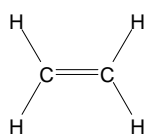


## 4.1.3 Alkenes

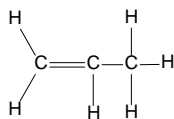
Alkenes are unsaturated hydrocarbons

General formula is  $C_nH_{2n}$

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

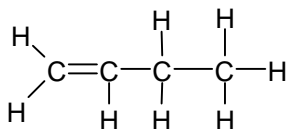


**Ethene**

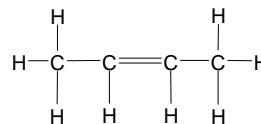


**Propene**

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

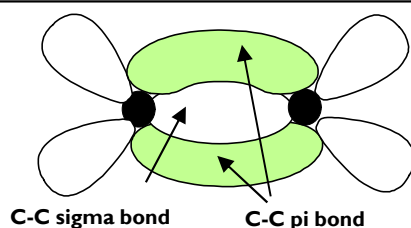


**But-1-ene**



**But-2-ene**

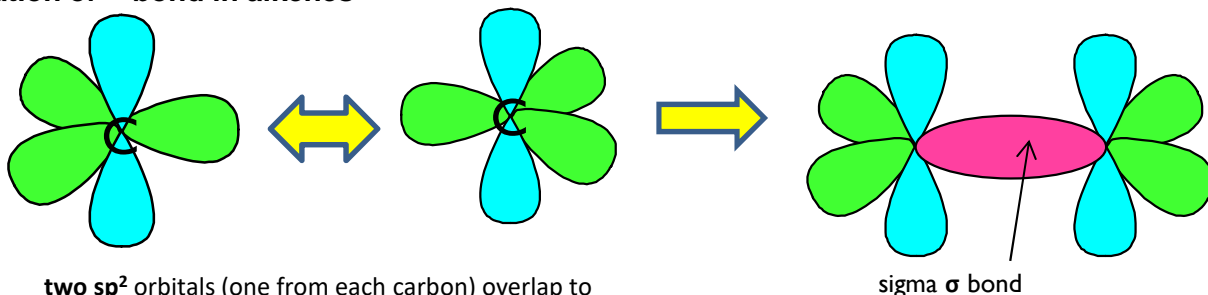
$C=C$  double covalent bond consists of **one sigma ( $\sigma$ ) bond and one pi ( $\pi$ ) bond.**



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

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

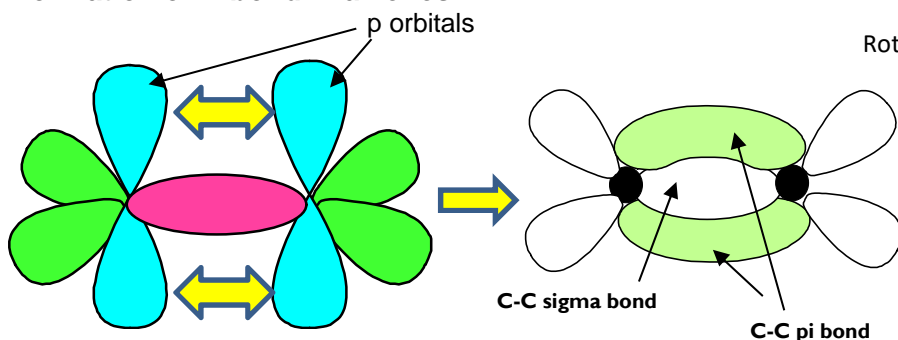
### Formation of $\sigma$ bond in alkenes



two  $sp^2$  orbitals (one from each carbon) overlap to form a single C-C bond called a sigma  $\sigma$  bond

sigma  $\sigma$  bond

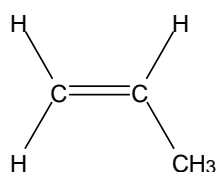
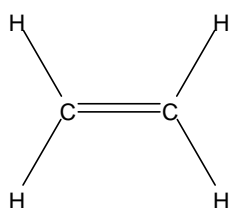
### Formation of $\pi$ bond in alkenes



Rotation can occur around a sigma 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.



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

## Stereoisomerism

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

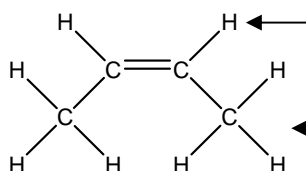
Alkenes can exhibit a type of isomerism called **E-Z stereoisomerism**

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

Single carbon-carbon covalent bonds can easily rotate

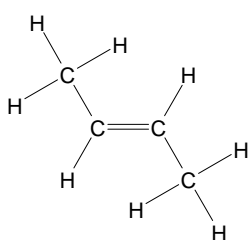
E-Z stereoisomers arise when:

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



**Z-but-2-ene**

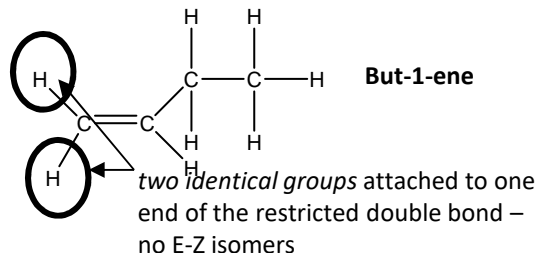
two different groups attached either end of the restricted double bond leads to E-Z isomers



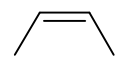
**E-but-2-ene**

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

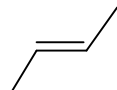
But-1-ene is a structural isomer of But-2-ene but does not show E-Z isomerism.



Skeletal formulae can also represent E-Z isomerism



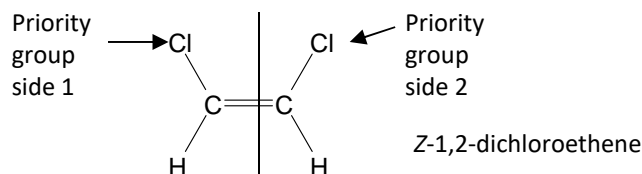
Z-but-2-ene



E-but-2-ene

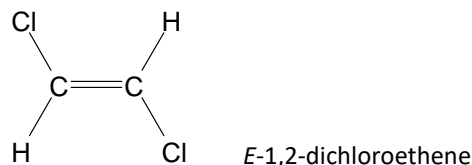
### Naming E-Z stereoisomers

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 Side!)

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

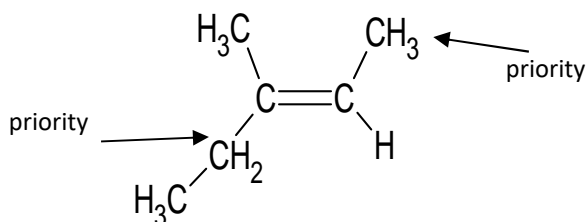
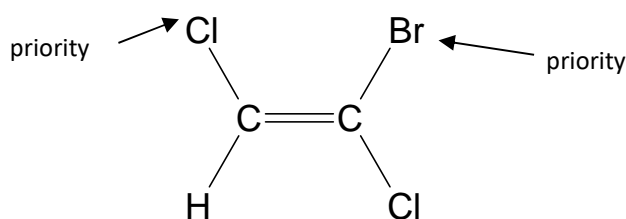


If the priority atom is on the opposite side of the double bond it is labelled E from the german entgegen (The Epposite side!)

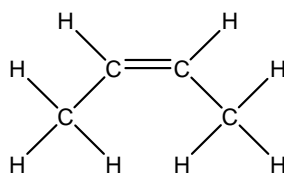
### Cahn-Ingold-Prelog (CIP) priority rules.

1. Compare the atomic number of the atoms directly attached to each side of the double bond; the atom of higher atomic number is given priority.

2. If the atoms are the same, consider the atoms at distance 2 from the double bond. Make a list of each atom bonded to the one directly attached to the double bond. Arrange list in order of decreasing atomic number. Compare the lists atom by atom; at the earliest difference, the group containing the atom of higher atomic number is given priority



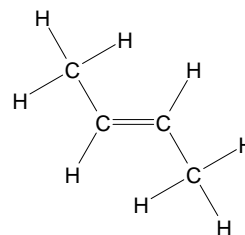
*cis-trans isomerism* is a special case of *EIZ* isomerism in which two of the substituent groups are the same.



**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

The alkenes are relatively reactive because of the relatively low bond enthalpy of the  $\pi$ -bond.

### 1. Reaction of Alkenes with Hydrogen

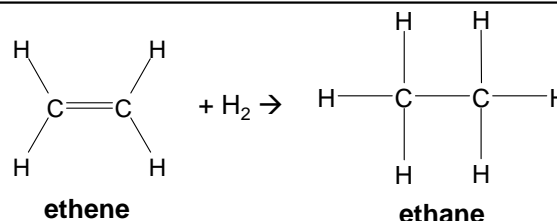
Addition reaction: a reaction where two molecules react together to produce one

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

**Reagent:** hydrogen

**Conditions:** Nickel Catalyst

**Type of reaction:** Addition/Reduction



### 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**

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

**Change in functional group:**

alkene  $\rightarrow$  dihalogenoalkane

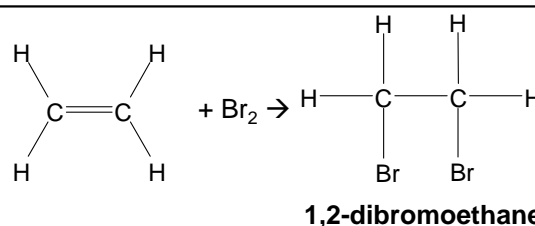
**Reagent:** Bromine

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

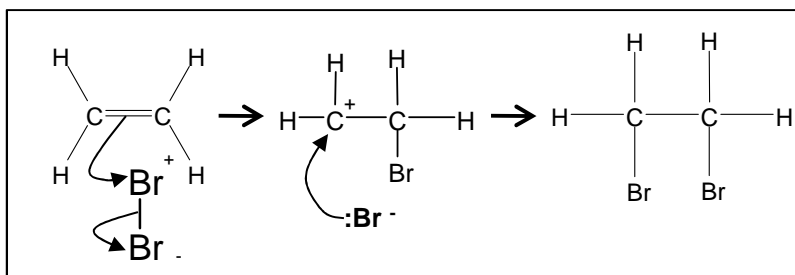
**Mechanism:** Electrophilic Addition

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

**Type of Bond Fission:** Heterolytic



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** ( $\text{Br}^+$ ).



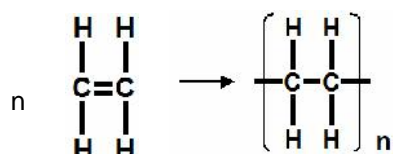
The **INTERMEDIATE** formed, which has a positive charge on a carbon atom is called a **CARBICATION**



## Addition Polymers

Addition polymers are formed from alkenes

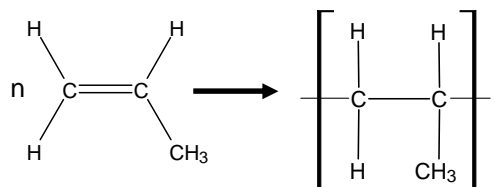
This is called **addition polymerisation**



Monomer

Ethene

Polymer  
polyethene



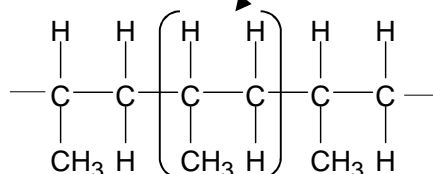
propene

poly(propene)

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)

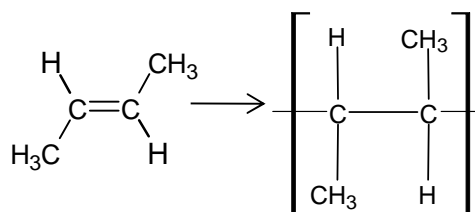


Add the **n's** if writing an equation showing the reaction where 'n' monomers become 'n' repeating units

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

e.g. For but-2-ene  
 $\text{H}_3\text{C}-\text{CH}=\text{CH}-\text{CH}_3$

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



### Industrial importance of alkenes

The formation of polymers from ethene based monomers is a major use of alkenes.

The manufacture of margarine by catalytic hydrogenation of unsaturated vegetable oils using hydrogen and a nickel catalyst is another important industrial process.

Liquid vegetable oils are generally polyunsaturated alkenes. Hydrogenation by the reaction of hydrogen using a nickel catalyst converts the double bonds to saturated single bonds. This increases the melting point of the oil making it harder and more solid.

### Dealing with waste polymers

Waste polymers can be processed in several ways.

#### Separation and recycling

The waste is sorted into each different type of polymer (ie PTFE, PVC, PET) and then each type can be recycled by melting and remoulding.

#### Feedstock for Cracking

Waste polymers can be used as a feedstock for the cracking process allowing for the new production of plastics and other chemicals.

#### Combustion for energy production

Waste polymers can be incinerated and the heat released can be used to generate electricity.

Combustion of halogenated plastics (ie PVC) can lead to the formation of toxic, acidic waste products such as HCl. Chemists can minimise the environmental damage of this by removing the HCl fumes formed from the combustion process.

Chemists have also been developing a range of biodegradable polymers, compostable polymers, soluble polymers and photodegradable polymers.

Polymers formed from isoprene (2-methyl-1,3-butadiene), maize and starch are biodegradable