Topic 9 – Alkenes
Revision Notes

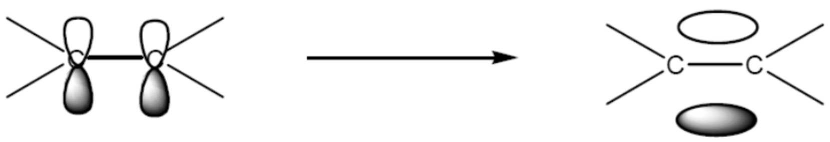
1) General

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

- Unsaturated = contain a double C=C bond
- Hydrocarbon = contains C and H only

2) Bonding in Alkenes

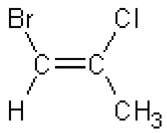
- The carbons at either end of the double bond and the 4 atoms they are bonded to are all in a plane (flat). These 6 atoms are joined by single bonds
- The bonds around each C in the C=C bond are trigonal planar in shape. There are 3 areas of electrons round each C (1 double bond and 2 single bonds) which repel equally to give a bond angle of 120°
- 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)



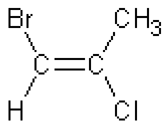
3) E/Z isomers

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
- 1-bromo-2-chloropropene displays E/Z isomerism. This is because one C of the C=C bond is attached to an H and a Br, which are different, and the other C of the C=C is attached to a Cl and a CH_3 which are also different

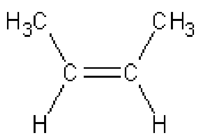


Z-1-bromo-2-chloropropene

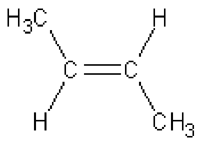


E-1-bromo-2-chloropropene

- For an example like this you only need to say that it will have E and Z isomers, not which one is which
- But-2-ene is a simpler example where it is more straightforward to say which is E and which is Z

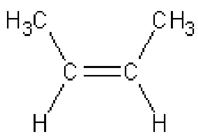


Z-but-2-ene
(CH_3's are together)

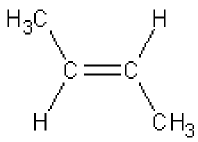


E-but-2-ene
(CH_3's on opposite sides of the double bond)

- Cis/trans isomerism is a special case of E/Z isomerism in which two of the substituent groups are the same. Cis corresponds to Z and trans corresponds to E
- Sticking with but-2-ene as the example



Cis-but-2-ene



trans-but-2-ene

4) <u>Addition Reactions of Alkenes</u>

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

a) Addition of hydrogen produces an alkane

e.g. $\mathbf{CH_2{=}CH_2 + H_2 \rightarrow CH_3CH_3}$
ethane

- Needs a Ni catalyst
- One mole of hydrogen needed per double bond
- This reaction is used to produce margarine from unsaturated vegetable oils by catalytic hydrogenation

b) Addition of halogens produces a dihalogenoalkane

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

c) Addition of hydrogen halides produces a halogenoalkane

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

- If this reaction is done with an unsymmetrical alkene, two isomeric products may be formed e.g.

$CH_3CH{=}CH_2 + HBr \rightarrow CH_3CHBrCH_3$
2-bromopropane

and $CH_3CH{=}CH_2 + HBr \rightarrow CH_3CH_2CH_2Br$
1-bromopropane

d) Addition of steam produces an alcohol

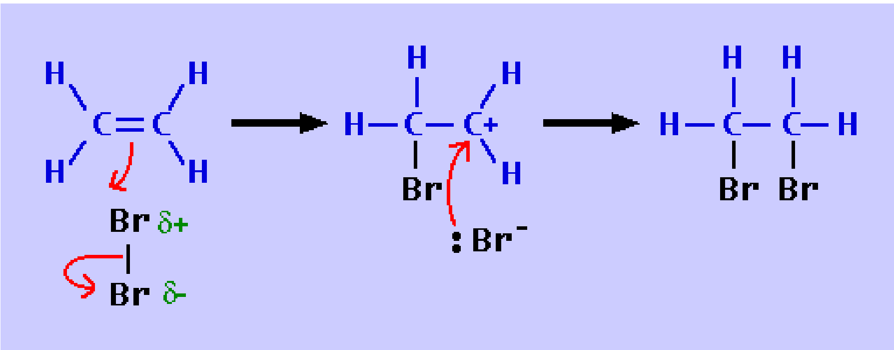
- e.g. $CH_2{=}CH_2 + H_2O \rightarrow CH_3CH_2OH$
  ethanol
- Needs a strong acid catalyst e.g. phosphoric acid, H_3PO_4
- Temperature must be above 100°C so that H_2O is in the form of steam

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 $\delta+$
- The Br-Br bond undergoes heterolytic fission to produce a cation (positive ion) and an anion (negative ion), Both electrons from the bond go to the negative ion

$$Br_2 \rightarrow Br^+ + :Br^-$$

- The Br^+ is the electrophile that accepts an electron pair from the π bond to produce an intermediate, $CH_2BrCH_2^+$
- The intermediate is a carbocation (it has a carbon with a positive charge)



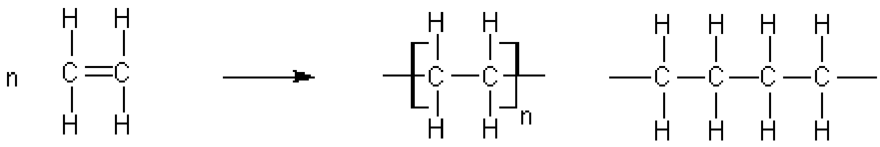
- In organic mechanisms, a curly arrow represents the movement of a pair of electrons
- Curly arrows should start from a bond or lone pair and finish at the atom where a bond or lone pair is being formed

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

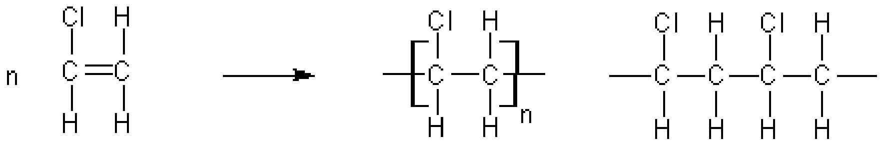
- Alkenes can join together to form addition polymers
- Monomer = small molecule that can be polymerised
- Polymer = long chain molecule formed by joining <u>many</u> monomers together (many means several thousand)
- The π bond breaks and forms single bonds that join the monomers together

a) Examples

Equation **2 repeat units of polymer**



Ethene poly(ethene)



Chloroethene poly(chloroethene)

b) Processing of waste polymers (e.g. plastic bottles)

- **Mechanical Recycling** Waste polymers can be melted down and re-used following separation into types (PTFE etc). However it is expensive to collect and sort waste polymers

- **Combustion for energy production** Waste polymers can be burnt as a fuel but this may produce toxic waste products (see below)

- **Feedstock recycling** Waste polymers can be cracked and the products used to make fuels and other polymers (after separation)

d) Minimising environmental damage in polymer disposal

Chemists and chemical processes can minimise the environmental damage caused by disposing of polymers

- **Combustion for energy production** Burning halogenated plastics, such as PVC, produces toxic products like HCl. However, the HCl can be removed by gas scrubbers which by dissolve it in a spray of alkali

- **Developing new polymers** Addition polymers are not biodegradable (they don't rot down). Chemists have developed biodegradable and compostable polymers that will rot down e.g. from isoprene (methyl-1,3-butadiene), maize and starch