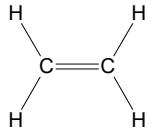
# 3.4 Alkenes

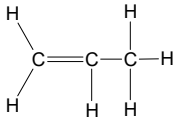
Alkenes are unsaturated hydrocarbons

General formula is **$C_nH_{2n}$**

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



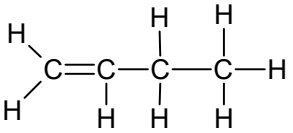
**Ethene**



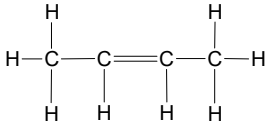
**Propene**

The arrangement of bonds around the >C=C< is planar and has the bond angle 120°

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

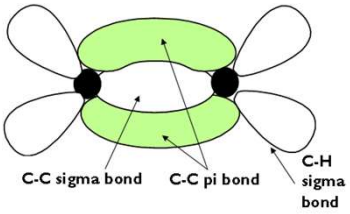


**But-1-ene**



**But-2-ene**

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




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

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

## Stereoisomerism

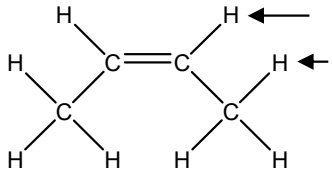
Stereoisomers have the same structural formulae but have a different spatial arrangement of atoms.

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

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

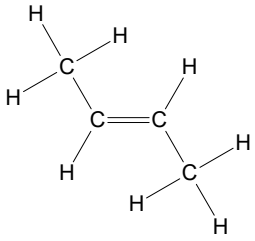
Single carbon-carbon covalent bonds can easily rotate

E-Z stereoisomers arise when:
(a) There is **restricted rotation** around the C=C double bond.
(b) There are **two different groups/atoms** attached both ends of the double bond.



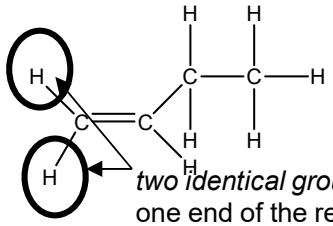
*two different groups* attached both ends of the restricted double bond- leads to EZ isomers

***Z*- but-2-ene**



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

***E* -but-2-ene**



**but-1-ene**

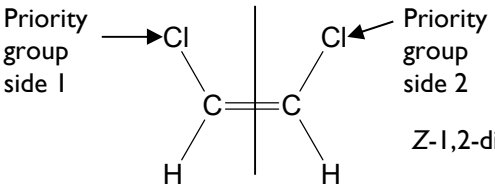
*two identical groups* attached to one end of the restricted double bond – no E-Z isomers

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

### Naming E-Z stereoisomers

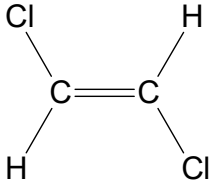
First determine the priority groups on both sides of the double bond

**Priority group**: The atom with the bigger atomic number is classed as the priority atom




*Z*-1,2-dichloroethene

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!)

## Electrophilic addition reactions of alkenes

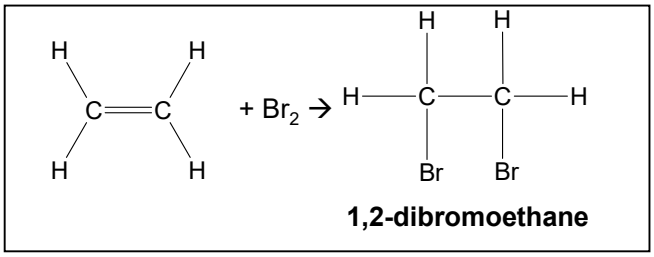
The double bonds in alkenes are areas with high electron density. This attracts electrophiles and the alkenes undergo addition reactions.

**Definition** Electrophile: an **electron pair acceptor**

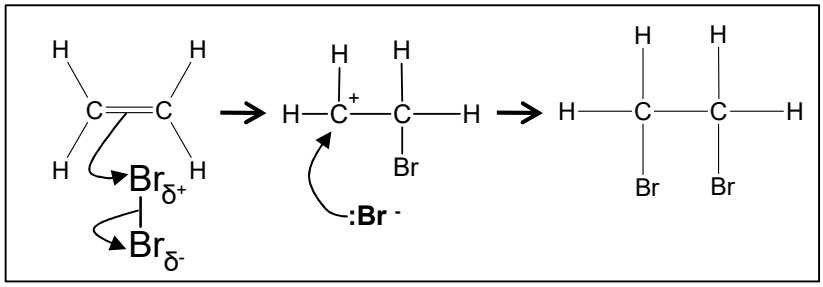
Addition reaction: a reaction where two molecules react together to produce one.

### 1. Reaction of bromine with alkenes

**Change in functional group: alkene → dihalogenoalkane**
**Reagent**: Bromine
**Conditions**: Room temperature (not in UV light)
**Mechanism**: Electrophilic addition
**Type of reagent**: Electrophile, $Br^{\delta+}$



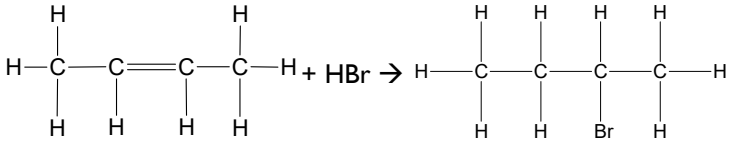

As the $Br_2$ molecule approaches the alkene, the pi bond electrons repel the electron pair in the Br-Br bond. This **induces** a **dipole**. $Br_2$ becomes **polar** and **electrophilic** (**$Br^{\delta+}$**).



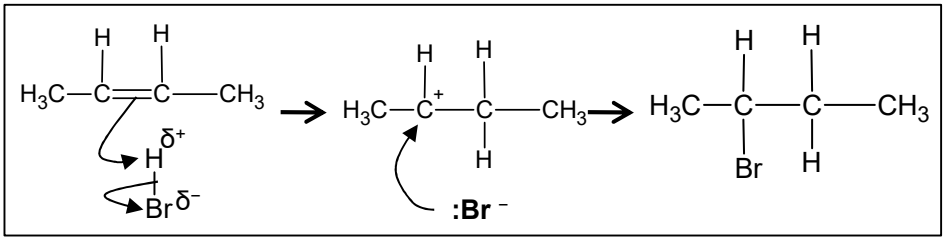

The **intermediate** formed, which has a positive charge on a carbon atom is called a **carbocation.**

### 2. 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, $H^{\delta+}$



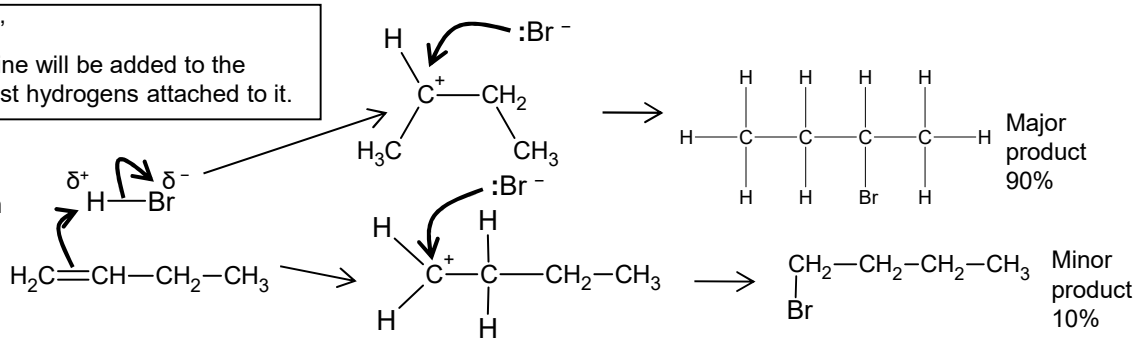

HBr is a polar molecule because Br is more electronegative than H. The H $^{\delta+}$ is attracted to the electron-rich pi bond.



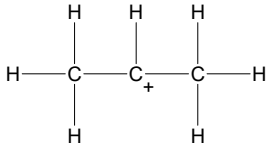

This reaction can lead to two products when the alkene is **unsymmetrical**

'Markownikoff's Rule'
In most cases, bromine will be added to the carbon with the fewest hydrogens attached to it.

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




**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.



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

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

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)

### 3. Reaction of sulfuric acid with alkenes

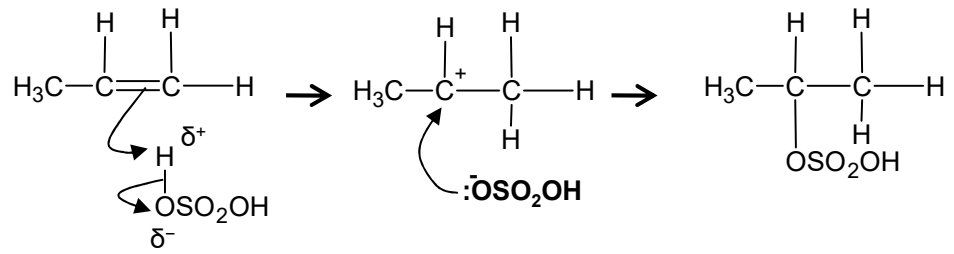
***Stage 1***
**Change in functional group**
**alkene → alkyl hydrogensulfate**
**Reagents**: concentrated $H_2SO_4$
**Conditions:** room temperature
**Mechanism**: Electrophilic addition
**Type of reagent**: Electrophile, $H_2SO_4$

$CH_2=CH_2 + H_2SO_4 \rightarrow CH_3CH_2OSO_2OH$

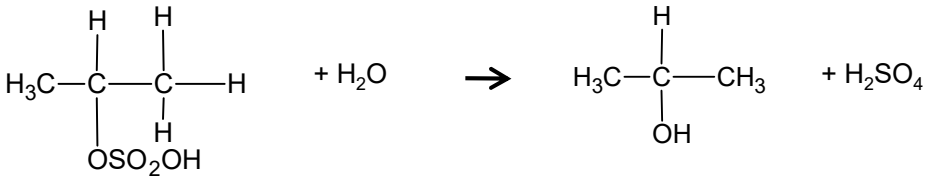
***Stage 2***
**Change in functional group**
**alkyl hydrogensulfate → alcohol**
**Reagents**: water
**Conditions:** warm mixture
**Type of reaction**: hydrolysis

$CH_3CH_2OSO_2OH + H_2O \rightarrow CH_3CH_2OH + H_2SO_4$

***Stage 1: electrophilic addition***



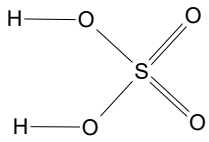

***Stage 2: hydrolysis***




$H_2SO_4$ is best drawn in exams as

**H-$OSO_2OH$**

Its displayed structure is




Overall role of sulfuric acid is that of a **catalyst** (as it is regenerated)

With unsymmetrical alkenes a minor and major product can also be formed similar to the addition of HBr. The same explanation applies.

**Definition: Hydrolysis** – a reaction where the molecule is **split** by the addition of water.

### Direct industrial hydration of alkenes to form alcohols

Industrially alkenes are converted to alcohols in one step rather than the two in the above sulfuric 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

$CH_2=CH_{2\ (g)} + H_2O_{\ (g)} \rightarrow CH_3CH_2OH_{\ (l)}$

**Essential conditions**

High temperature 300 to 600°C

High pressure 70 atm

Catalyst: **concentrated $H_3PO_4$**

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.

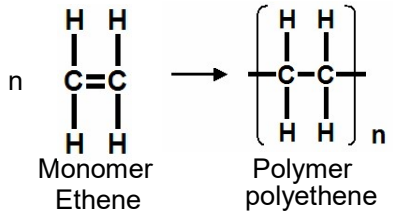
### Testing for alkenes with bromine water

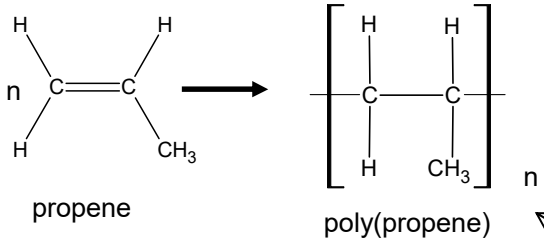
Bromine water decolourises in the presence of a double bond. This can be used as a test for the presence of a double bond in a molecule. It can be used quantitatively to show the presence of multiple double bonds in compounds like polyunsaturated oils.

## Addition Polymers

Addition polymers are formed from alkenes

This is called **addition polymerisation**

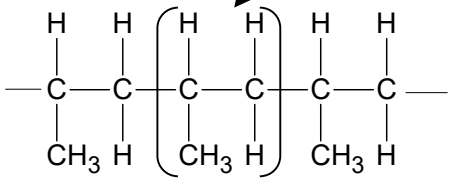



Poly(propene) is recycled

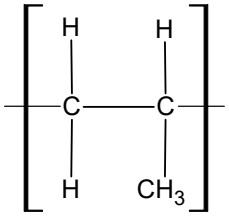
Poly(alkenes) like alkanes are unreactive due to the strong C-C and C-H bonds

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

If asked to draw **one repeating unit,** don't add the **n** on to your diagram, because n represents a large number

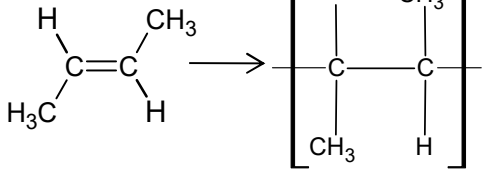


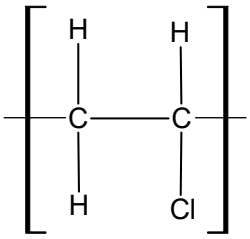
You should be able to draw the polymer repeating unit for any alkene

e.g. For but-2-ene

$H_3C—CH=CH—CH_3$

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





Poly(chloroethene) is a polymer that is water proof, an electrical insulator and doesn't react with acids.
In its pure form it is a rigid plastic due to the strong intermolecular bonding between polymer chains prevents them moving over each other. In this un-plasticised form it is used make uPVC window frame coverings and guttering.
If a plasticiser is added the intermolecular forces are weakened which allows the chains to move more easily, resulting in more flexibility in the polymer. In this form PVC is used to make insulation on electrical wires, and waterproof clothing.