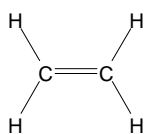


5 Alkenes

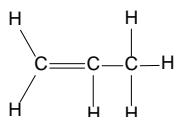
Alkenes are unsaturated hydrocarbons

General formula is C_nH_{2n}

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

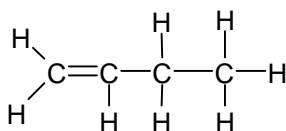


Ethene

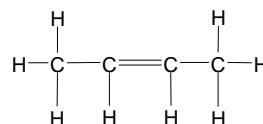


Propene

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

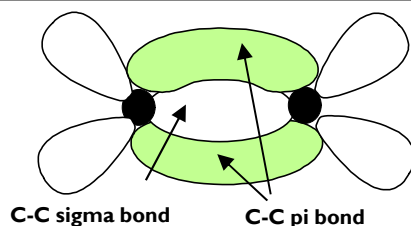


But-1-ene



But-2-ene

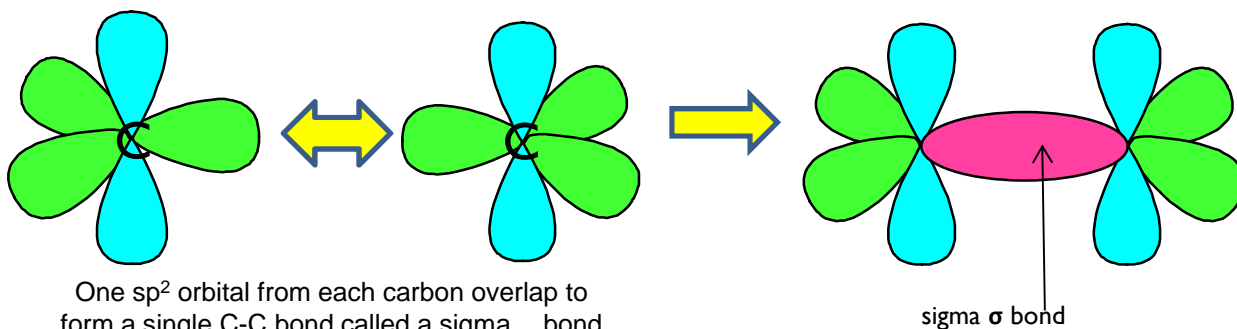
$C=C$ double covalent bond consists of **one sigma (σ) bond and one pi (π) bond.**



bonds are **exposed** and have **high electron density**.

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

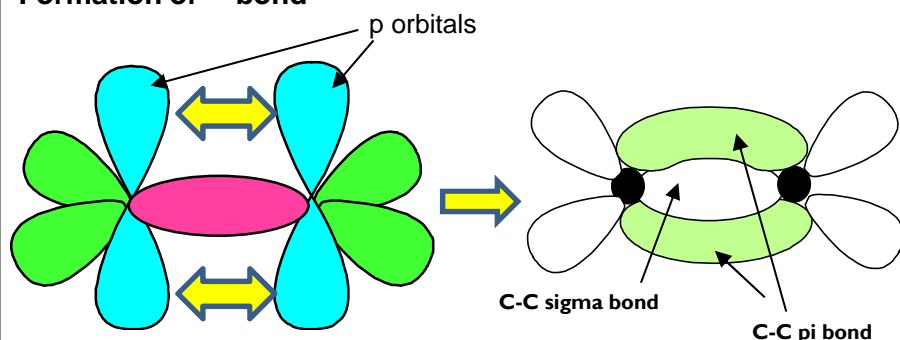
Formation of σ bond



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

Rotation can occur around a sigma bond

Formation of π bond



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

The π bond is weaker than the σ bond.

There is Restricted rotation about a π bond

The π 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.

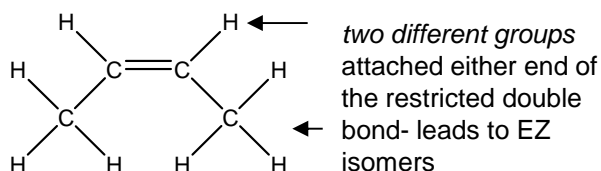
Alkenes can exhibit a type of isomerism called **E-Z stereoisomerism**

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

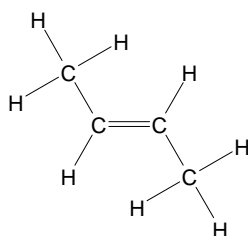
E-Z stereoisomers arise when:

- 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

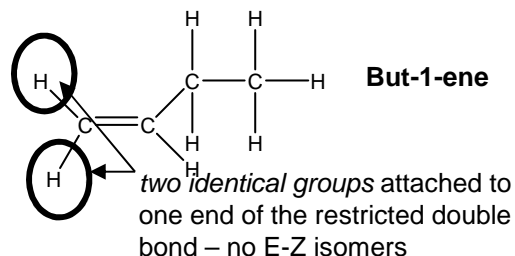


Z-but-2-ene



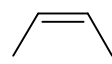
E-but-2-ene

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

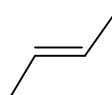


But-1-ene is a structural isomer of But-2-ene but does not show E-Z isomerism

Skeletal formulae can also represent E-Z isomerism



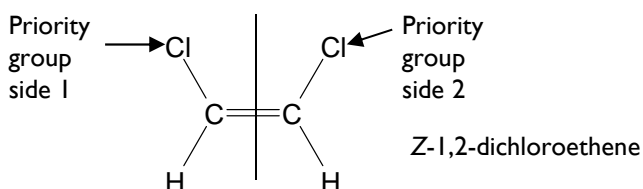
Z-but-2-ene



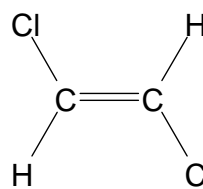
E-but-2-ene

Naming E-Z stereoisomers

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



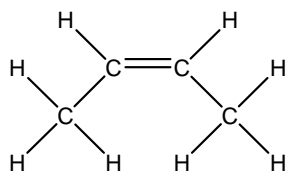
If the priority atom is on the same side of the double bond it is labelled Z from the german zusammen (The Zame Zide!)



E-1,2-dichloroethene

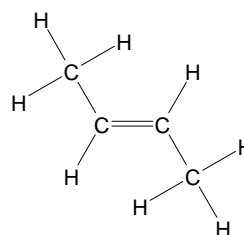
If the priority atom is on the opposite side of the double bond it is labelled E from the german entgegen (The Epposite side!)

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

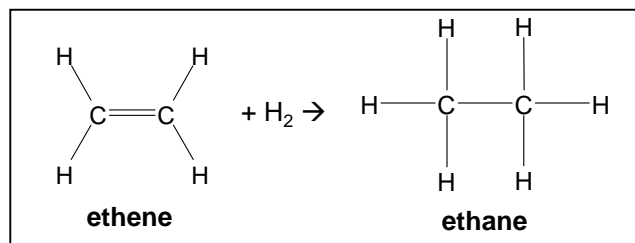
1. Reaction of Alkenes with Hydrogen

Change in functional group: alkene → alkane

Reagent: hydrogen

Conditions: Nickel Catalyst

Type of reaction: Addition/Reduction



Electrophilic Addition: Reactions of Alkenes

A π bond is weaker than a σ bond so less energy is needed to break π bond
The π 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

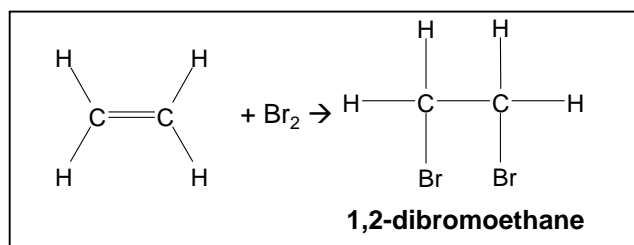
Reagent: Bromine (dissolved in organic solvent)

Conditions: Room temperature (not in UV light)

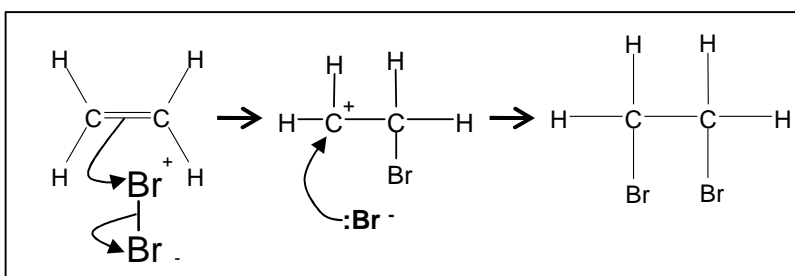
Mechanism: Electrophilic Addition

Type of reagent: Electrophile, Br δ^+

Type of Bond Fission: Heterolytic



As the Br₂ molecule approaches the alkene, the pi bond electrons repel the electron pair in the Br-Br bond. This **INDUCES** a **DIPOLE**. Br₂ becomes **polar** and **ELECTROPHILIC** (Br δ^+).



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

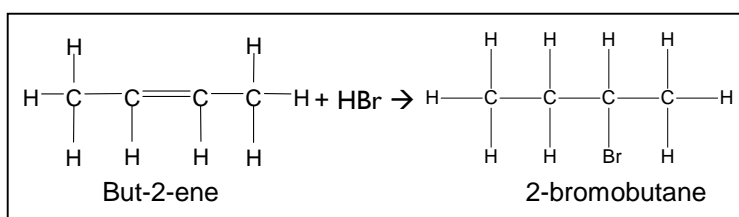
Reagent: HCl or HBr

Conditions: Room temperature

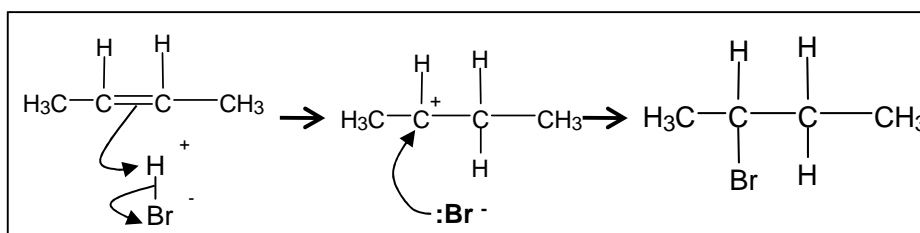
Mechanism: Electrophilic Addition

Type of reagent: Electrophile, H δ^+

Type of Bond Fission: Heterolytic

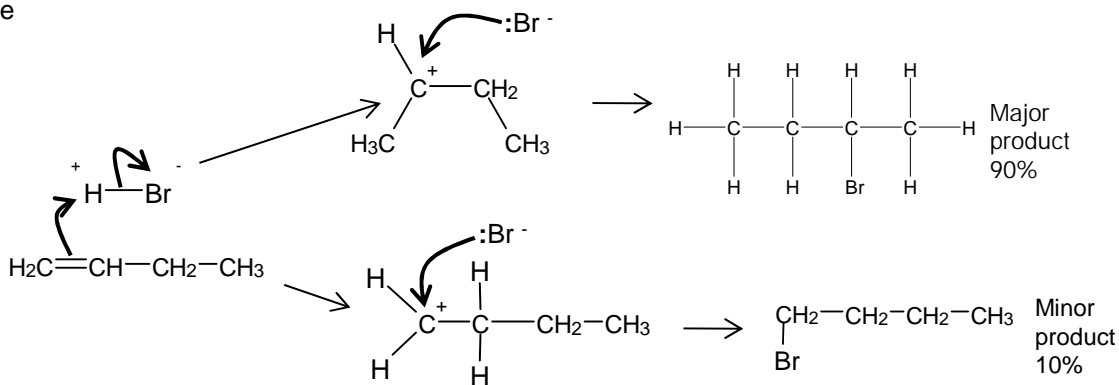


HBr is a polar molecule because Br is more electronegative than H. The H δ^+ is attracted to the electron-rich pi bond.



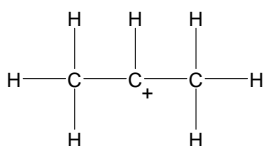
If the alkene is unsymmetrical, addition of hydrogen bromide can lead to two isomeric products.

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

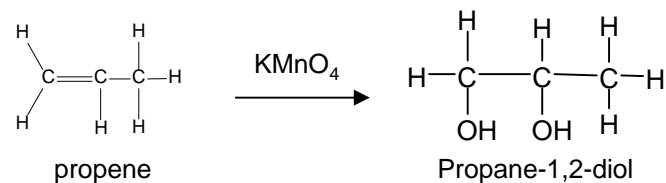
Change in functional group: alkene → diol

Reagent: KMnO_4 in an acidified solution

Conditions: Room temperature

Type of reaction: Oxidation

Observation: purple colour of 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

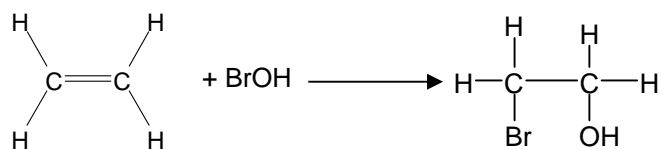
5. Reaction of Bromine Water with Alkenes

Reagent: Bromine dissolved in water

Conditions: Room temperature

Type of reaction: Addition

Observation: Orange colour of bromine water will decolourise to colourless

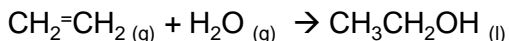


This reaction with its colour change is used as a test for the alkene functional group.

hydration of alkenes to form alcohols

Industrially alkenes are converted to alcohols in one step rather than the two in the above sulphuric acid reaction. They are reacted with water in the presence of an acid catalyst.

This reaction can be called **hydration**: a reaction where water is **added** to a molecule



Essential Conditions

High temperature 300 to 600°C

High pressure 70 atm

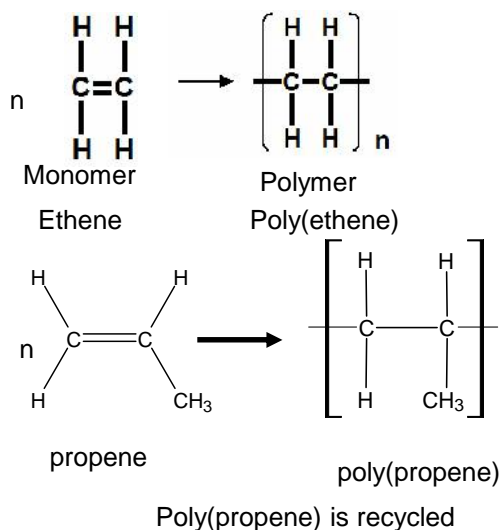
Catalyst of **concentrated H₃PO₄**

The high pressures needed mean this cannot be done in the laboratory. It is preferred industrially, however, as there are no waste products and so has a high atom economy. It would also mean separation of products is easier (and cheaper) to carry out. See equilibrium chapter for more on the industrial conditions for this reaction.

Addition Polymers

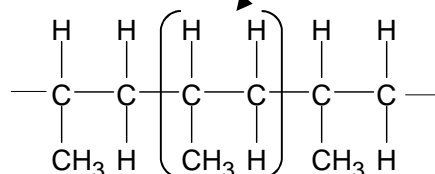
Addition polymers are formed from alkenes

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)

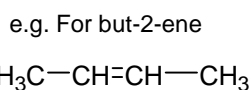


← Add the **n**'s if writing an equation showing the reaction where 'n' monomers become 'n' repeating units

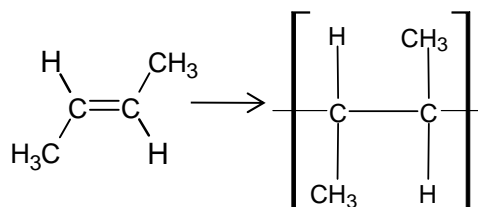
Poly(ethene): is used to make plastics bags, buckets, bottles. It is a flexible, easily moulded, waterproof, chemical proof, and low density plastic.

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



Methods of disposal of waste Polymers

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.

feedstock for cracking

Polymers can be cracked into small molecules which can be used to make other chemicals and new polymers- Saves raw materials-

Chemists have designed ways to remove toxic waste products like HCl before they are emitted into the atmosphere. The waste gases from the incinerator are scrubbed/reacted with a base or carbonate. The base reacts with the acidic HCl gas, neutralising it (eg $\text{CaO} + 2\text{HCl} \rightarrow \text{CaCl}_2 + \text{H}_2\text{O}$)

Chemists have also develop biodegradable and compostable polymers. Biodegradable polymers can be made from substances such as maize and starch