WJEC Chemistry A-Level

C3.2: Hydrocarbons

Detailed Notes

English Specification

Alkanes

These hydrocarbon compounds contain only **C-H** and **C-C single bonds**, known as **σ-bonds**.

Alkanes are produced from **crude oil** through the processes of **fractional distillation** and cracking. Cracking makes smaller, more useful molecules that make **good fuels** and can go on to be used in various other chemical processes.

Combustion of Alkanes

Alkanes make good fuels as they release a lot of **energy** when burned. With **sufficient** oxygen present, they undergo **complete combustion** to produce carbon dioxide and water.

$$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$$

If there is **insufficient** oxygen present, combustion is **incomplete** and carbon monoxide gas or carbon particulates are produced alongside water.

$$2CH_4 + 3O_2 \longrightarrow 2CO + 4H_2O$$

$$CH_4 + O_2 \longrightarrow C + 2H_2O$$

Carbon monoxide is a colourless, odourless gas which is poisonous and fatal if breathed in. Carbon particulates (soot) also cause breathing problems and can build up in engines, causing them to not work efficiently.

Acid rain is caused by sulfur dioxide. When fossil fuels which contain sulfur are burnt, the sulfur reacts to form sulfur dioxide. Once the sulfur dioxide gets into the atmosphere, it dissolves in the moisture and forms sulfuric acid. This causes acid rain which destroys vegetation, as well as corroding buildings and acidifying lakes.

Photochlorination of Alkanes

Alkanes react with halogens in the presence of **UV light** to produce **halogenoalkanes**. This is called a **free radical substitution** reaction. The UV light breaks down the halogen bonds producing **reactive intermediates** called **free radicals**. These attack the alkanes resulting in a series of reactions: **initiation, propagation** and **termination**.

Example:

1. **Initiation** - the halogen is broken down with UV light.

$$Cl_2 \xrightarrow{UV} 2Cl\bullet$$

Free radicals are indicated using a dot.

2. **Propagation** - a hydrogen is replaced and the Cl• radical reformed. This shows the radical acts as a catalyst.

$$Cl\bullet + CH_4 \longrightarrow \bullet CH_3 + HCl$$

$$\bullet CH_3 + Cl_2 \longrightarrow CH_3Cl + Cl\bullet$$

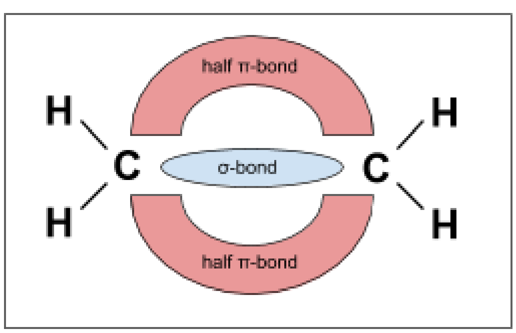
3. **Termination** - two radicals join to end the chain reaction and form a stable product.

$$\bullet CH_3 + \bullet CH_3 \longrightarrow C_2H_6$$

The propagation step can continue many times to result in **multiple substitutions**. This is a chain reaction. **Conditions** of the reaction can be altered to favour the **termination step** and limit the number of substitutions.

Alkenes

Alkenes are **unsaturated** hydrocarbons meaning they contain a **carbon-carbon double bond**. This is an area of **high electron density** making it susceptible to attack from **electrophiles** (species that are attracted to negatively charged areas). The double bond consists of a normal **σ-bond** and a **π-bond** that wraps around the centre of the C=C bond. The **π-bonds** involve sideways **overlap of p-orbitals** above and below the plane of the molecule:



Tests for alkenes

Bromine water is used to identify alkenes. When bromine water is added to an organic compound the solution will turn from **orange-brown to colourless** if a double bond is present in the substance. A dibromo-alkane will be produced as the double bond will open up to form bonds with both bromine atoms.

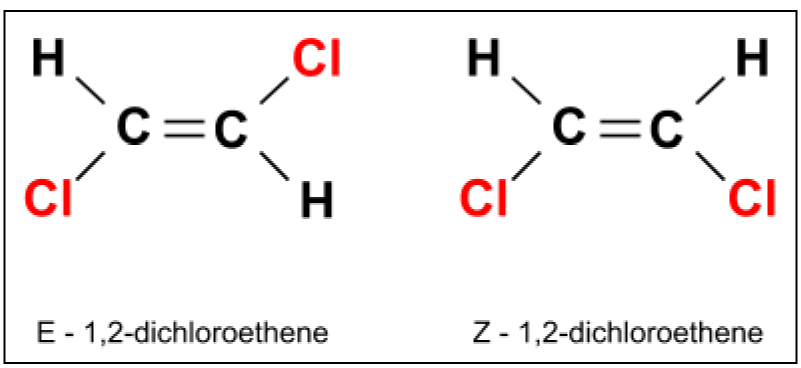
Potassium manganate(VII) is also used to test for alkenes. The colour change observed depends on if the potassium manganate(VII) is used under acidic or alkaline conditions. If the potassium manganate(VII) is in **acidic conditions** then the purple solution will **decolourise** in the presence of an alkene. If the potassium manganate(VII) is in **alkaline conditions** then the purple solution will turn **dark green** and then form a **dark brown precipitate**.

Alkene Isomerism

Alkenes display **stereoisomerism. Stereoisomers** have the same **molecular formula** but a different **spatial arrangement** of atoms. A type of stereoisomerism is **E-Z isomerism**, which arises since the restricted rotation around a double carbon bond means that groups can either be ‘together’ or ‘apart’.

The ***E*-isomer** (German for entgegen meaning apart) has the high-priority groups apart. This means they are diagonally across from each other. The ***Z*-isomer** (German for zusammen meaning together) has the high priority groups together on the same side. This means that either the high priority groups are both on the top or both on the bottom:

Example:



The atom with the higher atomic number on each carbon is given the **higher priority**.

Electrophilic Addition

Alkenes undergo electrophilic addition due to the **electron-dense** double bond. **Electrophiles** are electron acceptors and are attracted to areas of **high electron density**.

Some of the most common electrophiles are:

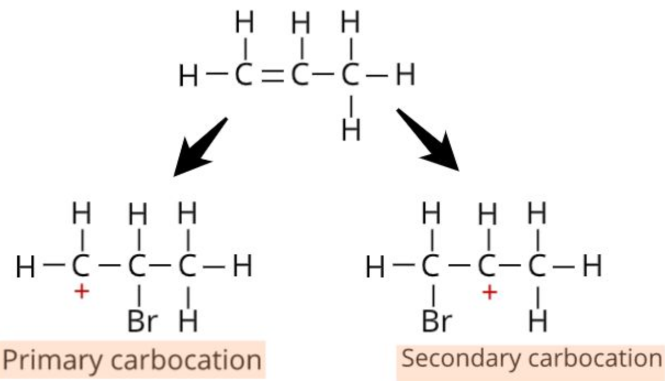
- $H^{\partial+}$ (e.g. from HBr or H_2SO_4)
- $Br^{\partial+}$ (e.g. from Br_2)

The reaction mechanism shows how electrophiles **attack the double bond** in alkenes, leading to the formation of a positive **carbocation intermediate**. This is a carbon atom with only three bonds, meaning it has a positive charge.

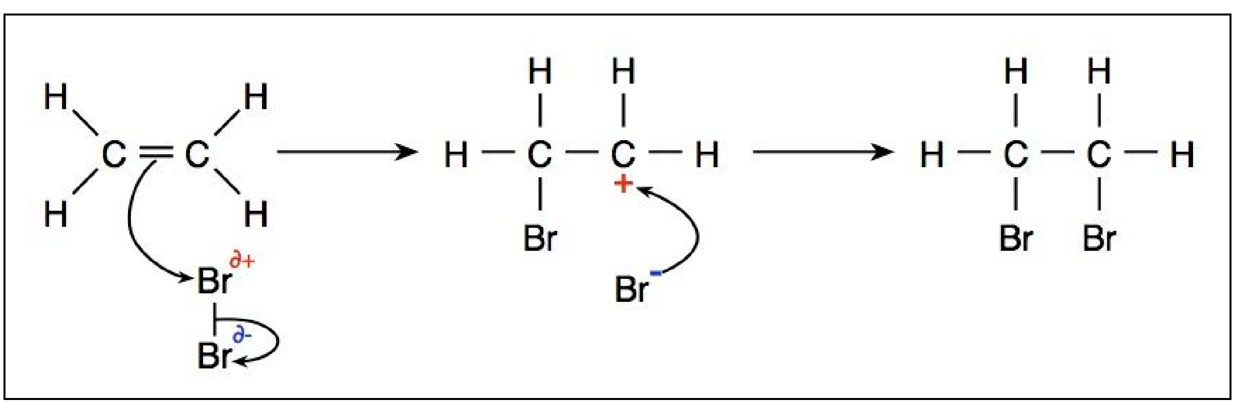
Carbocations can have **varying stability**. Stability increases from primary to tertiary so that in order of increasing stability we have:

Primary carbocation<secondary carbocation<tertiary carbocation

The more stable the carbocation, the more likely it is to form. Therefore in addition reactions, **multiple products can form** but the major product will always form from the most stable carbocation.



Mechanism - Electrophilic addition to form halogenoalkanes

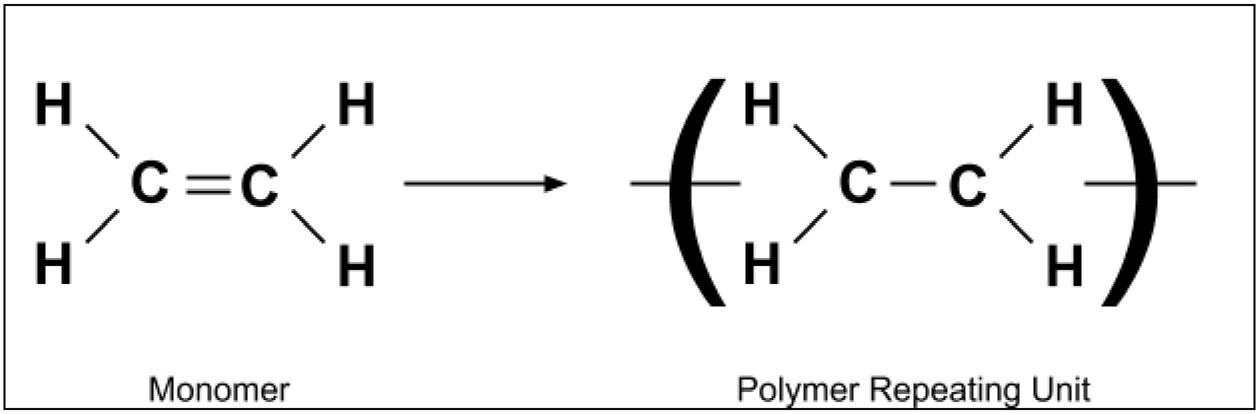


The π bond causes the bromine molecule to gain a temporary dipole so that electrons are unevenly distributed on the the bromine molecule

Alkenes can also undergo this type reaction with **hydrogen (H_2)** molecules at **150°C** in the presence of a **nickel catalyst** to form **alkanes**. This is an important reaction in food production as it allows for the **hydrogenation** of liquid fats to create solid fats such as sunflower oil spread. The **mechanism** of hydrogenation is similar to the one outlined above - just with a hydrogen molecule rather than a bromine molecule.

Addition Polymers

Addition polymers are **long chain molecules** formed from lots of short chain alkenes (monomers). **Alkenes** act as **monomers** because the double bond can open up and join together to form long chains. The repeating section of the polymer is called the **repeat unit.**
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.
The **naming** of polymers is generally very simple. The prefix of **poly-** is added to the name of the alkene which produced the polymer. For example, many **propene** molecules undergo addition polymerisation to form **polypropene**.

Reaction Conditions

The reaction conditions used in the production of these polymer chains can be altered to produce plastics with **differing properties**.

High pressures and temperatures produce **branched chain** polymers with weak intermolecular forces. Whereas lower pressures and temperatures produce **straight chain** polymers with strong intermolecular forces.

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. For example, shopping bags are made of poly(ethene).

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

PVC

Poly(chloroethene), more commonly known as PVC, is a waterproof addition polymer formed from chloroethene. PVC is made up of closely packed polymer chains which makes it hard, but brittle. This makes it useful for use in **drain pipes** or **window frames**. To make it **flexible**, PVC can be **plasticised**. This makes it suitable for use in **clothing** and **cable insulation**. The plasticiser works by the plasticiser molecules getting between the polymer chains and pushing them apart.