CAIE Chemistry A-level

35: Polymerisation

(A-level only)

Notes

Condensation Polymerisation

Condensation polymerisation is the joining together of **monomers** to form a polymer with the **release of a small molecule** such as water or HCl.

Polyesters

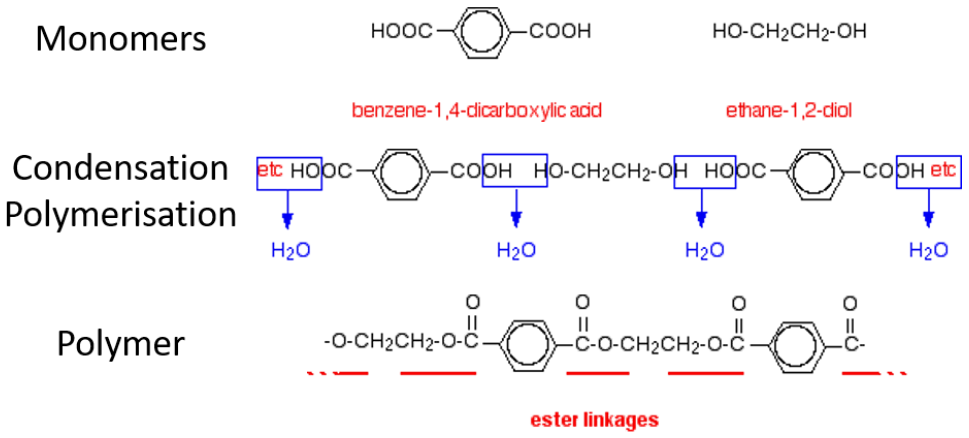
A polyester contains monomers linked with **ester bonds**. For this link to form, either of the following is needed:

- A monomer containing 2 carboxylic acid groups and a monomer containing 2 alcohol groups.
- A monomer containing both an alcohol and a carboxylic acid group.

The ester linkage is formed during a condensation reaction when H is lost from the OH of an **alcohol** and OH is lost from the COOH of a **carboxylic acid**. The H^+ and OH^- combine to form water.

A monomer containing two -COCl (**acyl chloride**) groups may be used instead of the carboxylic acid. The only difference is that **HCl** forms instead of water.

Below is a diagram showing the formation of Terylene:



'Polyesters', Jim Clark, Chemguide

Polyamides

A polyamide contains monomers held together by **amide bonds**. For this link to form, either of the following is needed:

- A monomer containing 2 carboxylic acid groups and a monomer containing 2 amine groups.
- A monomer containing both a carboxylic acid and an amine group.

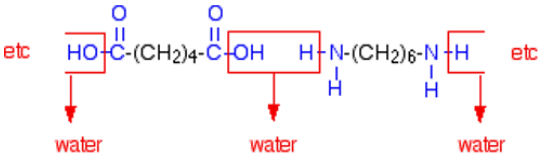
The amide linkage is formed during a condensation reaction when H is lost from the NH_2 of an **amine** and OH is lost from the COOH of a **carboxylic acid**. Water forms when the H^+ and OH^- combine.
As with ester bond formation, a monomer containing two -COCl (**acyl chloride**) groups can be used instead of the carboxylic acid, forming **HCl** instead of water.

Below are some diagrams showing the polyamides nylon 6,6, nylon 6 and Kelvar (the amide bond is shown in blue in the polymers):

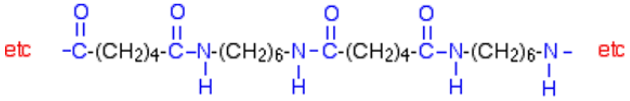
Nylon 6,6

Monomers

Condensation Polymerisation

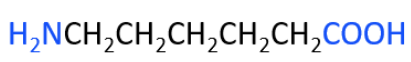


Polymer

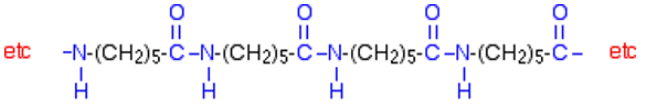


Nylon 6

Monomer



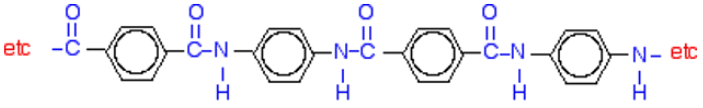
Polymer



Kevlar

Monomers

Polymer



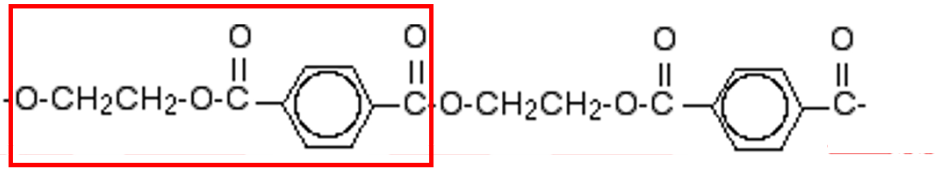
'Polyamides', Jim Clark, Chemguide

Repeat Units

A **repeat unit** is a structure that **occurs in a molecule many times**. Sometimes the repeat unit is made up of one monomer, sometimes it contains a pair of monomers.

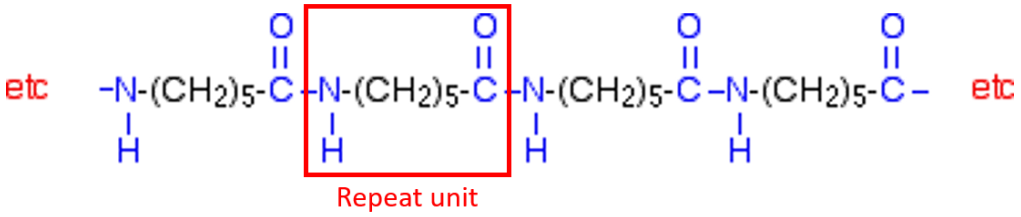
Below are examples of repeat units in polymers:

Terylene



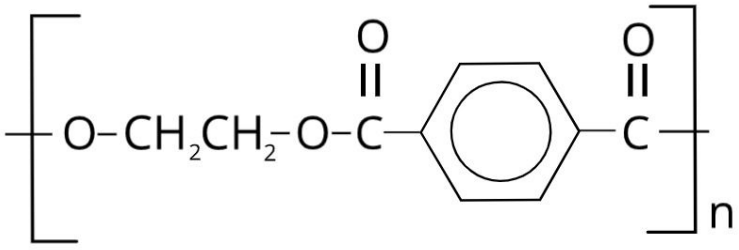
'Polyesters', Jim Clark, Chemguide

Nylon 6



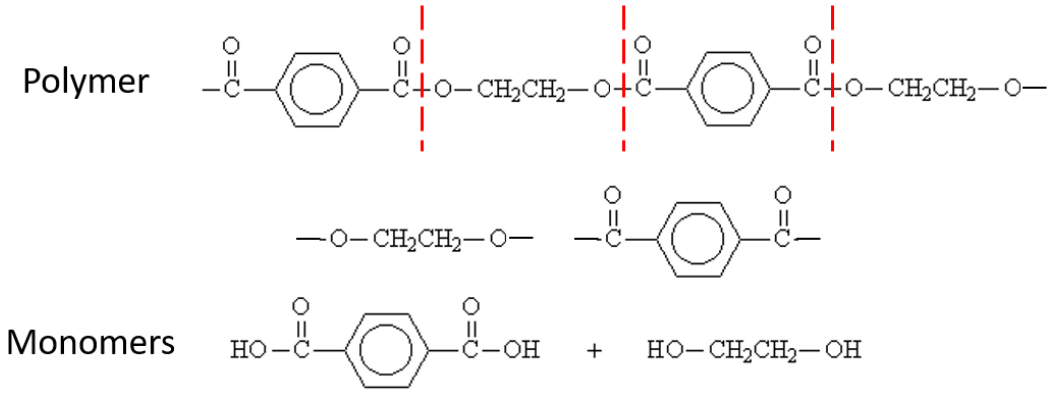
'Polyamides', Jim Clark, Chemguide

Polymers can also be represented using their repeat unit and square brackets. The **'n'** in the diagram of **Terylene** below is used to show that there are many repeat units in the polymer.



Monomers

To identify the monomers in a polymer, draw a line through the ester or amide linkages. Add OH or H to create the monomers.

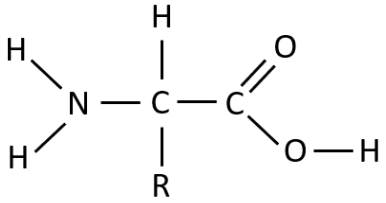


Predicting Types of Polymerisation

Addition polymerisation	Condensation polymerisation
Monomers contain C=C double bonds.	Monomers contain -OH and -COOH or -COCl for polyesters. Monomers contain $-NH_2$ and -COOH or -COCl for polyamides.
Main chain of the polymer only contains C-C single bonds.	Main chain contains nitrogen or oxygen atoms as well as carbon atoms.
The polymer is the only product of the reaction.	The polymer and a small molecule like water or HCl are formed during the reaction.

Proteins

Proteins are polymers made from **amino acids**. Amino acids contain an **amine** group ($-NH_2$) and a **carboxylic acid** group (-COOH). The general structure of an alpha amino acid is shown below (where R represents any group):



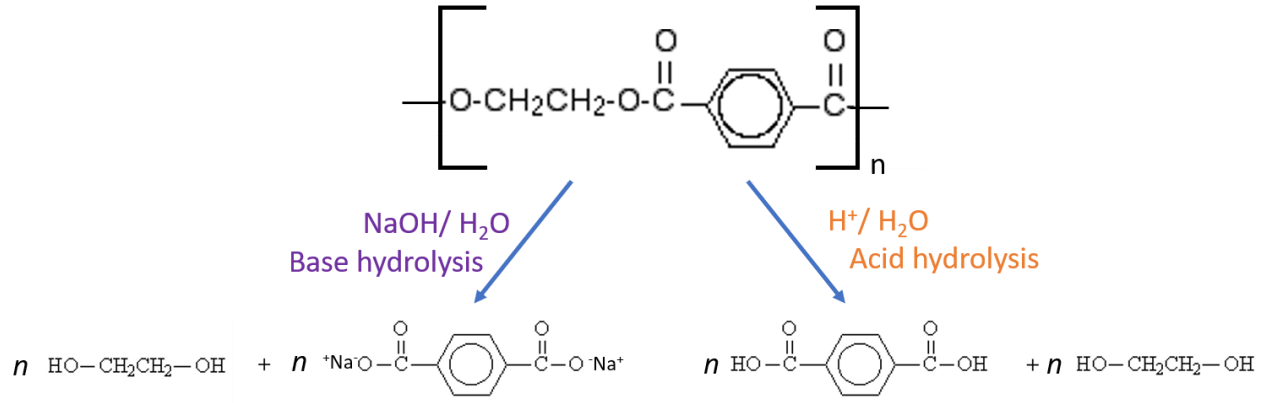
A **dipeptide** contains 2 amino acids joined together with an amide bond. A **polypeptide** contains many amino acids bonded together in a chain by amide bonds.

Degradable Polymers

Poly(alkenes) are chemically **inert** (very unreactive) meaning they are **difficult to biodegrade**.

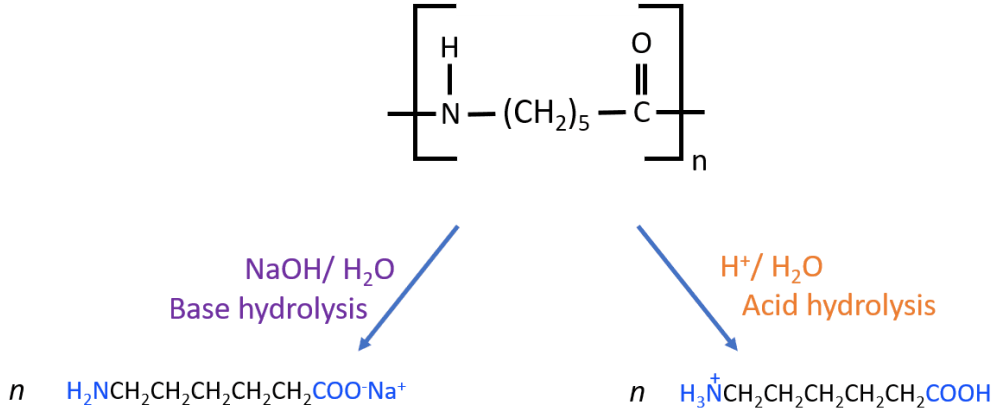
Some polymers, such as LDPE, can be **degraded using light**. Light (typically **UV**) causes the polymer chains to break so the material crumbles.

Polyesters are **biodegradable** and can be **hydrolysed** using dilute acids or alkalis (slower hydrolysis with acids). Below is an example of hydrolysis of the polyester Terylene:



'Polyesters', Jim Clark, Chemguide (image modified from original)
'Polymer Chemistry: Polymerization Reactions', Engineering LibreTexts (image modified from original), CC BY-NC-SA 3.0 US

Polyamides are also **biodegradable** and can be **hydrolysed** using dilute strong acids or alkalis (slower hydrolysis with alkalis). Below is an example of hydrolysis of the polyamide nylon 6:



The **acid hydrolysis** of proteins is very similar to the acid hydrolysis of polyamides. There are two ways to complete this reaction:

- Heat protein at 110°C with 6 mol dm^{-3} hydrochloric acid for 8 hours (slow method).
- Place protein in a sealed tube containing 6 mol dm^{-3} hydrochloric acid and an atmosphere of nitrogen. Place in a microwave for 5-30 minutes (depending on the protein), using temperatures up to 200°C. Faster method for small samples of protein during analysis.

When proteins are hydrolysed using acid, amino acids are formed, however the **amine group accepts a proton** to become **$-NH_3^+$**. The general structure of the product of protein hydrolysis is shown below (where R represents any group):