

## 5. Organic: Basic Concepts

### Basic definitions to know

**Hydrocarbon** is a compound consisting of hydrogen and carbon **only**

**Saturated:** Contain single carbon-carbon bonds only

**Unsaturated :** Contains a C=C double bond

**Molecular formula:** The formula which shows the actual **number of each type of atom**

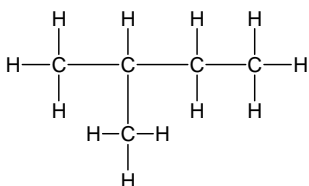
**Empirical formula:** shows the simplest whole number ratio of atoms of each element in the compound

**General formula:** algebraic formula for a homologous series e.g.  $C_nH_{2n}$

**Structural formula** shows the minimal detail that shows the arrangement of atoms in a molecule, eg for butane:  $CH_3CH_2CH_2CH_3$  or  $CH_3(CH_2)_2CH_3$ ,

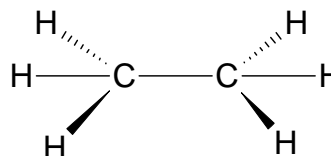
**Displayed formula:** show all the covalent bonds present in a molecule

### Drawing Displayed formulae

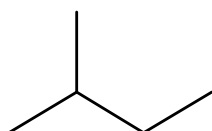


When drawing organic compounds add the hydrogen atoms so that each carbon has 4 bonds

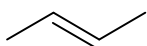
Remember that the shape around the carbon atom in saturated hydrocarbons is tetrahedral and the bond angle is  $109.5^\circ$



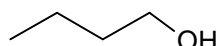
**Skeletal formula** shows the simplified organic formula, shown by removing hydrogen atoms from alkyl chains, leaving just a carbon skeleton and associated functional Groups.



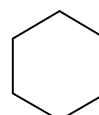
2-methylbutane



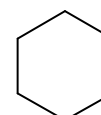
But-2-ene



Butan-1-ol



cyclohexane



cyclohexene

**Homologous series** are families of organic compounds with the **same functional group** and **same general formula**.

- They show a gradual change in physical properties (e.g. boiling point).
- Each member differs by  $\text{CH}_2$  from the last.
- same chemical properties.

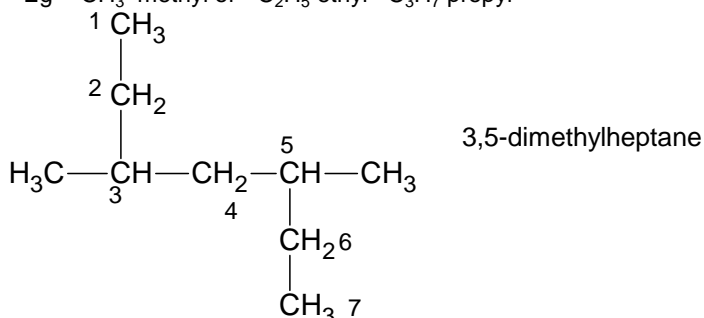
**Functional group** is an atom or group of atoms which when present in different molecules causes them to have similar chemical properties

homologous series	functional group	prefix / suffix (* = usual use)	example
Alkane		-ane	$\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_3$ Butane
Alkenes		suffix <b>-ene</b>	propene
Alcohols		suffix* <b>-ol</b> prefix <b>hydroxy-</b>	Propan-1-ol
Halogenoalkanes		prefix <b>chloro-</b> <b>bromo-</b> <b>iodo-</b>	1-chloropropane
Aldehydes		suffix <b>-al</b> prefix <b>formyl-</b>	ethanal
Ketones		suffix* <b>-one</b> prefix <b>oxo-</b>	Propanone
carboxylic acids		suffix <b>-oic acid</b>	Ethanoic acid
Esters		-yl -oate	methylethanoate

### General rules for naming carbon chains

- Count the longest carbon chain and name appropriately
- Find any branched chains and count how many carbons they contain
- Add the appropriate prefix for each branch chain

Eg -CH<sub>3</sub> methyl or -C<sub>2</sub>H<sub>5</sub> ethyl -C<sub>3</sub>H<sub>7</sub> propyl



code	no of carbons
meth	1
eth	2
prop	3
but	4
pent	5
hex	6
hept	7
oct	8
non	9
dec	10

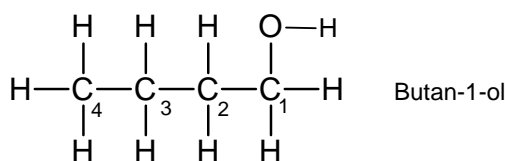
### Basic rules for naming functional groups

- When using a suffix, add in the following way :

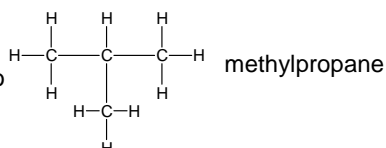
If the suffix starts with a vowel- remove the -e from the stem alkane name  
e.g. Propan-1-ol, butan-1-amine, ethanoic acid, ethanoylchloride, butanamide

If the suffix starts with a consonant or there are two or more of a functional group meaning di, or tri needs to be used then **do not remove the -e** from the stem alkane name  
e.g. Propanenitrile, ethane-1,2-diol, propanedioic acid, propane-1,2,3-triol, Pentane-2,4-dione.

- The position of the functional group on the carbon chain is given by a number – counting from the end of the molecule that gives the functional group the lowest number. For aldehydes, carboxylic acids & nitriles, the functional group is always on carbon 1.



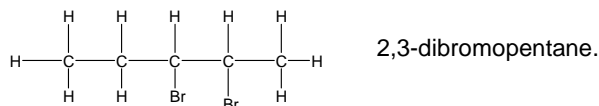
- We only include numbers, however, if they are needed to avoid ambiguity.



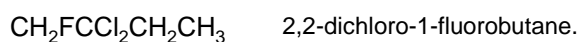
- The functional groups take precedence over branched chains in giving the lowest number

3-methylbut-1-ene is correct and not 2-methylbut-3-ene

- Where there are two or more of the same groups, *di-*, *tri-*, *tetra-*, *penta-* or *hexa-* are used. Note the point made above about the addition of 'e' to the stem



- Words are separated by numbers with dashes



- numbers are separated by commas



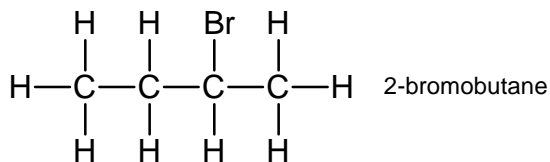
- If there is more than one functional group or side chain, the groups are listed in alphabetical order (ignoring any *di*, *tri*).

The suffix for alkenes can go in front of other suffixes.



### Halogenoalkanes

Class the halogen as a substituent on the C chain and use the suffix **-fluoro**, **-chloro**, **-bromo**, or **-iodo**. (Give the position number if necessary)

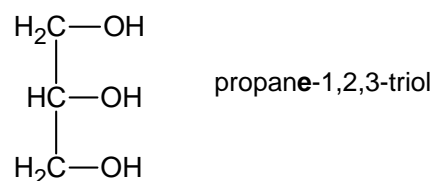
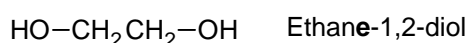
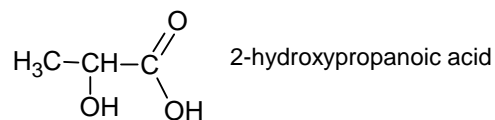
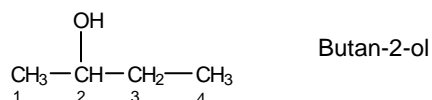


### Alcohols

These have the ending **-ol** and if necessary the position number for the OH group is added between the name stem and the **-ol**

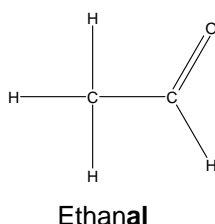
If the compound has an **-OH** group in addition to other functional groups that need a suffix ending then the OH can be named with the prefix **hydroxy-**:

If there are two or more **-OH** groups then di, tri are used. Add the **'e'** on to the stem name though.



### Aldehydes

An aldehyde's name ends in **-al**. It always has the **C=O** bond on the first carbon of the chain so it does not need an extra number. It is by default number one on the chain.

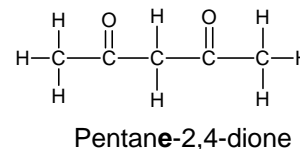
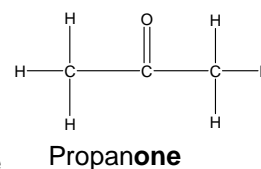


### Ketones

Ketones end in **-one**

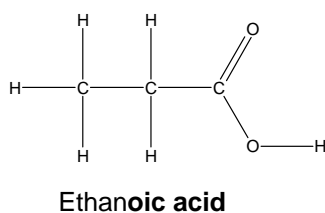
When ketones have 5C's or more in a chain then it needs a number to show the position of the double bond. E.g. pentan-2-one

If two ketone groups then **di** is put before **-one** and an **e** is added to the stem.

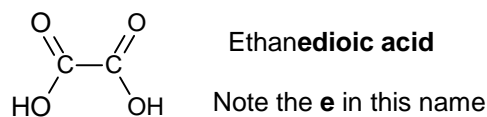


### Carboxylic acids

These have the ending **-oic acid** but no number is necessary for the acid group as it must always be at the end of the chain. The numbering always starts from the carboxylic acid end.



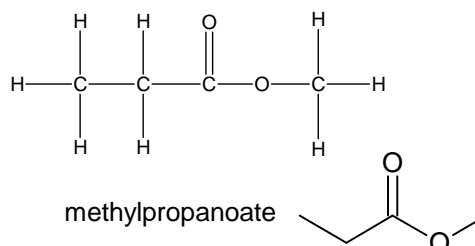
If there are carboxylic acid groups on both ends of the chain then it is called a **-dioic acid**



### Esters

Esters have two parts to their names

The bit ending in **-yl** comes from the alcohol that has formed it and is next to the single bonded oxygen. The bit ending in **-anoate** comes from the carboxylic acid. (This is the chain including the **C=O** bond)



## Isomers

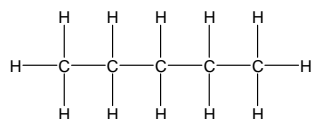
**Structural isomers:** same molecular formula different structures (or structural formulae)

Structural isomerism can arise from

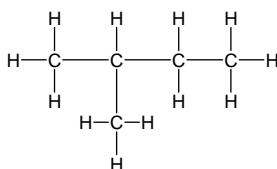
- Chain isomerism
- Position isomerism
- Functional group isomerism

EDEXCEL does not split structural isomers into the different categories. They are all classed as structural isomers.

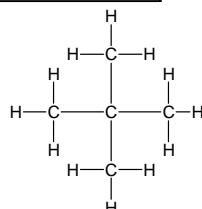
**Chain isomers:** Compounds with the same molecular formula but different structures of the carbon skeleton



pentane

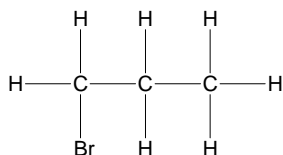


2-methylbutane

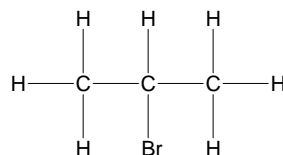


2,2-dimethylpropane

**Position isomers:** Compounds with the same molecular formula but different structures due to different positions of the same functional group on the same carbon skeleton

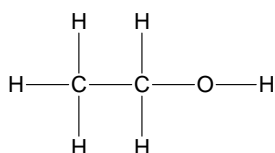


1-bromopropane

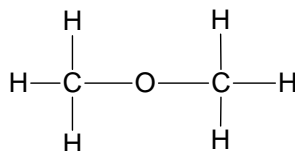


2-bromopropane

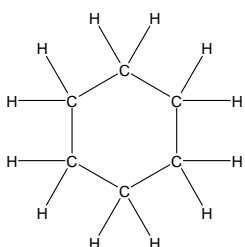
**Functional group isomers:** Compounds with the same molecular formula but with atoms arranged to give different functional groups



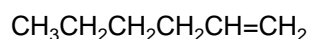
ethanol: an alcohol



Methoxymethane: an ether



Cyclohexane- cyclo alkane



hexene- alkene

Note: alkene and cyclo alkanes have the same general formula. Hexene and cyclohexane have the same molecular formula but have a different functional group

## Alkanes

Alkanes are saturated hydrocarbons

**General formula** alkane  $C_nH_{2n+2}$

**Saturated:** Contain single carbon-carbon bonds only

**Hydrocarbon** is a compound consisting of hydrogen and carbon **only**

### Fuels from crude oil

They are obtained from the crude oil in the order of fractional distillation, cracking and reformation of crude oil

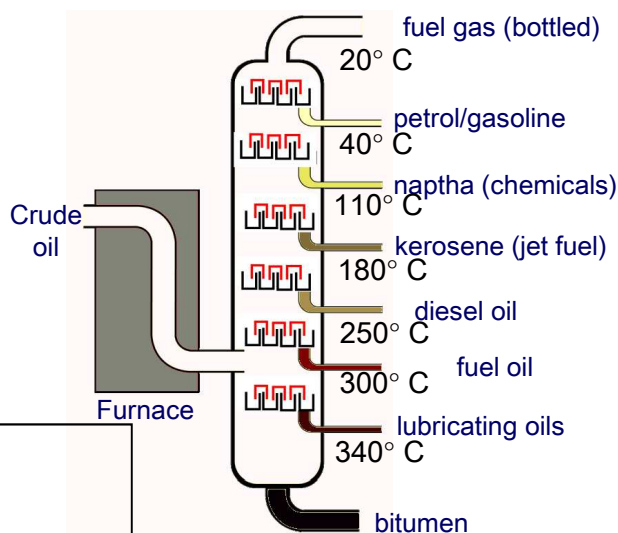
Alkanes are used as fuels

### Refining crude oil

#### Fractional Distillation:

Petroleum is a mixture consisting mainly of alkane hydrocarbons

**Petroleum fraction:** mixture of hydrocarbons with a similar chain length and boiling point range



This is a physical process involving the splitting of weak London forces between molecules

- Oil is pre-heated
- then passed into column.
- The fractions condense at different heights
- The temperature of column decreases upwards
- The separation depends on boiling point.
- Boiling point depends on size of molecules.
- The larger the molecule the larger the London forces
- Similar molecules (size, bp, mass) condense together
- Small molecules condense at the top at lower temperatures
- and big molecules condense at the bottom at higher temperatures.

### Cracking

**Cracking:** conversion of large hydrocarbons to smaller molecules by breakage of C-C bonds

High Mr alkanes  $\rightarrow$  smaller Mr alkanes + alkenes + (hydrogen)

#### Economic reasons for catalytic cracking

- The petroleum fractions with shorter C chains (e.g. petrol and naphtha) are in **more demand** than larger fractions.
- To make use of excess larger hydrocarbons and to supply demand for shorter ones, longer hydrocarbons are cracked.
- The products of cracking are **more useful and valuable** than the starting materials (e.g. ethene used to make poly(ethene) and ethane-1,2-diol, and ethanol) The smaller alkanes are used for motor fuels which burn more efficiently.

This is a chemical process involving the splitting of strong covalent bonds so requires high temperatures.

### Reforming

**Turns straight chain alkanes into branched and cyclic alkanes and Aromatic hydrocarbons**

Branched and cyclic hydrocarbons burn more cleanly and are used to give fuels a higher octane number.

Used for making motor fuels

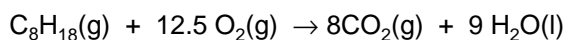
## Alkanes as Fuels

**Fuel** : releases heat energy when burnt

### Complete Combustion

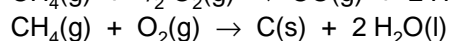
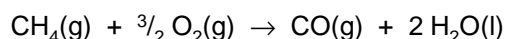
In excess oxygen alkanes will burn with complete combustion

The products of *complete* combustion are CO<sub>2</sub> and H<sub>2</sub>O.



### Incomplete Combustion

If there is a **limited amount of oxygen** then *incomplete* combustion occurs, producing CO (which is very toxic) and/or C (producing a sooty flame)



**Alkanes** readily burn in the presence of oxygen. This combustion of alkanes is highly exothermic, explaining their use as **fuels**.

Incomplete combustion produces less energy per mole than complete combustion.

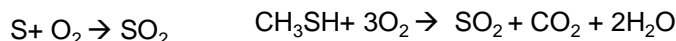
Carbon (soot) can cause global dimming- reflection of the sun's light

Carbon monoxide is an highly toxic but odourless gas. It can cause death if it builds up in a enclosed space due to faulty heating appliances.

CO is toxic to humans as CO can form a strong bond with haemoglobin in red blood cells. This is a stronger bond than that made with oxygen and so it prevents the oxygen attaching to the haemoglobin.

## Pollution from Combustion

Sulphur containing impurities are found in petroleum fractions which produce SO<sub>2</sub> when they are burned.



Coal is high in sulphur content, and large amounts of sulphur oxides are emitted from power stations.

SO<sub>2</sub> will dissolve in atmospheric water and can produce **acid rain**.

## Nitrogen Oxides NO<sub>x</sub>

Nitrogen oxides form from the reaction between N<sub>2</sub> and O<sub>2</sub> inside the car engine.

The **high temperature** and **spark** in the engine provides sufficient energy to break strong N<sub>2</sub> bond



Pollutant	Environmental consequence
Nitrogen oxides (formed when N <sub>2</sub> in the air reacts at the <b>high temperatures and spark</b> in the engine)	NO is toxic and can form smog NO <sub>2</sub> is toxic and acidic and forms acid rain
Carbon monoxide	toxic
Carbon dioxide	Contributes towards global warming
Unburnt hydrocarbons (not all fuel burns in the engine)	Contributes towards formation of smog
soot	Global dimming and respiratory problems

## Global warming

•Carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>) and water vapour (H<sub>2</sub>O) are all greenhouse gases. (They trap the Earth's radiated infra red energy in the atmosphere).

•Water is the main greenhouse gas (but is natural), followed by carbon dioxide and methane.

Carbon dioxide levels have risen significantly in recent years due to increasing burning of fossil fuels. Carbon dioxide is a particularly effective greenhouse gas and its increase is thought to be largely responsible for global warming.

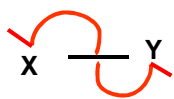
The Earth is thought to be getting warmer, and many scientists believe it is due to increasing amounts of greenhouse gases in the atmosphere.

## Introduction to Mechanisms

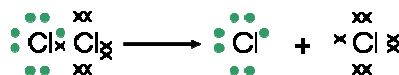
To understand how the reaction proceeds we must first understand how bonds are broken in organic mechanisms  
There are two ways to break a covalent bond:

### 1. HOMOLYTIC FISSION:

*each atom gets one electron from the covalent bond*



one headed arrow shows movement of one electron



The bond has broken in a process called **homolytic** fission.

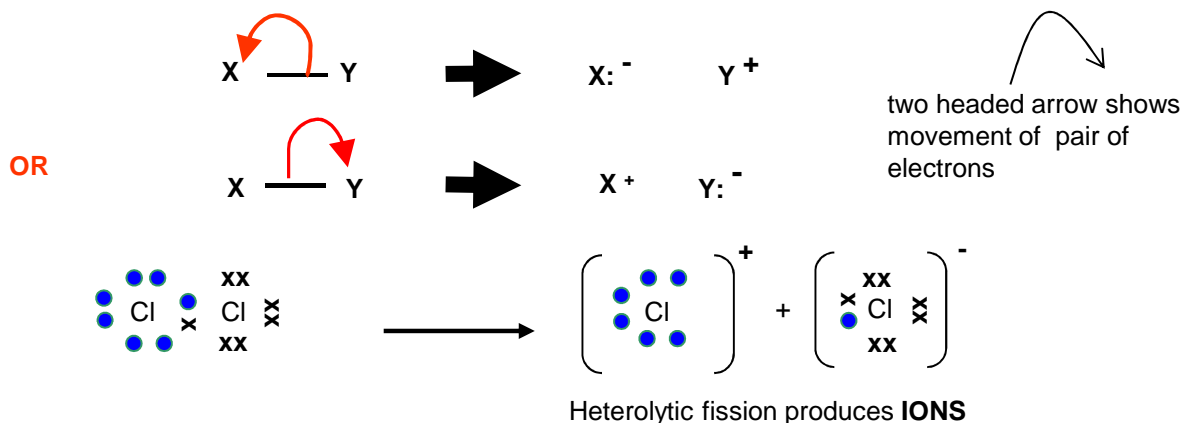
When a bond breaks by homolytic fission it forms two **Free Radicals**.

**Free Radicals** do not have a charge and are represented by a  $\cdot$

#### DEFINITION

A **Free Radical** is a reactive species which possess an **unpaired electron**

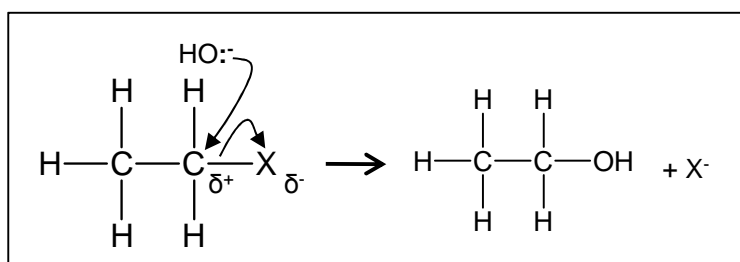
### 2. HETEROLYTIC FISSION: (*one atom gets both electrons*)



Most organic reactions occur via heterolytic fission, producing ions

### The Mechanism:

To understand a reaction fully we must look in detail at how it proceeds step by step. This is called its **mechanism**



The carbon has a small positive charge because of the electronegativity difference between the carbon and the halogen

We use curly arrows in mechanisms to show the movement of an electron pair showing either breaking or formation of a covalent bond;

A curly arrow will always **start** from a **lone pair** of electrons or the **centre of a bond**



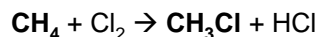
## Free Radical Substitution Reactions of Alkanes

### Reaction of alkanes with bromine / chlorine in UV light

In the presence of **UV light** alkanes react with chlorine to form a mixture of products with the halogens substituting hydrogen atoms.

In general, alkanes do not react with many reagents. This is because the C-C bond and the C-H bond are relatively strong.

#### Overall Reaction



methane      chloromethane

*This is the overall reaction, but a more complex mixture of products is actually formed*

The **MECHANISM** for this reaction is called a **FREE RADICAL SUBSTITUTION**

It proceeds via a series of steps:

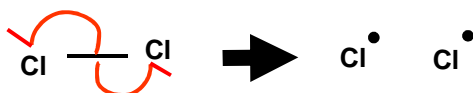
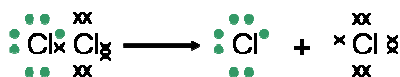
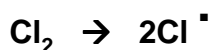
STEP ONE: **Initiation**

STEP TWO: **Propagation**

STEP THREE: **Termination**

#### STEP ONE Initiation

Essential condition: UV light



The UV light supplies the energy to break the Cl-Cl bond. It is broken in preference to the others as it is the weakest.

UV light does not have enough energy to break the C-H bond

The bond has broken in a process called **homolytic fission**.

*each atom gets **one** electron from the covalent bond*

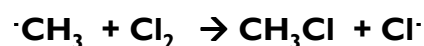
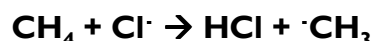
When a bond breaks by homolytic fission it forms **Free Radicals**.

**Free Radicals** do not have a charge and are represented by a  $\bullet$

#### DEFINITION

A **Free Radical** is a reactive species which possess an **unpaired electron**

#### STEP TWO Propagation



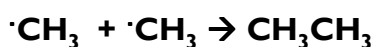
The chlorine free radicals are very reactive and remove an H from the methane leaving a methyl free radical

The methyl free radical reacts with a  $\text{Cl}_2$  molecule to produce the main product and another Cl free radical

All propagation steps have a **free radical** in the **reactants** and in the **products**.

As the Cl free radical is regenerated, it can react with several more alkane molecules in a **CHAIN REACTION**

#### STEP THREE Termination



Collision of two free radicals *does not generate* further free radicals: the chain is **TERMINATED**.

Minor step leading to impurities of ethane in product. **Write this step using structural formulae** and don't use molecular formulae

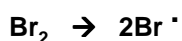
### Applying the mechanism to other alkanes

Example: Write mechanism of Br<sub>2</sub> and Propane

The same mechanism is used: Learn the patterns in the mechanism

#### STEP ONE Initiation

Essential condition: UV light

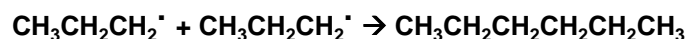


Br<sub>2</sub> splits in the same way as Cl<sub>2</sub>

#### STEP TWO Propagation



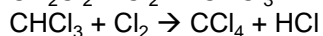
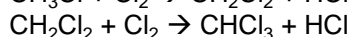
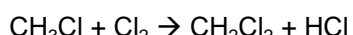
#### STEP THREE Termination



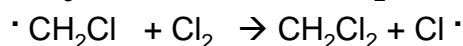
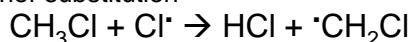
### Further substitution

Excess Cl<sub>2</sub> present will promote further substitution and could produce **CH<sub>2</sub>Cl<sub>2</sub>, CHCl<sub>3</sub> and CCl<sub>4</sub>**

These reactions could occur

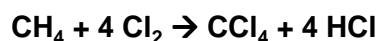


Example propagation steps that would lead to further substitution

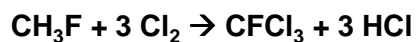


You should be able to write **overall reaction** equations for various reactions

Example 1. Write the overall reaction equation for the formation of CCl<sub>4</sub> from CH<sub>4</sub> + Cl<sub>2</sub>



Example 2. Write the overall reaction equation for the formation of CFCI<sub>3</sub> from CH<sub>3</sub>F + Cl<sub>2</sub>



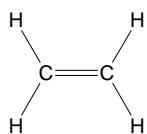
Note HCl is always the side product – never H<sub>2</sub>

# Alkenes

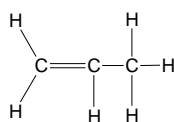
Alkenes are unsaturated hydrocarbons

General formula is  $C_nH_{2n}$

Alkenes contain a carbon-carbon double bond somewhere in their structure

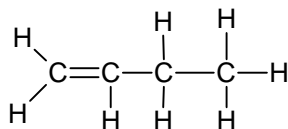


**Ethene**

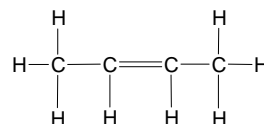


**Propene**

Numbers need to be added to the name when positional isomers can occur

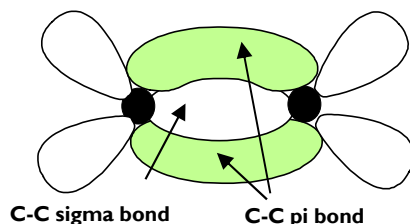


**But-1-ene**



**But-2-ene**

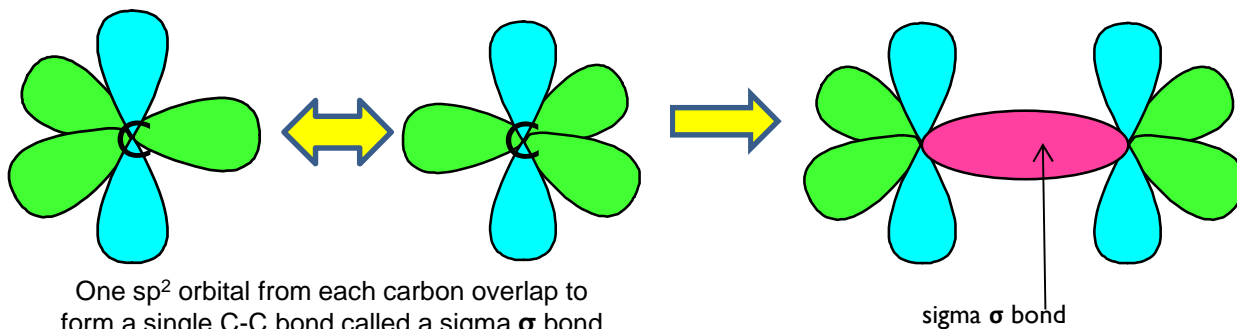
$C=C$  double covalent bond consists of **one sigma ( $\sigma$ ) bond and one pi ( $\pi$ ) bond.**



$\pi$  bonds are **exposed** and have **high electron density**.

They are therefore vulnerable to attack by species which 'like' electrons: these species are called **electrophiles**.

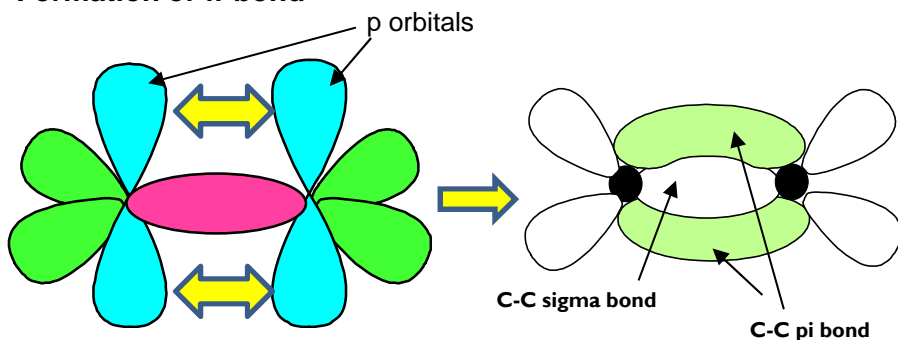
## Formation of $\sigma$ bond



One  $sp^2$  orbital from each carbon overlap to form a single C-C bond called a sigma  $\sigma$  bond

Rotation can occur around a sigma bond

## Formation of $\pi$ bond



**The  $\pi$  bond** is formed by sideways overlap of two p orbitals on each carbon atom forming a  $\pi$ -bond above and below the plane of molecule.

The  $\pi$  bond is weaker than the  $\sigma$  bond.

There is Restricted rotation about a pi bond

The pi bond leads to resultant high electron density above and below the line between the two nuclei

## Stereoisomerism

Stereoisomers have the same structural formulae but have a different spatial arrangement of atoms.

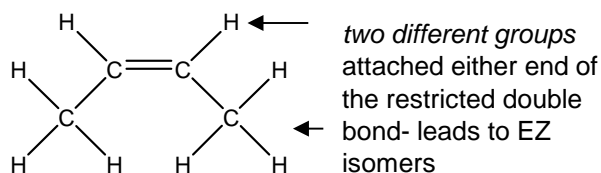
Alkenes can exhibit a type of isomerism called **E-Z stereoisomerism**

E-Z isomers exist due to restricted rotation about the C=C bond

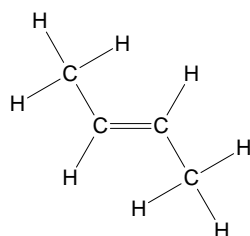
E-Z stereoisomers arise when:

- There is **restricted rotation** around the C=C double bond.
- There are **two different groups/atoms** attached both ends of the double bond

Single carbon-carbon covalent bonds can easily rotate

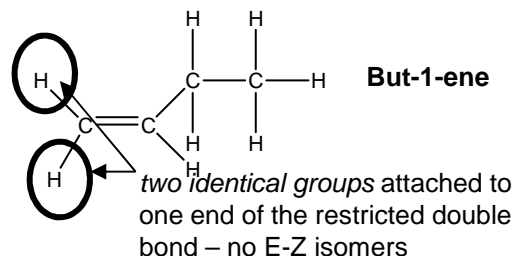


**Z-but-2-ene**



**E-but-2-ene**

These are two isomers as the lack of rotation around the double bonds means one cannot be switched to the other

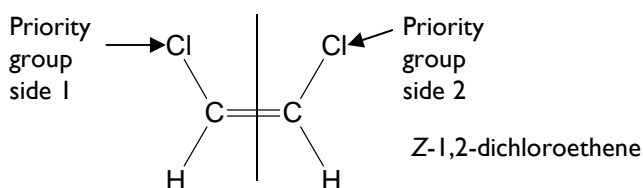


But-1-ene is a structural isomer of But-2-ene but does not show E-Z isomerism

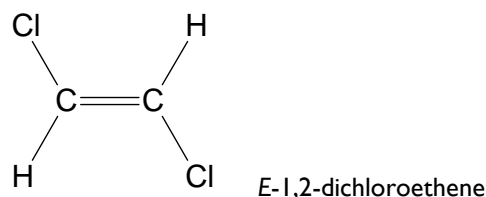
### Naming E-Z stereoisomers

First determine the priority groups on both sides of the double bond

**Priority Group:** The atom with the bigger  $A_r$  is classed as the priority atom

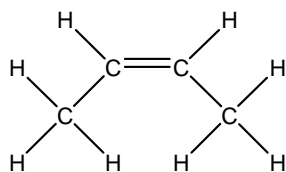


If the priority atom is on the same side of the double bond it is labelled Z from the german zusammen (The Zame Zide!)



If the priority atom is on the opposite side of the double bond it is labelled E from the german entgegen (The Epposite side!)

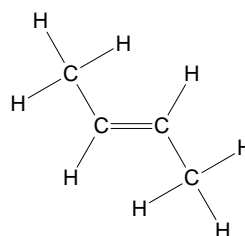
*cis-trans isomerism* is a special case of *EIZ* isomerism in which two of the substituent groups are the same.



**Z-but-2-ene**

Can also be called

**Cis-but-2-ene**



**E-but-2-ene**

Can also be called

**trans-but-2-ene**

## Addition Reactions of Alkenes

Addition reaction: a reaction where two molecules react together to produce one

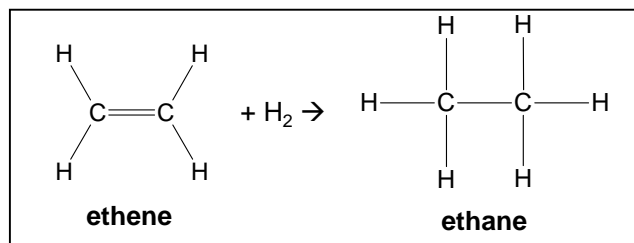
### 1. Reaction of Alkenes with Hydrogen

**Change in functional group:** alkene → alkane

**Reagent:** hydrogen

**Conditions:** Nickel Catalyst

**Type of reaction:** Addition/Reduction



### Electrophilic Addition: Reactions of Alkenes

A  $\pi$  bond is weaker than a  $\sigma$  bond so less energy is needed to break  $\pi$  bond. The  $\pi$  bonds in alkenes are areas with high electron density. This is more accessible to electrophilic attack by electrophiles. Alkenes undergo addition reactions.

**Definition Electrophile:** an electron pair acceptor

### 2. Reaction of Alkenes with bromine/chlorine

**Change in functional group:**

alkene → dihalogenoalkane

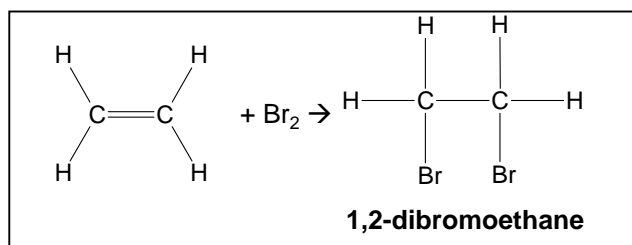
**Reagent:** Bromine (dissolved in organic solvent)

**Conditions:** Room temperature (not in UV light)

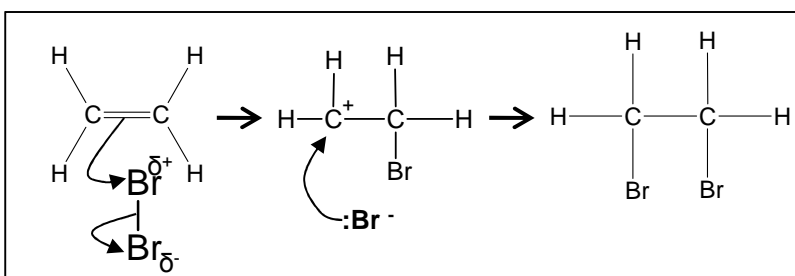
**Mechanism:** Electrophilic Addition

**Type of reagent:** Electrophile, Br $\delta^+$

**Type of Bond Fission:** Heterolytic



As the Br<sub>2</sub> molecule approaches the alkene, the pi bond electrons repel the electron pair in the Br-Br bond. This **INDUCES** a **DIPOLE**. Br<sub>2</sub> becomes **polar** and **ELECTROPHILIC** (Br $\delta^+$ ).



The **INTERMEDIATE** formed, which has a positive charge on a carbon atom is called a **CARBICATION**

### 3. Reaction of Hydrogen Bromide with alkenes

**Change in functional group:**

alkene → halogenoalkane

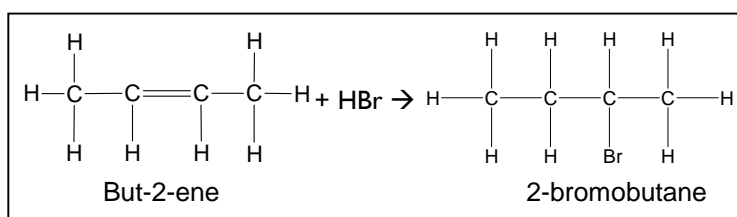
**Reagent:** HCl or HBr

**Conditions:** Room temperature

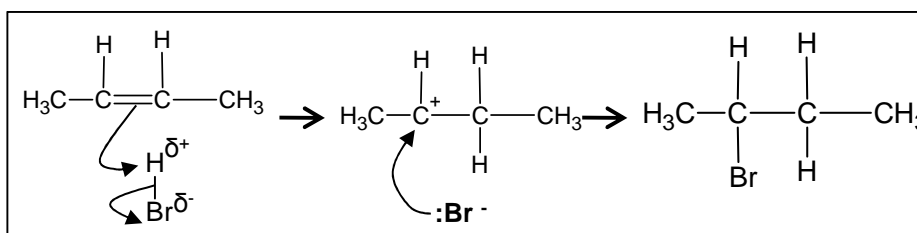
**Mechanism:** Electrophilic Addition

**Type of reagent:** Electrophile, H $\delta^+$

**Type of Bond Fission:** Heterolytic

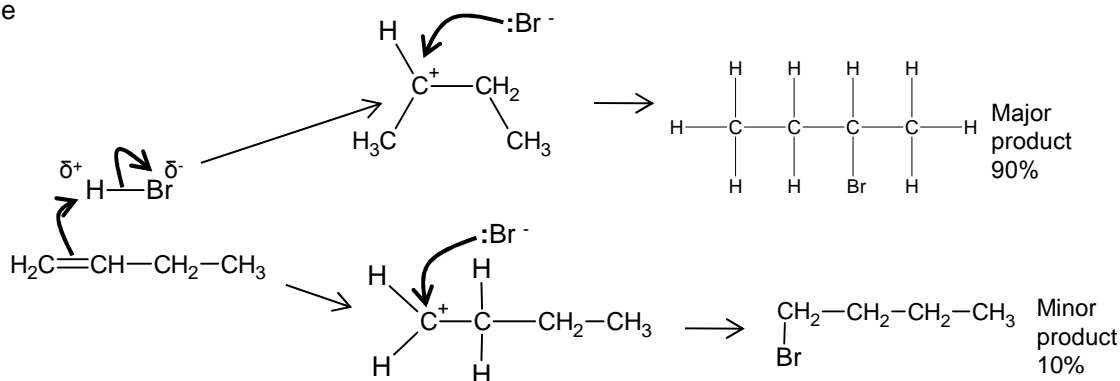


HBr is a polar molecule because Br is more electronegative than H. The H $\delta^+$  is attracted to the electron-rich pi bond.



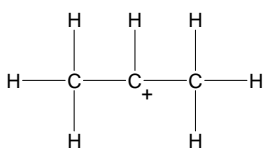
If the alkene is unsymmetrical, addition of hydrogen bromide can lead to two isomeric products.

But-1-ene will form a mixture of 1-bromobutane and 2-bromobutane on reaction with hydrogen bromide



#### WHY?

This carbocation intermediate is more stable because the methyl groups on either side of the positive carbon are electron releasing and reduce the charge on the ion which stabilises it.



The order of stability for carbocations is tertiary > secondary > primary

In **electrophilic addition** to alkenes, the **major product** is formed **via the more stable carbocation** intermediate.

In exam answers

- Draw out both carbocations and identify as primary, secondary and tertiary
- State which is the more stable carbocation e.g. secondary more stable than primary
- State that the more stable carbocation is stabilised because the methyl groups on either (or one) side of the positive carbon are electron releasing and reduce the charge on the ion.
- (If both carbocations are secondary then both will be equally stable and a 50/50 split will be achieved)

#### 4. Reaction of Potassium Manganate(VII) with Alkenes

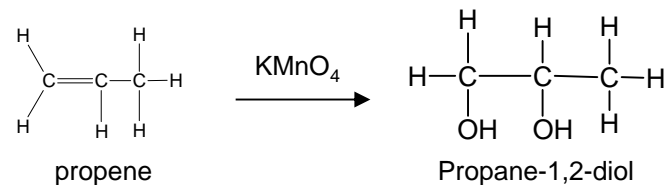
**Change in functional group:** alkene  $\rightarrow$  diol

**Reagent:**  $\text{KMnO}_4$  in an acidified solution

**Conditions:** Room temperature

**Type of reaction:** Oxidation

**Observation:** purple colour of  $\text{MnO}_4^-$  ion will decolourise to colourless



This reaction with its colour change can be used as a test for the alkene functional group. It would not change colour with alkanes

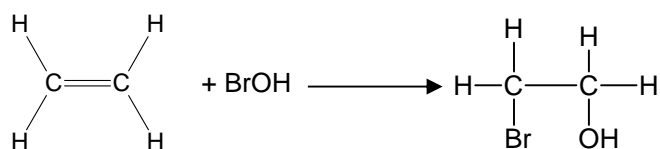
#### 5. Reaction of Bromine Water with Alkenes

**Reagent:** Bromine dissolved in water

**Conditions:** Room temperature

**Type of reaction:** Addition

**Observation:** Orange colour of bromine water will decolourise to colourless

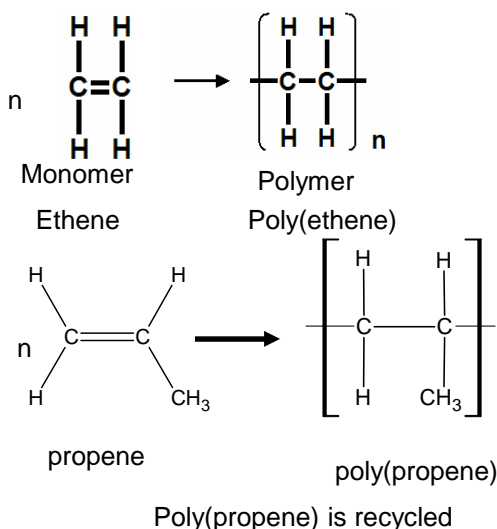


This reaction with its colour change is used as a test for the alkene functional group.

## Addition Polymers

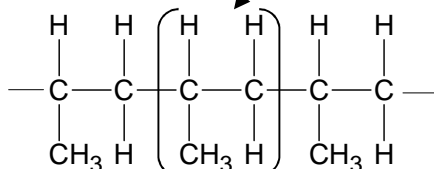
Addition polymers are formed from alkenes

This is called **addition polymerisation**



Poly(alkenes) like alkanes are unreactive due to the strong C-C and C-H bonds.

be able to recognise the repeating unit in a poly(alkene)

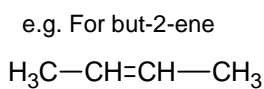


← Add the **n**'s if writing an equation showing the reaction where 'n' monomers become 'n' repeating units

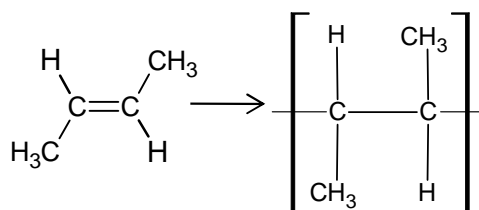
Poly(ethene): is used to make plastics bags, buckets, bottles. It is a flexible, easily moulded, waterproof, chemical proof, and low density plastic.

Poly(propene) is a stiffer polymer, used in utensils and containers and fibres in rope and carpets.

You should be able to draw the polymer repeating unit for any alkene



It is best to first draw out the monomer with groups of atoms arranged around the double bond



## Disposal of Polymers

### Landfill

The most common method of disposal of waste in UK. Many are now reaching capacity.

European regulations will mean councils are charged much more for using landfill.

Most polymers (polyalkenes) are non-biodegradable and take many years to break down.

Could use more biodegradable plastics, e.g. Polyamides and cellulose and starch based polymers to improve rates of decomposition.

### Incineration

Rubbish is burnt and energy produced is used to generate electricity.

Some toxins can be released on incineration. (e.g. Combustion of halogenated plastics (ie PVC) can lead to the formation of toxic, acidic waste products such as HCl.) Modern incinerators can burn more efficiently and most toxins and pollutants can be removed. Greenhouse gases will still be emitted though.

Volume of rubbish is greatly reduced.

### Recycling

Saves raw materials- nearly all polymers are formed from compounds sourced/produced from crude oil. Saves precious resources.

Polymers need collecting/ sorting- expensive process in terms of energy and manpower.

Polymers can only be recycled into the same type – so careful separation needs to be done.

Thermoplastic polymers can be melted down and reshaped.