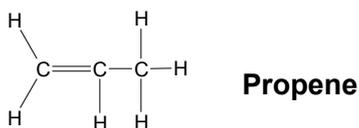
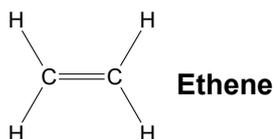


# 9. Alkenes

Alkenes are unsaturated hydrocarbons

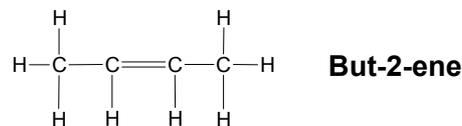
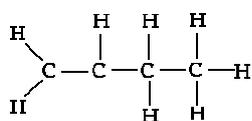
general formula is  $C_nH_{2n}$

contain a carbon-carbon double bond somewhere in their structure

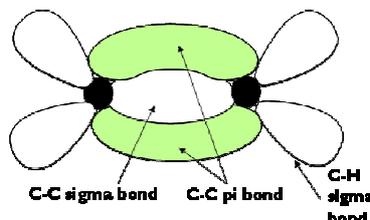


The arrangement of bonds around the  $>C=C<$  is planar and has the bond angle  $120^\circ$

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



$C=C$  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**.

## Stereoisomerism

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

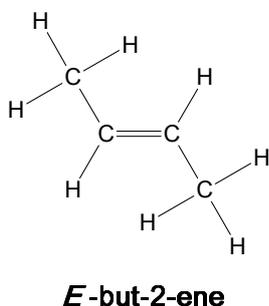
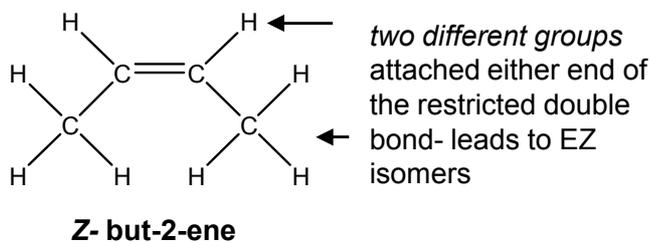
alkenes can exhibit a type of isomerism called **E-Z stereoisomerism**

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

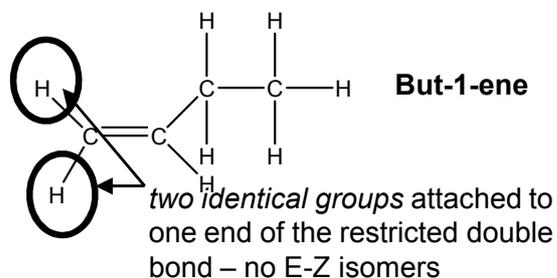
Single carbon-carbon covalent bonds can easily rotate

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 restricted double bond



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

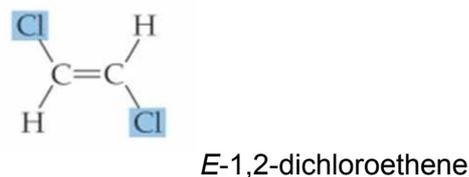
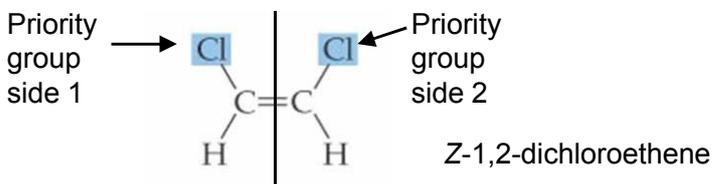


But-1-ene is a structural isomer of But-2-ene but does not show E-Z isomerism

## Naming E-Z stereoisomers

On both sides of the double bond determine the priority group

**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!)

# 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

Electrophiles: electron pair acceptor

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

## 1. Reaction of bromine with alkenes

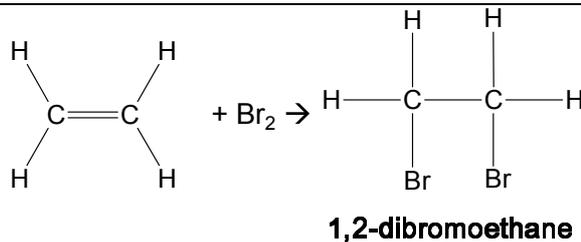
**Change in functional group:** alkene  $\rightarrow$  dihaloalkane

**Reagent:** Bromine

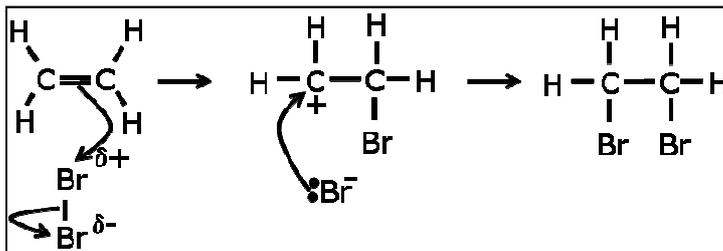
**Conditions:** Room temperature (not in UV light)

**Mechanism:** Electrophilic Addition

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



As the  $\text{Br}_2$  molecule approaches the alkene, the pi bond electrons repel the electron pair in the Br-Br bond. This **INDUCES a DIPOLE**.  $\text{Br}_2$  becomes **polar** and **ELECTROPHILIC** ( $\text{Br}^{\delta+}$ ).



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

## 2. Reaction of hydrogen bromide with alkenes

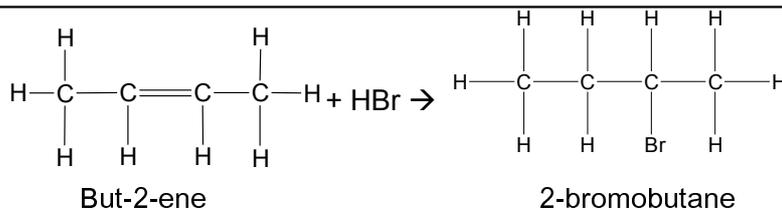
**Change in functional group:** alkene  $\rightarrow$  haloalkane

**Reagent:** HCl or HBr

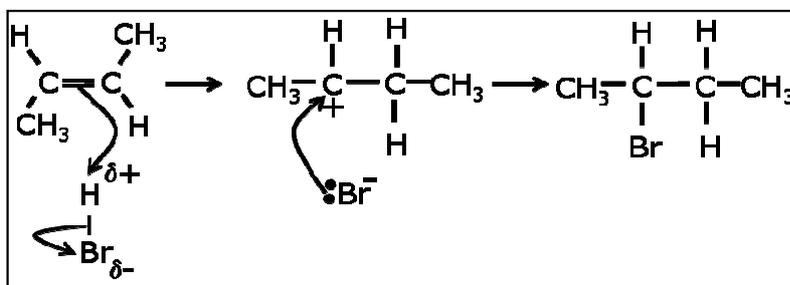
**Conditions:** Room temperature

**Mechanism:** Electrophilic Addition

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

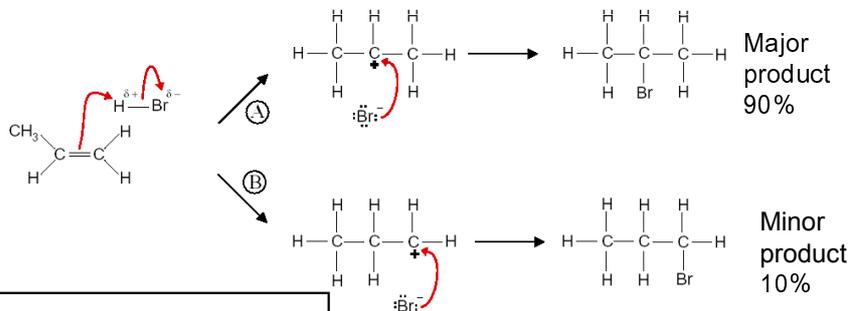


HBr is a polar molecule because Br is more electronegative than H. The  $\text{H}^{\delta+}$  is attracted to the electron-rich pi bond.



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

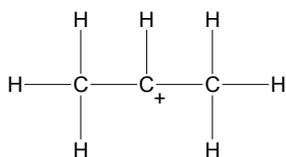
If the alkene is unsymmetrical, addition of hydrogen bromide can lead to two isomeric products.



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

### 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.

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)

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

### 3. Reaction of sulphuric acid with alkenes

#### Stage 1

##### Change in functional group

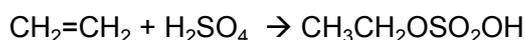
alkene → alkyl hydrogensulphate

Reagents: concentrated H<sub>2</sub>SO<sub>4</sub>

Conditions: room temperature

Mechanism: Electrophilic Addition

Type of reagent: Electrophile, H<sub>2</sub>SO<sub>4</sub>



#### Stage 2

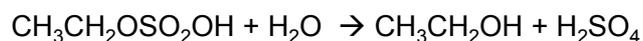
##### Change in functional group

alkyl hydrogensulphate → alcohol

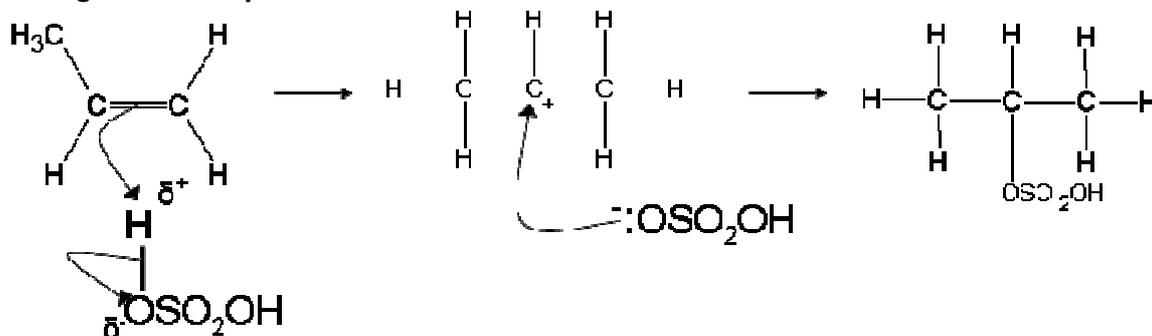
Reagents: water

Conditions: warm mixture

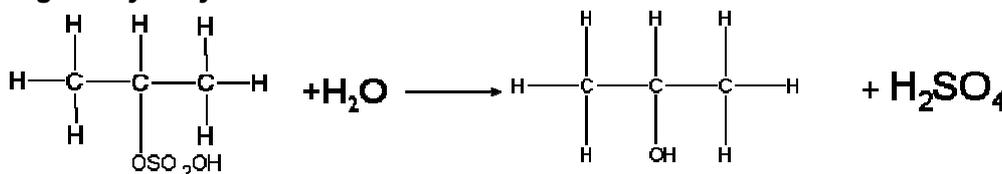
Type of reaction: hydrolysis



#### Stage 1: electrophilic addition



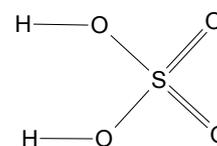
#### Stage 2: hydrolysis



H<sub>2</sub>SO<sub>4</sub> is best drawn as



In exams. Its real structure is



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

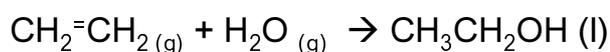
With unsymmetrical alkenes a minor and major product can also be formed similar to the addition of HBr. The same explanation applies

### Direct Industrial 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**

For ethene



#### Essential Conditions

high temperature 300 °C

high pressure 70 atm

strong acidic catalyst of H<sub>3</sub>PO<sub>4</sub>

The high pressures needed mean this cannot be done in the laboratory. It is preferred industrially 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.

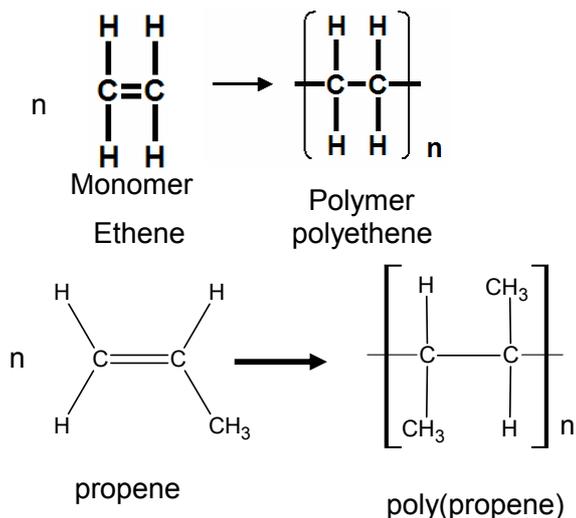
### Testing for Alkenes with Bromine water

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

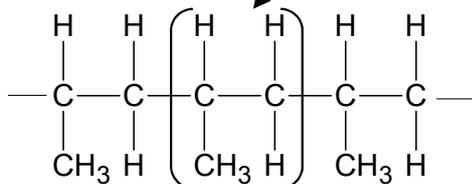
Addition polymers are formed from alkenes

This is called **addition polymerisation**



Poly(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)



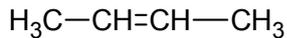
Polypropene is recycled

Polyethene is used to make plastics bags, buckets, bottles. It is a flexible, easily moulded, waterproof, chemical proof, and low density plastic.

Polypropene 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

e.g. For but-2-ene



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

