Topic 6 – Alkenes
Revision Notes

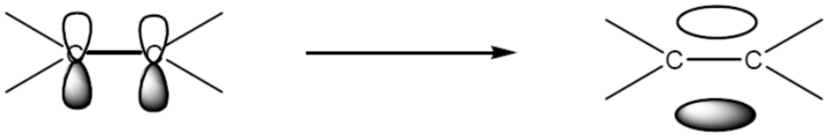
1) General

Alkenes are unsaturated hydrocarbons with general formula C_nH_{2n}

- Unsaturated = contain a double C=C bond
- Hydrocarbon = contains C and H <u>only</u>

2) Bonding in Alkenes

- The carbons at either end of the double bond and the 4 atoms they are bonded to are all in a plane (flat). These 6 atoms are joined by single bonds
- The double bond is formed by sideways overlap of p orbitals producing a π bond (sausage-shaped clouds of electrons above and below the plane of the single bond framework)

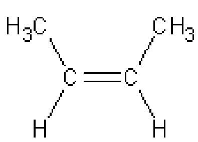


- The double bond is a **centre of high electron density**
- While single bonds allow free rotation, double bonds have **restricted rotation**

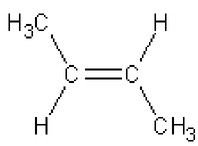
3) E/Z isomers

Isomers
- Structural Isomers
- Stereoisomers
  - E/Z isomers
  - Optical isomers (A2 only)

- Stereoisomers have the same structural formula but with a different arrangement in space
- E/Z isomerism is one type of stereoisomerism arising from restricted rotation about a double bond when two different groups are attached to each carbon of the C=C group
- E is short the German word *entgegen* which means opposite i.e. on opposite sides of the double bond. Z is short for the German word *zusammen* which means together i.e. on the same side of the double bond
- Using, but-2-ene as an example:



Z-but-2-ene
(CH_3's are on **ze** same side)



E-but-2-ene
(CH_3's on opposite sides of the double bond)

4) Addition Reactions of Alkenes

- In addition reactions, 2 molecules join to form 1 molecule.
- Alkenes undergo addition reactions because they have a double bond.

a) Addition of halogens produces a dihaloalkane

e.g. $CH_2{=}CH_2 + Br_2 \rightarrow CH_2BrCH_2Br$

1,2-dibromoethane

- The colour change in this reaction is from orange to colourless
- This is used as a test for unsaturation (to show the presence of a double bond)

b) Addition of hydrogen halides produces a haloalkane

e.g. $CH_2{=}CH_2 + HBr \rightarrow CH_3CH_2Br$

bromoethane

c) Addition of steam produces an alcohol

- e.g. $CH_2{=}CH_2 + H_2O \rightarrow CH_3CH_2OH$

  ethanol
- Needs a strong acid catalyst e.g. phosphoric acid, H_3PO_4, temperature of 300°C and pressure of 60 atm

d) Addition of H_2SO_4 produces an alkyl hydrogensulphate

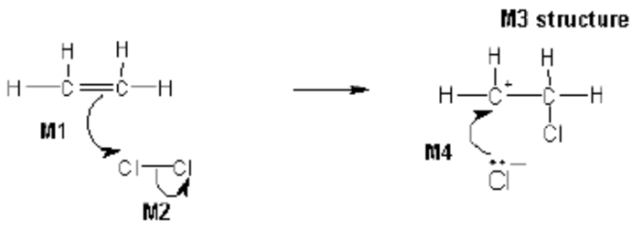
- e.g. $CH_2{=}CH_2 + H_2SO_4 \rightarrow CH_3CH_2OSO_3H$

  Ethyl hydrogensulphate

- Product can be hydrolysed to an alcohol by warming with dilute H_2SO_4

e) Mechanism for Electrophilic Addition

- The high electron density in the π bond makes alkenes attractive to electrophiles (electron pair acceptors, such as Br_2 and HBr)
- As the bromine molecule approaches the π bond, the electrons in the Br-Br bond are repelled. A dipole is induced in the bond with the Br nearer the alkene being δ+
- The intermediate is a carbocation (it has a carbon with a positive charge)



- In organic mechanisms, a curly arrow represents the movement of a pair of electrons
- Curly arrows should start from a bond or lone pair and finish at the atom where a bond or lone pair is being formed

e) Addition to unsymmetrical alkenes

- When adding HBr to an unsymmetrical alkene, like propene, there are 2 possible carbocations

$CH_3CH{=}CH_2$ + H^+ $\rightarrow$ **$CH_3C^+HCH_3$**
(a secondary carbocation, + is on middle C)

$CH_3CH{=}CH_2$ + H^+ $\rightarrow$ **$CH_3CH_2CH_2^+$**
(a primary carbocation, + is on end C)

- The secondary carbocation is more stable than the primary carbocation
- This means that 2-bromopropane is the major product in this reaction and 1-bromopropane is the minor product as it is formed via the less stable primary carbocation

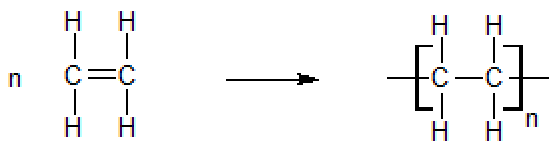
$CH_3CH{=}CH_2$ + HBr $\rightarrow$ $CH_3CHBrCH_3$
Major product formed via more stable 2° carbocation

$CH_3CH{=}CH_2$ + HBr $\rightarrow$ $CH_3CH_2CH_2Br$
Minor product formed via less stable 1° carbocation

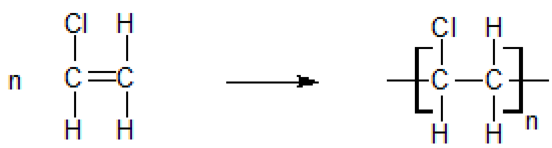
- A tertiary carbocation, like $(CH_3)_3C^+$ is more stable than both a secondary and a primary carbocation

5) <u>Polymerisation of Alkenes</u>

- Alkenes can join together to form addition polymers
- Monomer = small molecule that can be polymerised
- Polymer = long chain molecule formed by joining <u>many</u> monomers together (many means several thousand)
- The π bond breaks and forms single bonds that join the monomers together
- Poly(alkenes) are unreactive because their backbone consists of strong C-C bonds. This means that they are not biodegradable (they don't rot down)
- Poly(ethene) is used to make plastic bags, insulation for wires and material for squeezy bottles
- Poly(propene) is used to make clothing, carpets and ropes. Poly(propene) is recycled
- The repeating unit in a poly(alkene) is the bracketed section in the following equations



Ethene poly(ethene)



Chloroethene poly(chloroethene)