FACTFILE:
GCE CHEMISTRY

2.4 ALKENES

Rewarding Learning

Alkenes

Students should be able to:

2.4.1 define the term unsaturated hydrocarbon and explain why alkenes are described as unsaturated hydrocarbons;

2.4.2 recall the qualitative test for alkenes using bromine water;

2.4.3 use sigma and pi bonds to explain the relative bond strength and relative bond length of the C=C bond;

2.4.4 recall that the C=C bond is a centre of high electron density and use this to explain the difference in reactivity of alkanes and alkenes;

2.4.5 describe the catalytic hydrogenation of alkenes using finely divided nickel;

2.4.6 describe the reaction of chlorine, bromine, hydrogen chloride and hydrogen bromide with alkenes;

2.4.7 define the terms electrophile and heterolytic fission;

2.4.8 recall the mechanism of electrophilic addition between chlorine, bromine, hydrogen chloride and hydrogen bromide with alkenes using curly arrows;

2.4.9 explain, with reference to the stability of the carbocation intermediates involved, the formation of major and minor products during the electrophilic addition of hydrogen bromide to unsymmetrical alkenes; and

2.4.10 describe the addition polymerisation of alkenes, for example ethene and propene.

Alkenes

Alkenes are *unsaturated* hydrocarbons. **Unsaturated means they contain at least one C=C or C≡C**.

They contain a carbon-carbon double bond as their particular functional group and are named according to IUPAC rules:

- select the longest chain of C atoms containing the double bond;
- place the ending -ene on the basic name
- number the chain starting from the end nearer the double bond
- use a number to indicate the lower number carbon of the C=C
- as in alkanes, prefix with substituents; side chain positions are based on the number allocated to the first C of the C=C

For example:

$CH_2{=}CH_2$ $CH_2{=}CHCH_3$
ethene Propene

$CH_3CH_2CH{=}CHCH_3$

pent-2-ene

$CH_3CH{=}CHCH_2CH(CH_3)CH_3$

5-methylhex-2-ene

The C=C bond is comprised of a sigma (σ) and pi (π) bond. A sigma bond is a covalent bond formed by the linear overlap of atomic orbitals. A pi bond is a covalent bond formed by the sideways overlap of p orbitals. The pi bond is slightly weaker than the sigma bond and is easier to break as a result. This makes alkenes more reactive than the corresponding alkanes and makes their chemistry more varied and interesting.

The C=C bond is an area of high electron density and species attracted to such areas are known as electrophiles. Examples of electrophiles include halogens and hydrogen halides. These react with alkenes by adding to the double bond resulting in new structures. For example, ethene reacts with bromine and hydrogen bromide to give bromoalkanes:

$C_2H_4(g) + HBr(g) \rightarrow C_2H_5Br(l)$

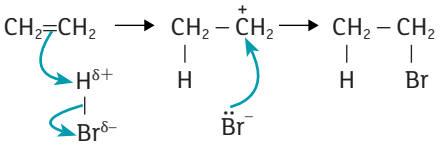
1-bromoethane

$C_2H_4(g) + Br_2(1) \rightarrow CH_2BrCH_2Br(l)$

1,2-dibromoethane

The use of bromine solution is a diagnostic test for the alkene functional group as the yellow/orange/brown bromine water decolourises in the presence of a C=C double bond.

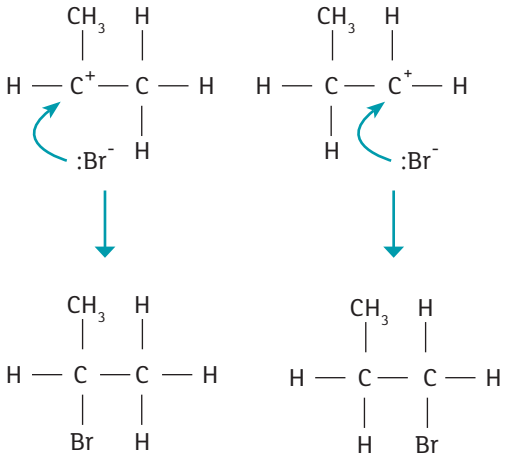
The **electrophilic addition** of HBr to an alkene such as ethene involves a two-step reaction mechanism. In the first step the HBr molecule (which is polar) acts as an electrophile and attacks the π bond in the ethene molecule. An electrophile is an ion or molecule that attacks regions of high electron density. In the second step the *carbocation intermediate* is attacked by the bromide ion to complete the addition.



With unsymmetrical alkenes, such as propene, a mixture of a major and a minor products is formed. This is due to the nature of the carbocation intermediate produced.

- A **primary carbocation** is a carbocation which has one carbon directly bonded to the positively charged carbon.
- A **secondary carbocation** is a carbocation which has two carbon atoms directly bonded to the positively charged carbon.
- A **tertiary carbocation** is a carbocation which has three carbon atoms directly bonded to the positively charged carbon.

The secondary carbocation is more stable than the primary carbocation as the methyl group can help stabilise the positive charge. In the case of the primary carbocation, the two hydrogen atoms offer no such stabilisation.



Major product:
2-bromopropane

Minor product:
1-bromopropane

Alkenes can be converted to alkanes in the presence of hydrogen gas and a finely divided nickel catalyst. This is an important reaction in the production of margarine and other soft spreads from vegetable oils.

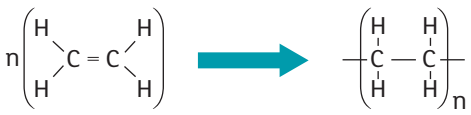
$$CH_2{=}CH_2 + H_2 \xrightarrow{Ni} CH_3{-}CH_3$$

Alkenes are also used to produce plastics by a process called addition polymerisation.

Polymerisation is the joining together of many small molecules (monomers) to form a large molecule.

A polymer is a large molecule formed when monomers join together.

Monomers are the many small molecules which join together to form a polymer. Ethene is used to produce polyethene, the polymer used in plastic bags.



ethene monomer

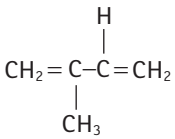
polythene polymer

Revision Questions

1 The reaction of hydrogen bromide with ethene is an example of

A. electophilic addition.
B. electophilic substitution.
C. nucleophilic addition.
D. nucleophilic substitution. [1]

2 Rubber is a polymer of isoprene, C_5H_8, whose structural formula is shown below.



(a) (i) Draw the full structure of isoprene showing **all** bonds present.

[1]

(ii) Explain whether isoprene is capable of forming E-Z isomers.

.....

..... [2]

(b) Deduce the systematic name for isoprene.

..... [1]

Revision Questions

(c) Isoprene is fully hydrogenated when it reacts with hydrogen in the presence of a metal catalyst.

(i) Write the equation for the reaction.

..... [1]

(ii) Name the metal catalyst.

..... [1]

(iii) In what form is the solid metal used?

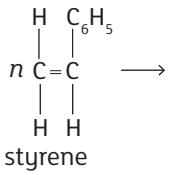
..... [1]

3 Ethene and propene can be converted into polythene and polypropene respectively.

(i) Name the type of reaction involved in the conversion of propene to polypropene.

..... [2]

(ii) Suggest the equation for the conversion of styene to polystyene:



styrene

[1]

Credits

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