

WJEC Chemistry A-level

4.8: Organic Synthesis and Analysis

Detailed Notes

Welsh Specification

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Organic Synthesis

This area of chemistry focuses on **creating required compounds** through a series of intentional, planned out reactions. Synthesis often involves the changing of organic **functional groups** or the **lengthening** of the main carbon chain.

At A-Level, all the main functional group molecules can be linked together in a **synthesis chart** by the various reaction mechanisms they can undergo.

Obtaining Products

The chemical products formed in organic synthesis manipulations often have to undergo further **physical separations** to obtain the **pure** product. These include:

- Filtration
- Distillation
- Crystallisation
- Chromatography

These methods ensure the **maximum quality** of product and the **greatest percentage yield** possible from the synthesis processes.

Measuring Purity

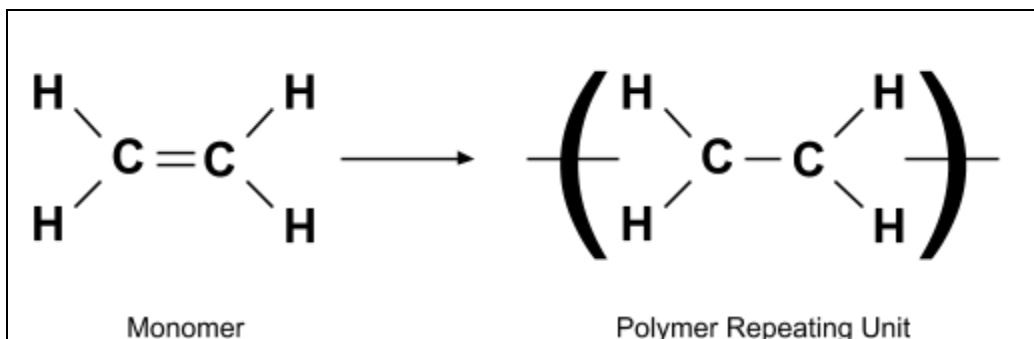
Melting points of substances can be used to determine how **pure** a substance is. Pure samples have very **sharp melting points** which can be compared to those quoted in a **data book**. **Impurities** will cause the melting point of the substance to be **lower** than expected and melting will occur over a **range** of temperatures.

Polymerisation

A polymer is a large chemical compound that is made up of **multiple repeating units**. Many **monomers** bond together to form polymers. There are two main types of polymer: **condensation** polymers and **addition** polymers.

Addition Polymers

Addition polymers are produced from **alkenes** where the **double bond** is broken to form bonds with adjacent alkenes.





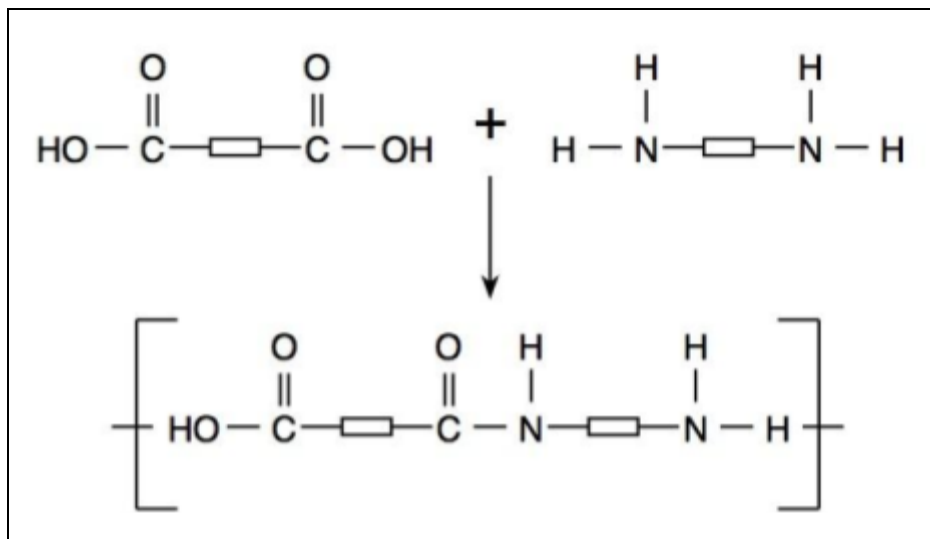
The main carbon chain of addition polymers is **non-polar**, which makes addition polymers very **unreactive**.

Condensation Polymers

Condensation polymers form when a **water molecule is removed** from the species of a reaction. There are **two main types** of condensation polymers:

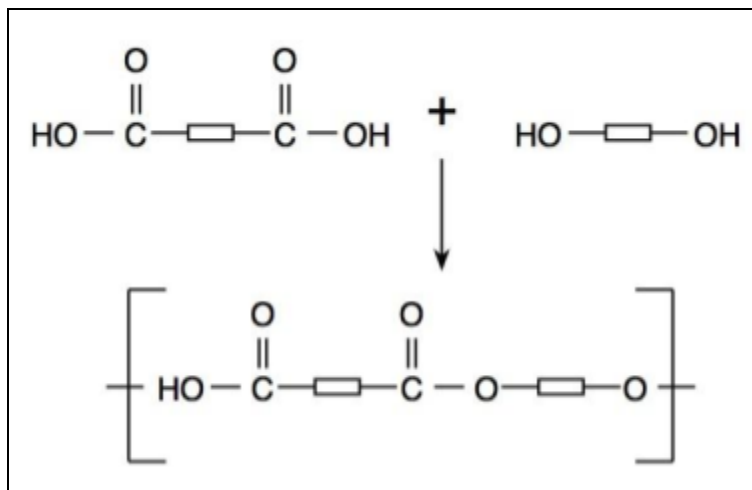
Polyamides - These are formed in a reaction between **dicarboxylic acids** and **diamines**. A molecule of water is removed, leaving an **amide linkage**. Common examples include nylon-6, nylon-6,6 and kevlar. **Nylon-6,6** is made up from **1,6-diaminohexane** and **hexanedioic acid**.

Example:



Polyesters - These are formed in a reaction between **dicarboxylic acids** and **diols**, producing an **ester linkage**. A water molecule is removed to produce the ester linkage. Common examples include **Terylene** (PET). **PET** is formed from **benzene-1,4-dicarboxylic acid** and **ethane-1,2-diol**

Example:



Condensation polymers are generally **stronger** than **addition** polymers. This is because the chains in condensation polymers contain **polar bonds**, so **permanent dipole-dipole forces** and **hydrogen bonds** exist between the polymer chains. In comparison, in **addition polymers**, the chains are generally only held together by **Van der Waals** forces.

Polymer Disposal

All polymers are **very useful** but they can be hard to get rid of as **waste products**. **Disposal** of these compounds and products made from them is where one of the **key differences** between **addition** and **condensation** polymers is highlighted.

Addition polymers are very inert with **non-polar bonds** meaning they are not easily broken down by species in nature. They are **not biodegradable**. Therefore, they have to be **broken down by burning** which produces **harmful gases** such as CO_2 , CO or SO_2 - which can lead to **acid rain**.

Condensation polymers such as **polyesters** and **polyamides** can be broken down through **hydrolysis** due to the **polarity** within the polymer molecules. Therefore, they are **biodegradable** and can be **broken down easily** in nature by naturally occurring water or moisture. This means polyester and polyamides can be put into landfill and will **gradually breakdown naturally**.

Chromatography

Chromatography is an **analytical technique** used to **separate** and **identify** component molecules of a mixture. It uses a **mobile phase** and a **stationary phase**.

Mobile and Stationary Phases

The **mobile phase** is a **substance** that allows molecules to **move over or through** the **stationary phase**. It can be in the form of a **liquid** or a **gas** depending on the type of chromatography being carried out. **More soluble** products **move further** with the mobile phase. The **stationary phase** is a **solid** or a **liquid on a solid support**. The **greater the affinity** of a molecule to the stationary phase, the **shorter the distance it moves** with the mobile phase.

Rf Values

Rf values are **unique** to each different component in the mixture being analysed. It is calculated by **comparing the distance** moved by the mobile phase and the individual component:

$$R_f = \frac{\text{Distance moved by component}}{\text{Distance moved by solvent}}$$

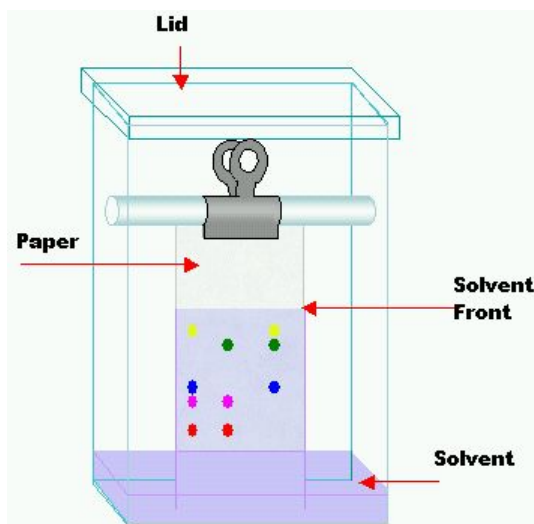
There are **four main types of chromatography** that use different mobile and stationary phases to obtain Rf values for the molecules present.



Thin-Layer Chromatography

In this method of chromatography, a **metal plate** is coated with a thin layer of **silica**. This is the **stationary phase**. The substance being analysed is dotted on the plate and then a **solvent** (**mobile phase**) is allowed to move up the plate. The plate is then **dried** in a fume cupboard to reduce toxic fumes. The **chemical traces** can then be viewed using a **UV lamp** and the distances travelled can be measured. Alternatively, a **developing agent** can be added, such as **iodine**, to allow the traces to be seen by the naked eye.

Example:

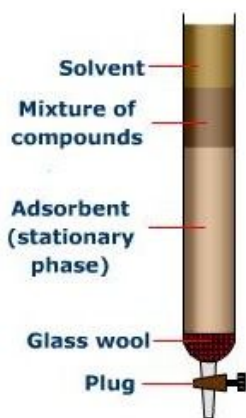


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Column Chromatography (HPLC)

For this method, a **vertical column** is packed with a **solid, powdered substance** which acts as the **stationary phase**. A **solvent** containing the mixture being analysed is then added and moves down the column as the **mobile phase**.

Example:



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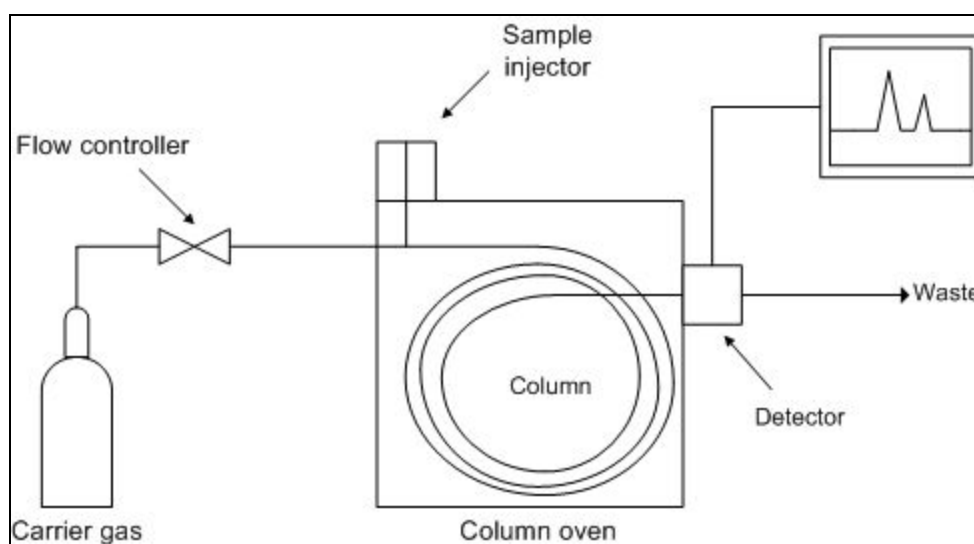


The **varying affinities** of the molecules present means they **drain out** of the column at **different times**, allowing them to be collected as **separate samples**. The time taken to drain out of the column is measured as the **retention time**. Similar to R_f values, retention times allow the **individual components** in the mixture to be **identified**.

Gas Chromatography

In this form of chromatography, a **thin tube is packed with a solid**, powdered substance which acts as the **stationary phase**. Instead of a solvent, a **high pressure gas** is passed through this tube as the **mobile phase**. This method is used to **separate mixtures of volatile liquids** which are fed into the gas chromatography machine as vapours.

Example:



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The analysis machine records a **retention time** for each component molecule in the mixture, allowing them to be **identified**.

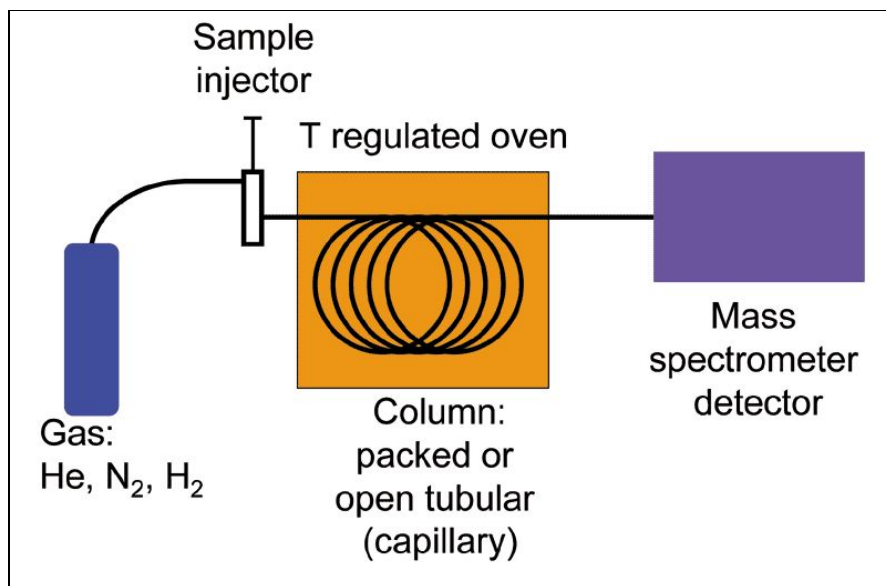
GC-MS

This is a combination of analytical techniques, **gas chromatography** and **mass spectrometry**, allowing for a **more advanced** level of molecule analysis. The molecules present are **first separated** using the gas chromatography technique. Then each molecule present is **fed directly into a mass spectrometer** so it can be accurately **identified**.

GC-MS is a much **faster analytical process** that produces **more accurate** results for molecule analysis and identification.



Example:



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