

Edexcel IAL Chemistry A-level

Topic 5: Alkenes

Detailed notes



Introduction to Alkenes

Alkenes are **unsaturated hydrocarbons** with at least one carbon-carbon **double bond**. They are part of a homologous series with the general formula C_nH_{2n} . Cycloalkenes are a type of alkene hydrocarbon, where the carbon atoms are arranged in a closed ring.

Structure and Reactivity

The carbon double bond is an area of **high electron density** making it susceptible to attack from electrophiles (species that are attracted to δ -areas). It consists of a normal covalent **σ bond** and a **π bond**.

Example:

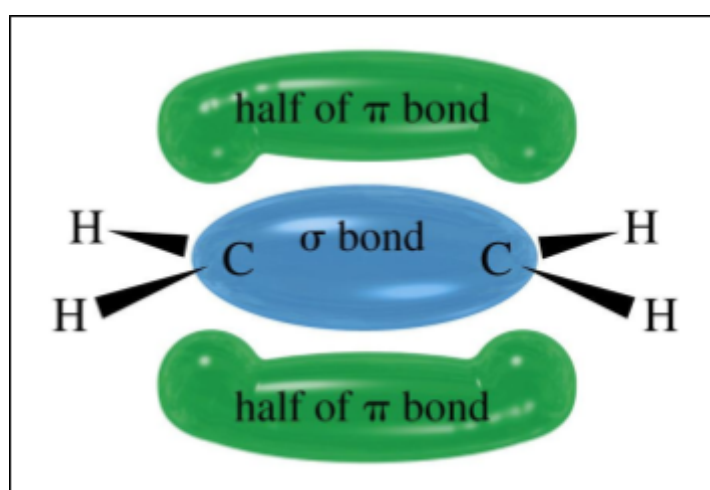


Image courtesy of wps.prenhall.com

Test for Alkenes

Bromine water is used to identify an alkene double bond and other unsaturated compounds. Alkenes cause bromine water to change colour from **orange-brown to colourless**. This is because the $C=C$ bond can 'open up' to accept bromine atoms, and thus become saturated.

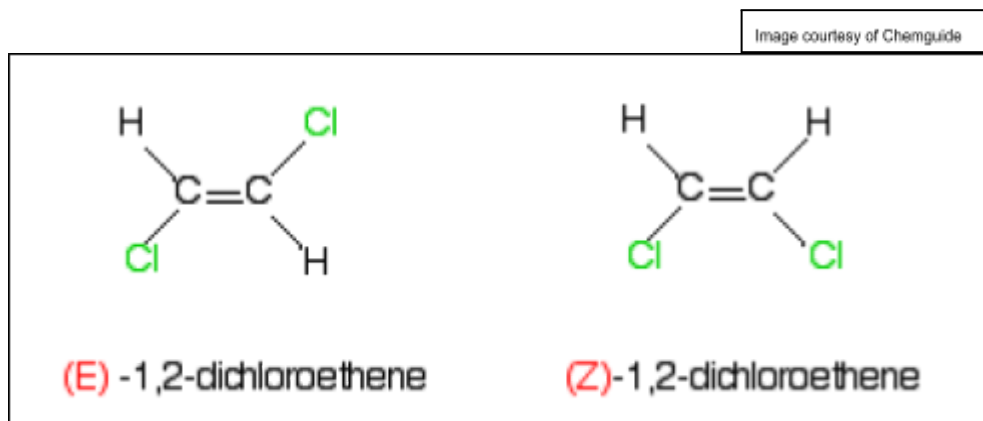


Geometric isomerism

Stereoisomers

These have a **different spatial arrangement**. A type of stereoisomerism is **E-Z isomerism**, where **limited rotation** around a double carbon bond means that functional groups can either be 'together' or 'apart'. The **E** isomer (german for entgegen meaning apart) has functional groups **on opposite sides**. The **Z** isomer (german for zusammen meaning together) has functional groups **together** on the same side of the double bond.

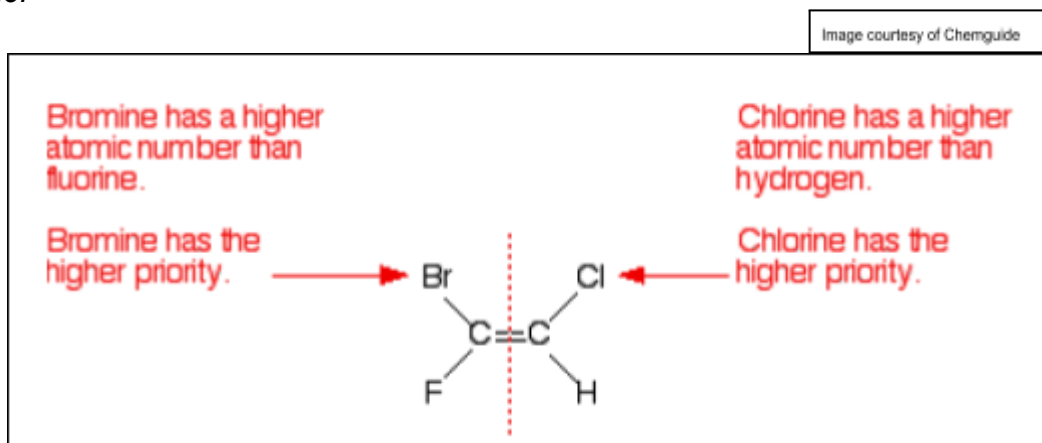
Example:



Cahn-Ingold-Prelog (CIP) Priority Rules

There is a **priority of different groups** in molecules that can display E-Z isomerism. The first atom which is directly bonded to the carbon with the double bond with the **higher atomic number** is given the **higher priority**. These groups are used to determine if it is the E or Z isomer.

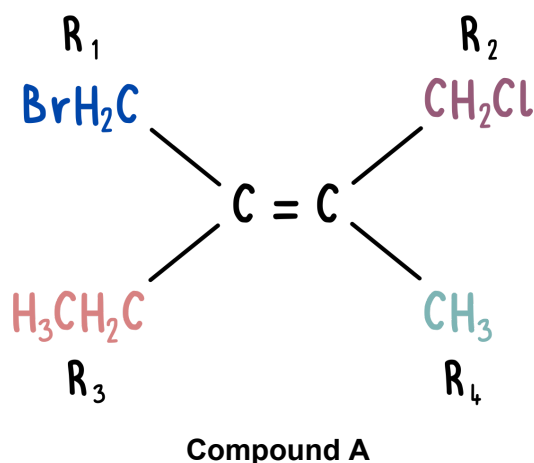
Example:



Therefore this molecule is the Z isomer as the highest priority atoms are on the same side.



How to determine a more complicated E/Z isomers



- **Step 1: Apply the CIP priority rules**

- Look at R1 and R3:
 - Carbon is the **first atom** attached to the C=C bond, on the left hand side
- Look at R2 and R4:
 - Carbon is the first atom attached to the C=C bond, on the right hand side
- This means that we cannot deduce if compound A is an *E* or *Z* isomer by applying the CIP priority rules to the first atom attached to the C=C bond
 - Therefore, we now have to look at the **second atoms** attached

- **Step 2: Apply the CIP priority rules (using the second atoms)**

- Look again at R1 and R3:
 - The second atoms attached to R1 are **hydrogens** and **bromine**
 - The second atoms attached to R3 are **hydrogens** and another **carbon**
 - We can ignore the hydrogens as both R groups have hydrogens
 - Bromine has a **higher atomic number** than carbon, so bromine is the **higher priority**
 - Therefore, the CH₂Br group has priority over the CH₃CH₂ group
- Look again at R2 and R4:
 - The second atoms attached to R2 are **hydrogens** and **chlorine**
 - The second atoms attached to R4 are **hydrogens**
 - Chlorine has a **higher atomic number** than hydrogen, so chlorine is the **higher priority**
 - Therefore, the CH₂Cl group has priority over the CH₃ group

- **Step 3: Deduce *E* or *Z***

- In compound A, the two highest priority groups are on the **same side** (both above) the C=C bond
 - Therefore, compound A is the ***Z* isomer**



Cis- and Trans- isomers

Stereoisomers can be named in the same process as above, but instead using **Cis-** for when the groups are on the **same side** and **trans-** for when they are **different sides**. Cis- and trans- differs from E/Z isomerism in that cis- and trans- can only be used when there are **hydrogen atoms** to compare the two other groups to. When there are more groups present, you have to assign E/Z isomerism by using the **Cahn-Ingold-Prelog (CIP) priority rules** described above.

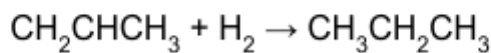
Reactions of alkenes

The **carbon-carbon double bond** in alkenes makes them reactive. During their reactions, the double bond opens up to form single bonds to other atoms.

Alkanes

Alkenes can undergo **electrophilic addition** with **hydrogen** to produce **alkanes**. The C=C bond opens up and forms single bonds to each of the hydrogen atoms. This reaction requires a **nickel catalyst**.

Example:



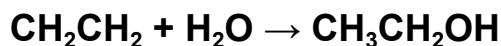
Halogenoalkanes

Halogenoalkanes are organic compounds with single carbon bonds only and halogen functional groups. Alkenes undergo **addition** reactions with **halogens** to form **di-substituted halogenoalkanes**, and with **hydrogen halides** to form **mono-substituted halogenoalkanes**. The mechanism for this reaction is given on the following page of these notes.

Alcohols

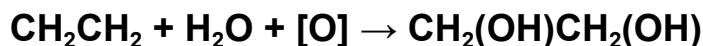
Alcohols are organic compounds with a **hydroxyl** functional group. Alkenes undergo **addition** reactions with **steam** to form alcohols. This reaction requires an **acid catalyst**, such as phosphoric acid.

Example:



Diols, alcohols with two hydroxyl functional groups, can also be formed from alkenes through an **oxidation** reaction. The double bond is oxidised by **acidified potassium manganate(VII) (KMnO₄)**. The manganate ions must be cold, dilute and acidified.

Example:



Electrophilic Addition

Alkenes undergo **electrophilic addition** about the double bond.

Electrophiles

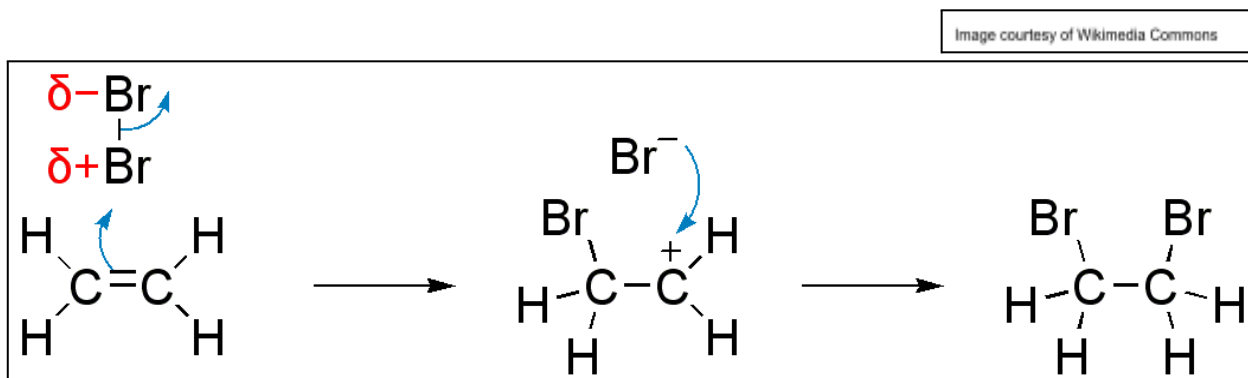
These are **electron acceptors** and are attracted to areas of high electron density. Some of the most common electrophiles are:

- HBr
- Br₂
- H₂SO₄

Electrophilic Addition

Electrophilic addition is the reaction mechanism that shows how electrophiles attack the double bond in alkenes. When the double bond is broken, a **carbocation** forms. This is a carbon atom with only **three bonds**, meaning it has a **positive** charge.

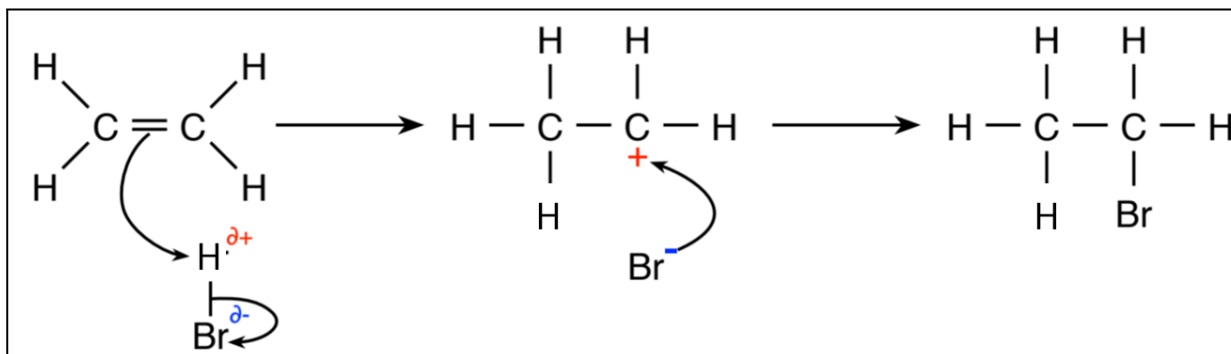
Mechanism: Alkene + Halogen → Dihalogenoalkane



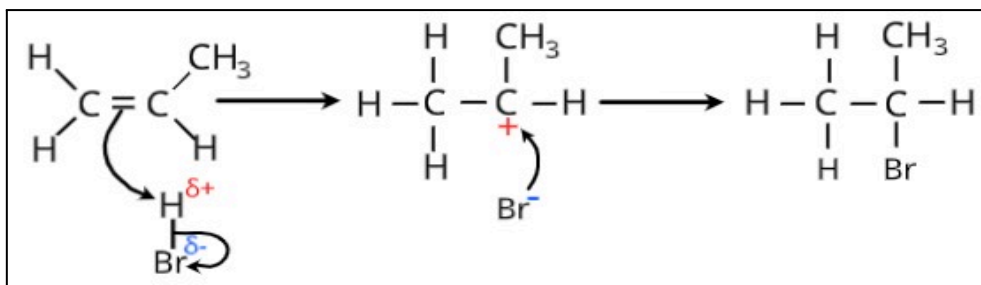
The π bond causes the bromine molecule to gain a temporary dipole so that electrons are transferred.

Mechanism: Alkene + Hydrogen Halide → Halogenoalkane

Example: Electrophilic addition of hydrogen bromide to ethene



Example: Electrophilic addition of hydrogen bromide to propene

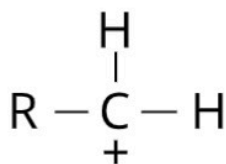


Hydrogen bromide is **polar** due to the difference in the electronegativities of hydrogen and bromine. The **electron pair** in the double bond attracts $\text{H}^{\delta+}$, forming a covalent bond between carbon and hydrogen. This produces a positively charged **carbocation intermediate** which attracts the negatively charged bromide ion. The hydrogen joins to the carbon atom which is bonded to the most hydrogen atoms. The bromide ion bonds to the carbon atom which is joined to the most carbon atoms. This is why **2-bromopropane** forms more often than 1-bromopropane in the mechanism of propene with hydrogen bromide. Further explanation of stability is given below.

Inductive effects of alkyl groups

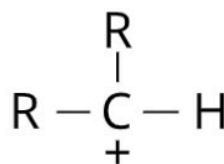
When a hydrogen halide bonds to an **unsymmetrical alkene**, there are two possible products. The quantities of each product produced depends on the **stability** of the **carbocation intermediate**. Carbocations with **more alkyl groups are more stable**. This is because alkyl groups have a **positive inductive effect** on the carbon atom and feed electrons towards the positive charge. The more stable carbocation is more likely to form so there will be higher quantities of this product. It is often referred to as the **major product**.

Primary carbocation

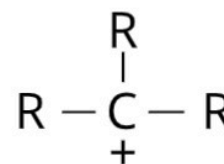


Least stable

Secondary carbocation



Tertiary carbocation



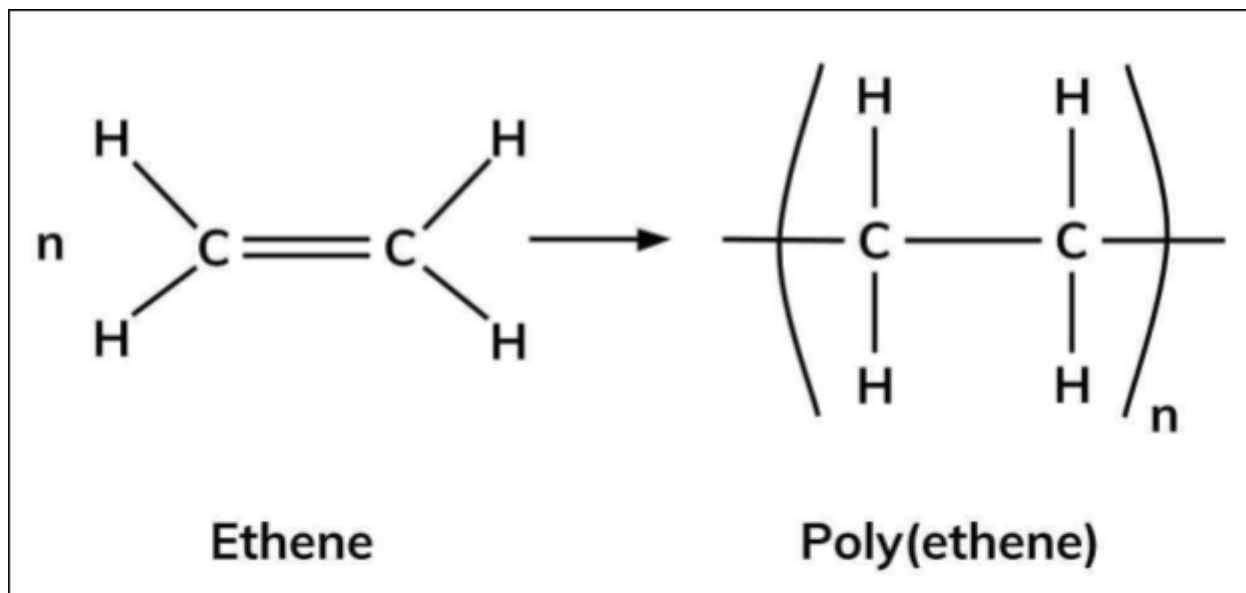
Most stable



Addition Polymers

Addition polymers are produced from **alkenes**, where the double bond is broken to form a **repeating unit**. Alkenes are short chain **monomers** which join together to form **long chain** polymers.

Example:



The repeating unit must always be shown with **extended bonds through the brackets**, showing that it bonds to other repeating units on both sides.

Uses of Polymers

Polymers are unreactive hydrocarbon chains with **multiple strong, non-polar covalent bonds**. This makes them useful for manufacturing many everyday plastic products such as **poly(ethene) shopping bags**.

However, the unreactive nature of the bonds in addition polymers means they are **not biodegradable** and cannot be broken down by species in nature.

Disposal of Polymers

Addition polymers are **non-biodegradable** which means disposal of them can be difficult. Waste polymers can be processed in different ways. Some can be **recycled**, some are used as **feedstock** for cracking and some are **incinerated** to produce energy for other industrial processes. Incineration can release **toxic gases** which must be removed to reduce the impact on the environment.

Scientists are developing **biodegradable polymers** to overcome the various disposal issues.

