temperature.

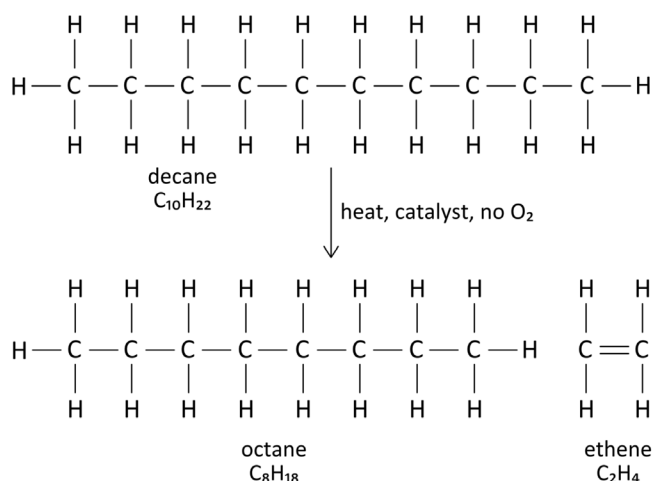
Catalyst – which is zeolite.

No oxygen.

Why is cracking done? Cracking is carried out because large alkanes are less useful as fuels so there is less demand for them. Smaller alkanes are much more useful as fuels as they burn quickly, for example petrol for cars.

The alkenes that are produced in this reaction can be used to make polymers and other useful chemicals.

The figure below shows the cracking of decane, $\text{C}_{10}\text{H}_{22}$ into octane C_8H_{18} and ethene, C_2H_4 .



Steam Cracking

Is another type of cracking that can be used instead of catalytic cracking.

How does it work? Hydrocarbons are mixed with steam and heated rapidly. The heat breaks down the hydrocarbon molecules into smaller ones

What are the conditions?

High temperature

Steam

No catalyst

What is it used for? Used to make lots of alkenes mostly.

Physical Properties of Alkanes

State: Methane, ethane, propane and butane are all colourless gases at room temperature. The other alkanes are all clear colourless liquids at room temperature.

Boiling and melting points: increase as the number of carbon atoms increases (due to stronger intermolecular forces).

Solubility: Alkanes are insoluble in water.

Density: All of the alkanes float on top of water because they are less dense than water.

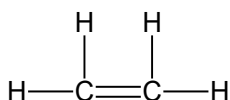
Alkenes

An Alkene: is an unsaturated hydrocarbon in which there is a carbon to carbon double bond. All alkenes have names that end in – **ene**.

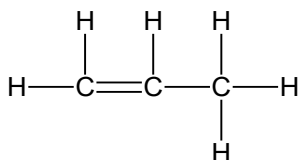
The general formula of an alkene is C_nH_{2n} . This mostly tends to come up as a multiple-choice question.

The simplest alkene is ethene. This has the formula C_2H_4 . The figure below shows the first 3 alkenes.

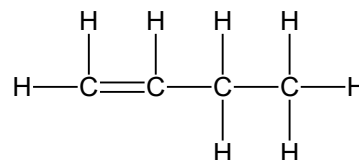
1. Ethene, C_2H_4



2. Propene, C_3H_6



3. Butene, C_4H_8



Reactions of Alkenes

Alkenes all react in a similar way. The double bond that each alkene has is much more reactive than single bonds so it is always the double bond which reacts.

Combustion

Like other hydrocarbons alkenes will burn in oxygen to form carbon dioxide and water. Alkenes tend to undergo incomplete combustion in air. Because of this, they burn in air with a smoky, yellow flame.

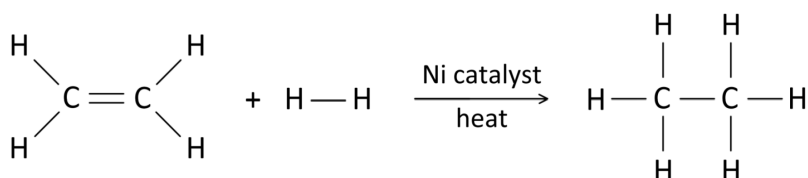
Hydrogenation

Hydrogenation is also known as saturation, this is the reaction of an alkene with hydrogen gas.

What are the conditions? 1. Nickel catalyst 2. A temperature of about 150°C

What is this reaction used for? It can be used to convert alkenes into alkanes by saturating them or it is also used in the food industry to saturate fats. This turns liquid oils into solid fats like margarine.

The figure below shows the hydrogenation of ethene.



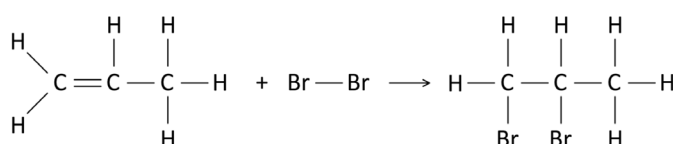
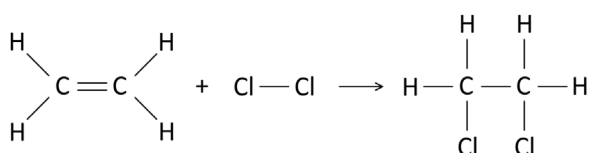
Addition Reactions with Halogens

Alkenes react with halogens, fluorine, chlorine, bromine or iodine in an addition reaction.

An addition reaction: a chemical reaction that combines two or more molecules to form a larger molecule. So, they literally added together to make a bigger one.

How does this reaction work? The double bond of the alkene breaks, and the halogen atoms bond to the carbon atoms, forming haloalkane. You might notice that the name changed to ending in ane. That because the molecule now doesn't have a double bond and they are all single bonds so the molecule is saturated.

The figures below show addition reactions of alkenes with the first two species of halogens.



In both reactions we can see that the alkene's double bond is broken and two single bonds are formed with the halogen atoms.

Hydration

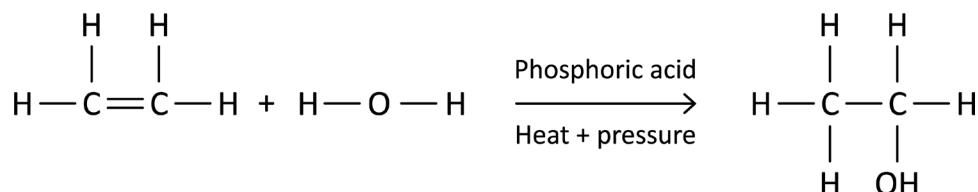
Alkenes can also react with water, but the water must be in the form of steam. This is another addition reaction, and it produces an alcohol.

The conditions are:

- Steam (High temperature, approx. 300 °C)
- High pressure
- A phosphoric acid catalyst

What is this reaction used for? It is used heavily in industry to make massive amounts of ethanol, this is the alcohol used in solvents and drinks and it's made from ethene.

Take the hydration of ethene as an example of this type of reaction.



Bromine Test for Alkenes

Bromine can be used to test a gas to see if it is an alkene. We can use either liquid bromine or more commonly bromine water is used for this test (as it's cheaper than liquid bromine).

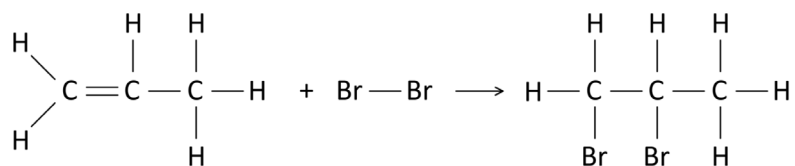
How does this reaction work? We bubble the alkene we are testing through either liquid bromine, Br₂ (l) or a solution of bromine (bromine water), Br₂ (aq).

Result: In both cases the orange bromine is immediately decolourised.

DO NOT SAY THE BROMINE WATER GOES CLEAR. THE EXAM BOARD WILL NOT ACCEPT THIS.

Alkanes do not react with bromine so this is a good test for alkenes.

This figure below shows the reaction of propene with aqueous bromine.



We can see in the figure that the bromine is no longer loose and is attached to the hydrocarbon. This is why the orange colour of the bromine is no longer visible.

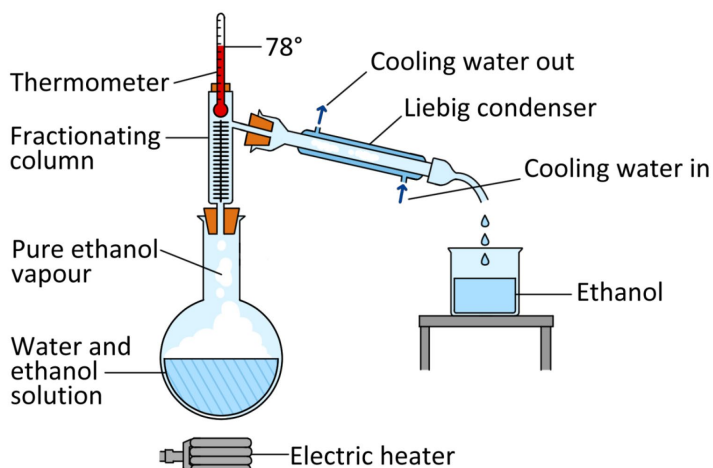
Fractional Distillation

Fractional distillation: a method of separating a mixture of liquids with different boiling points into individual components (fractions).

Where is it used? It is useful for separating ethanol from a mixture of ethanol and water and for separating crude oil into its different fractions, for example petrol and kerosene.

How does it work? Fractional distillation works by separating the different liquids based on their different boiling points. When the mixture is heated:

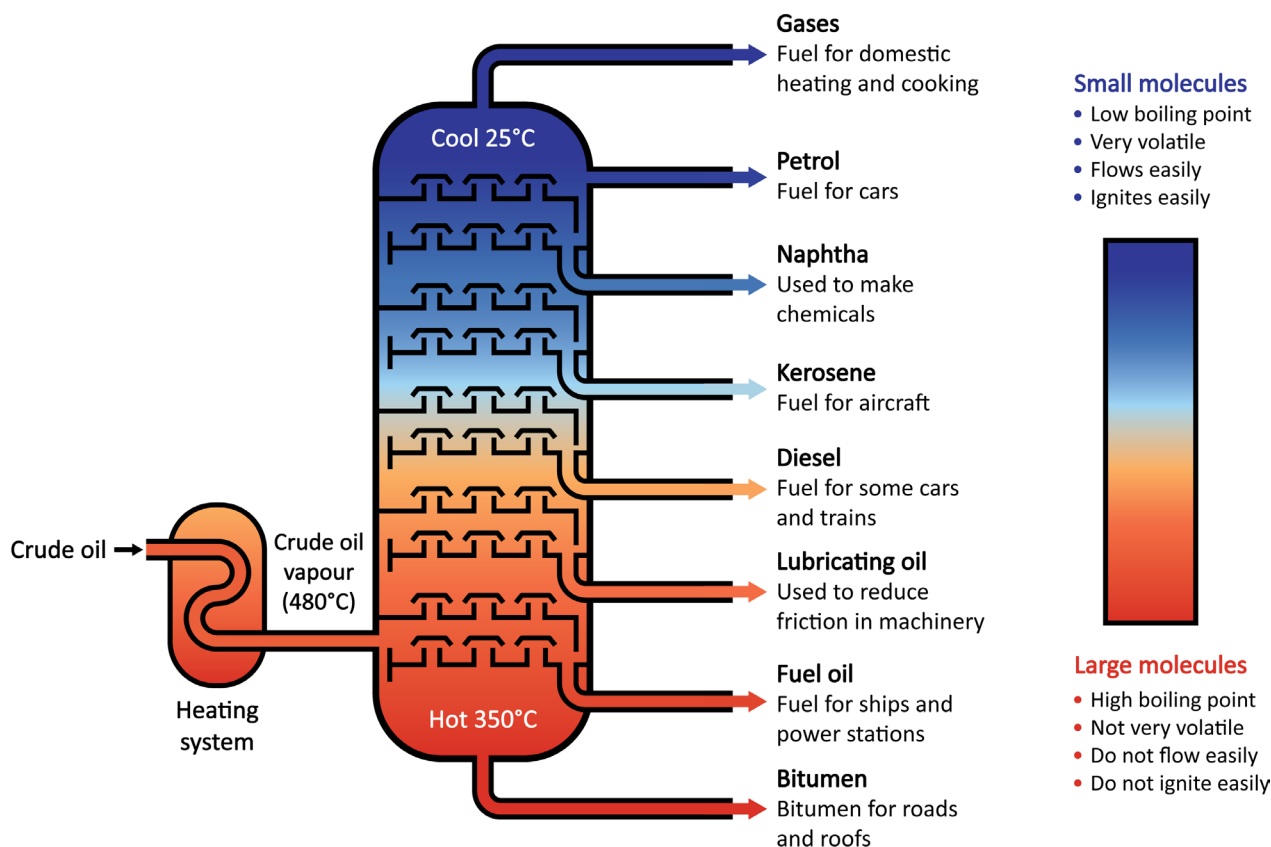
1. The vapours rise through a column which is hotter at the bottom, and cooler at the top.
2. A vapour rises up the column, cooling as it goes. When its temperature drops to its boiling point, it will condense back into a liquid at that level.
3. Each liquid is then removed from the column.



The figure shows the set up for a fractional distillation

Questions in exam papers tend to ask questions about fractional distillation in the form of fractionating columns dealing mostly with separating crude oil into its various fractions.

The diagram below gives a rough guide to the fractional distillation of crude oil. Please be aware of roughly where each fraction comes off and a use of each fraction.

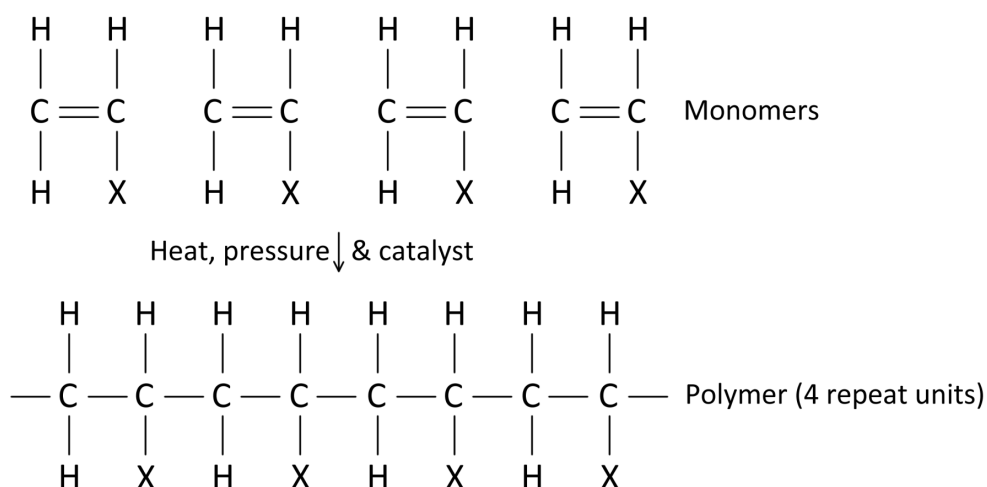


Addition Polymerisation

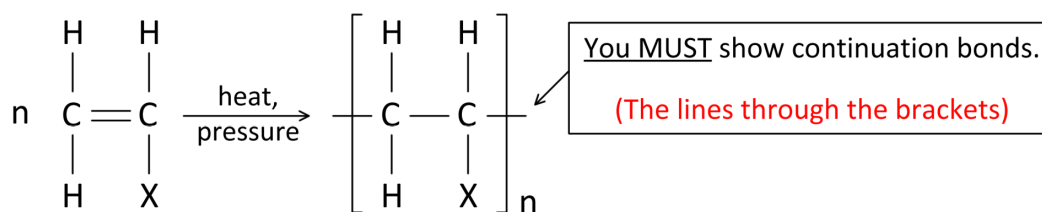
As we mentioned earlier, alkenes can be polymerised to form polymers. Addition polymers are formed by the joining up of many small molecules called monomers.

Alkenes can act as monomers as they are unsaturated so the double bond can break and bond with other monomers.

There is only **one product** in addition polymerisation. This is the polymer itself.



This reaction is usually written by simply showing the repeat unit:



where n represents a very large number (many thousands)