Cambridge (CIE) A Level Chemistry

Your notes

Condensation Polymerisation

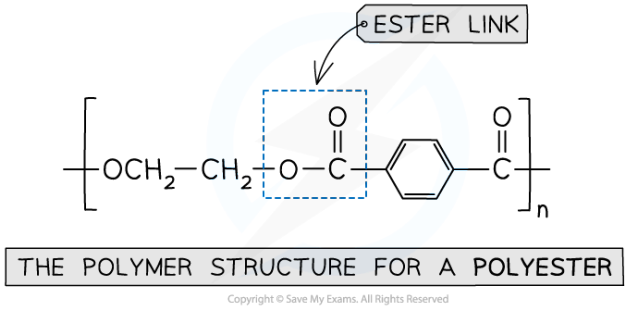
Contents

Your notes

Formation of Polyesters

- Addition polymerisation has been covered in reactions of alkenes
  - They are made using monomers that have C-C double bonds joined together to form polymers such as (poly)ethene
- Condensation polymerisation is another type of reaction and is used in the making of polyesters
  - A small molecule (e.g. a water molecule) is lost when the monomers join together to form a polyester
  - Polyesters contain ester linkages

Example of a polyester

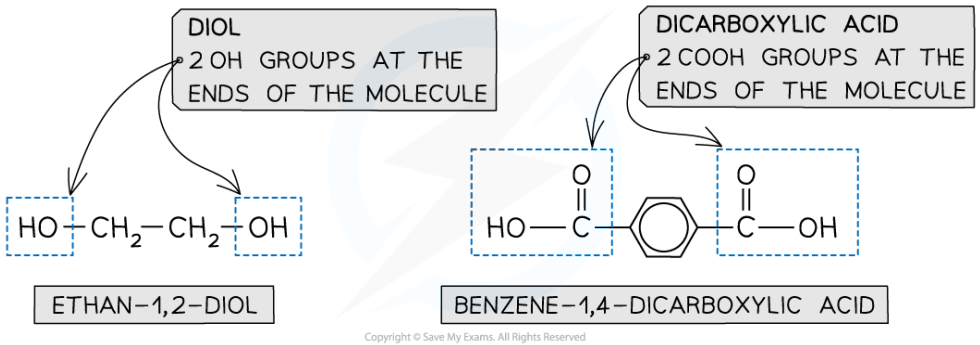


This polymer structure shows an ester functional group linking monomers together

Formation of polyesters

- A diol and a dicarboxylic acid are required to form a polyester
  - A diol contains 2 -OH groups
  - A dicarboxylic acid contains 2 COOH groups

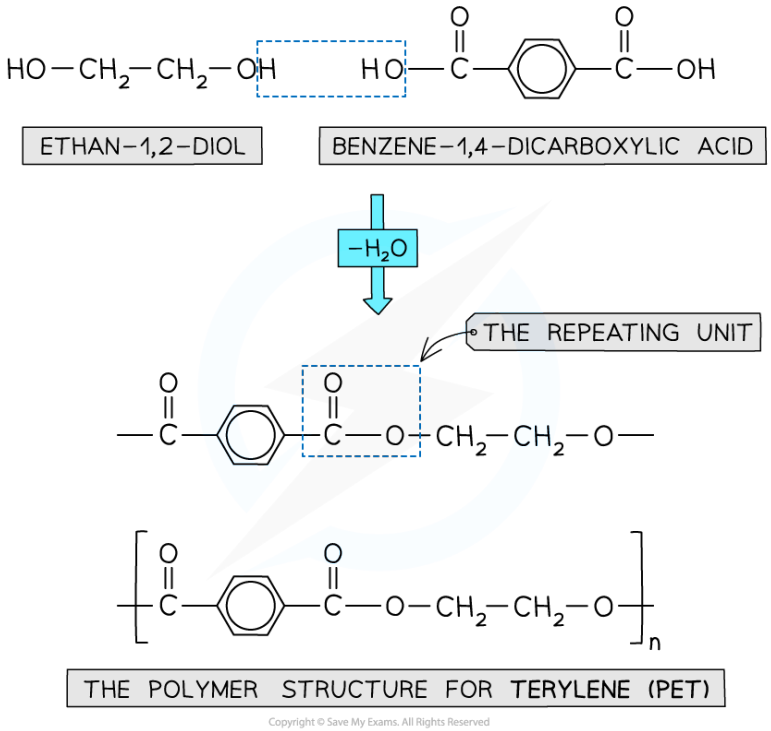
Diol and dicarboxylic acid examples



The position of the functional groups on both of these molecules allows condensation polymerisation to take place effectively

- When the polyester is formed, one of the -OH groups on the diol and the hydrogen atom of the -COOH are expelled as a water molecule (H_2O)
- The resulting polymer is a polyester

Forming polyethylene terephthalate (PET)



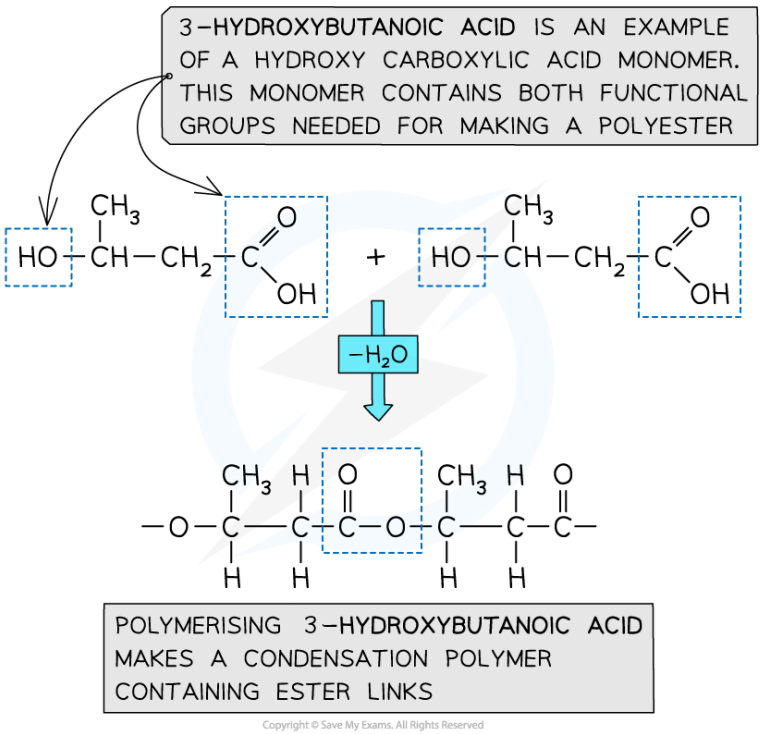
Expulsion of a water molecule in this condensation polymerisation forms the polyester called Polyethylene terephthalate also known as Terylene or PET

Hydroxycarboxylic acids

- So far the examples of making polyesters have focused on using 2 separate monomers for the polymerisation
- There is another route to making polyesters
- A single monomer containing both of the key functional groups can also be used
- These monomers are called hydroxycarboxylic acids
  - They contain an alcohol group (-OH) at one end of the molecule while the other end is capped by a carboxylic acid group (-COOH)

Using hydroxycarboxylic acids to form condensation polymers

Your notes



Both functional groups needed to make a polyester come from the same monomer

Examiner Tips and Tricks

- Polyesters can be made using condensation polymerisation
- The monomers needed are diols and dicarboxylic acids / dioyl chlorides or a single hydroxycarboxylic acid monomer

Your notes

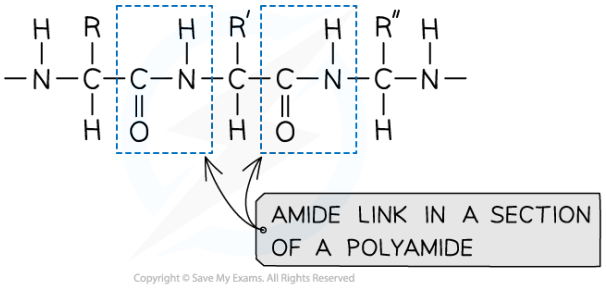
Your notes

Formation of Polyamides

Amide link

- Polyamides are also formed using condensation polymerisation

Section of a polyamide highlighting the amide links

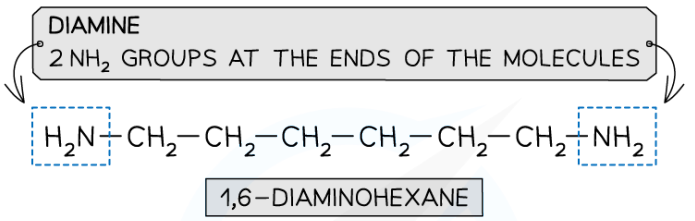


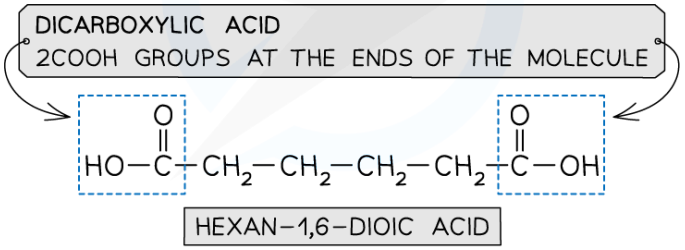
An amide link – also known as a peptide link – is the key functional group in a polyamide

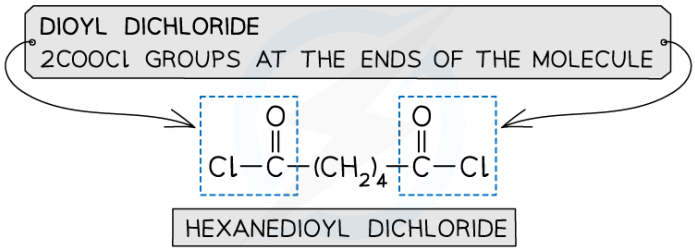
Monomers

- A diamine and a dicarboxylic acid are required to form a polyamide
  - A diamine contains 2 -NH_2 groups
  - A dicarboxylic acid contains 2 -COOH groups
- Dioyl dichlorides can also used to react with the diamine instead of the acid
  - A dioyl chloride contains 2 -COCl groups
- This is a more reactive monomer than dicarboxylic acid. However, a more expensive alternative

Examples of the monomers required to form polyamides



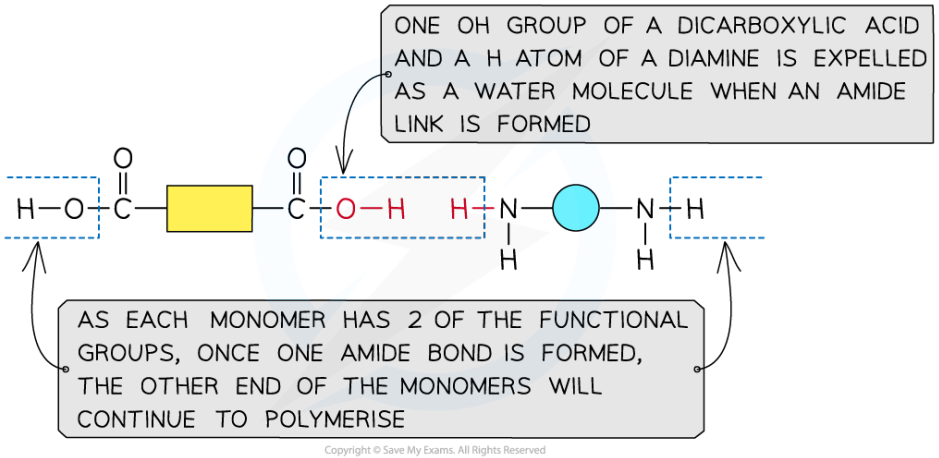




The position of the functional groups on these molecules allows condensation polymerisation to take place effectively

Formation of polyamides

Forming an amide link

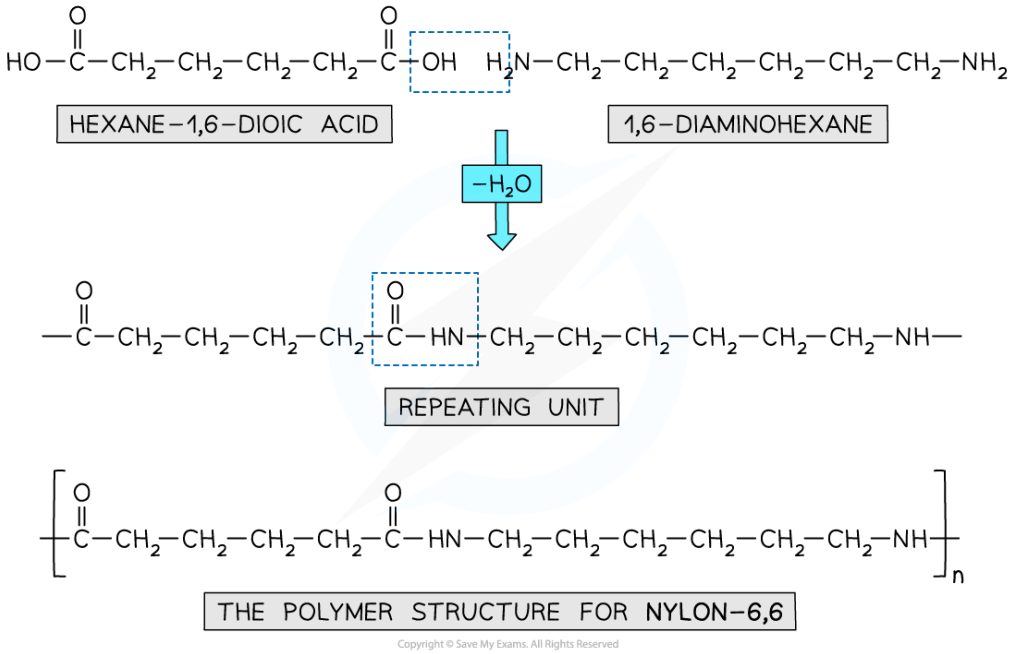


Your notes

This shows the expulsion of a small molecule as the amide link forms

- Nylon 6,6 is a synthetic polyamide
- Its monomers are 1,6-diaminohexane and hexane-1,6-dioic acid
  - The '6,6' part of its name arises from the 6 carbon atoms in each of Nylon 6,6 monomers

Forming nylon 6,6



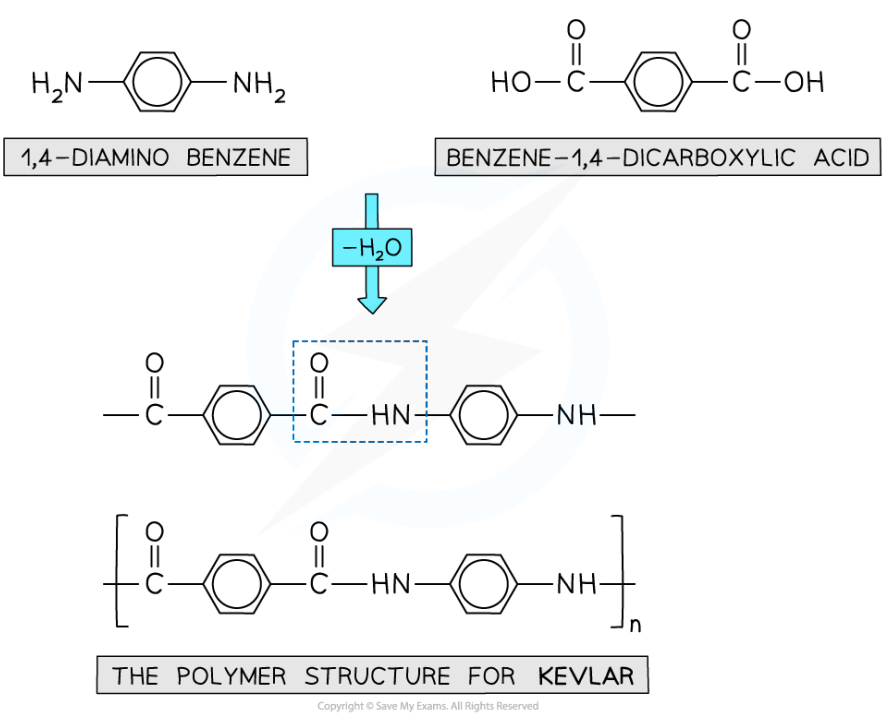
Nylon 6,6 is a synthetic polyamide made using specific diamine and dicarboxylic acid monomers

Kevlar

- Kevlar is another example of a polymer formed through condensation polymerisation
- The polymer chains are neatly arranged with many hydrogen bonds between them
- This results in a strong and flexible polymer material with fire resistant properties
- These properties also lend Kevlar to a vital application in bullet-proof vests
- The monomers used to make Kevlar
  - 1,4-diaminobenzene
  - Benzene-1,4-dicarboxylic acid
- As seen with Nylon, a dioyl chloride can be used instead of the acid as well (benzene-1,4-dioyl chloride)

Forming Kevlar

Your notes



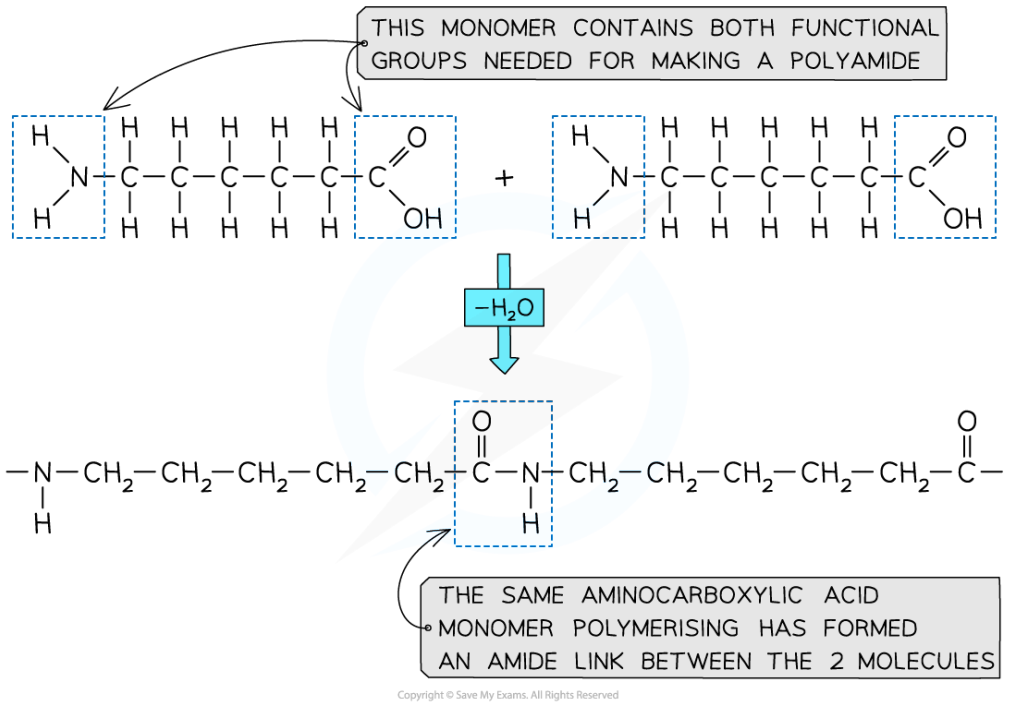
Kevlar is made using specific diamine and dicarboxylic acid monomers

Your notes

Aminocarboxylic acids

- So far, condensation polymerisation has covered the use of monomers that contain 2 of the same functional group (eg. diamine, Diol etc.)
- It is possible to carry out a condensation polymerisation where one monomer provides both of the function groups necessary for an amide/peptide link
- For example, 6–aminohexanoic acid has an amino group and a carboxylic acid group on the same molecule
- Molecules like this are called amino carboxylic acids
- They are able to polymerise to form a structure similar to Nylon 6,6

Forming nylon 6,6 using a single monomer

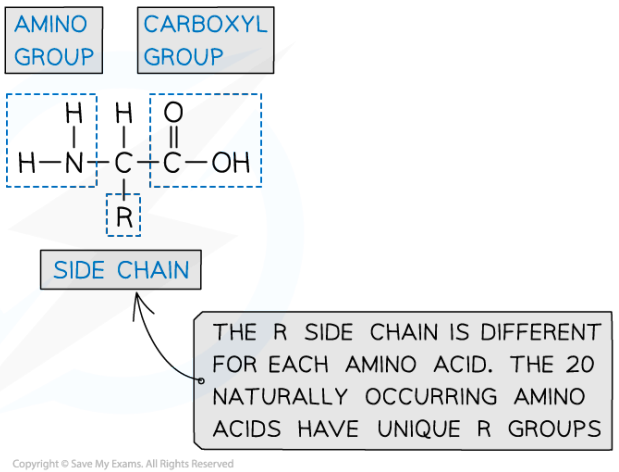


6-aminohexanoic acid polymerises to make the synthetic polymer nylon 6,6

Making Proteins

- Proteins are vital biological molecules with varying functions within the body
- They are essentially polymers made up of amino acid monomers
- Amino acids have an aminocarboxylic acid structure
- Their properties are governed by a branching side group - the R group

The functionality of an amino acid



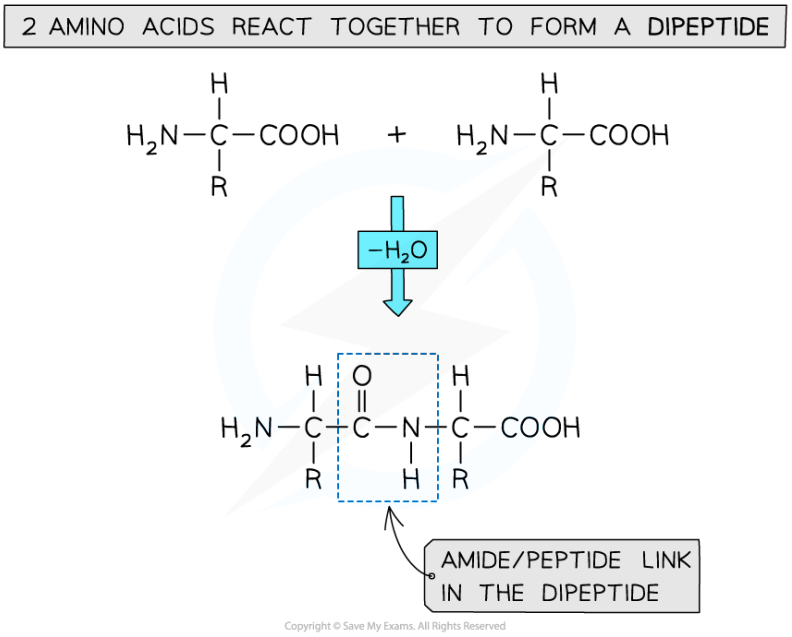
Amino acids contain an amine group, an acid group and a unique R group

Your notes

- Different amino acids are identified by their unique R group
- The name of each amino acid is given using 3 letters
  - For example, Glutamine is known as 'Gln'
- Dipeptides can be produced by polymerising 2 amino acids together
  - The amine group ($-NH_2$) and acid group (-COOH) of each amino acid are used to polymerise with another amino acid
- Polypeptides are made by polymerising more than 2 amino acids together

Your notes

Forming dipeptides and polypeptides

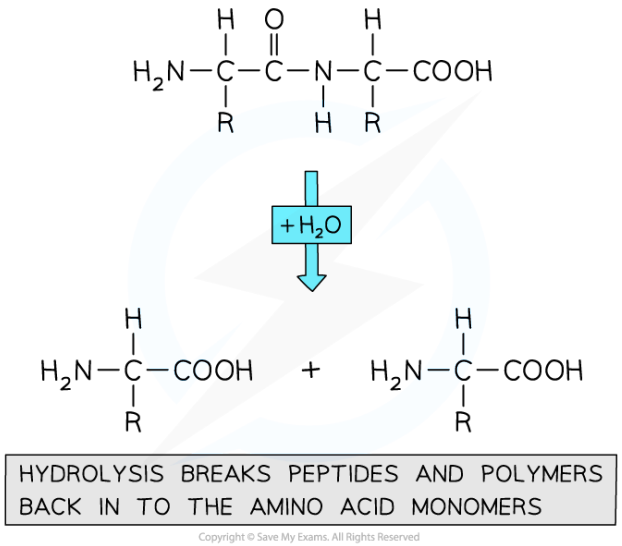


Dipeptides and polypeptides are formed by polymerising amino acid molecules together

Protein hydrolysis

- Proteins (polypeptides) can be broken down into its constituent amino acids
- This process occurs through a hydrolysis reaction

Hydrolysing proteins



Hydrolysis of proteins produces the component amino acids

Your notes

Examiner Tips and Tricks

- Become familiar with the structures of the different monomers that can be used to make condensation polymers.
- Also, remember that exam questions will require you to identify the key functional groups and also draw small sections of polymers.

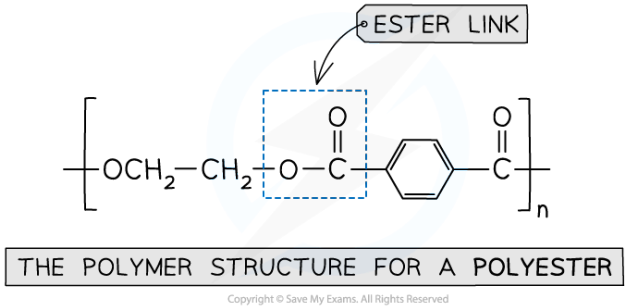
Your notes

Deducing the Repeat Unit of a Condensation Polymer

Repeat units for condensation polymers

- Remember we can tell the type of polymerisation by identifying the linking between the monomers
  - If a chain of carbon atoms is present, the polymer is an addition polymer
  - If there is an ester link, the polymer is a polyester (formed by condensation polymerisation)

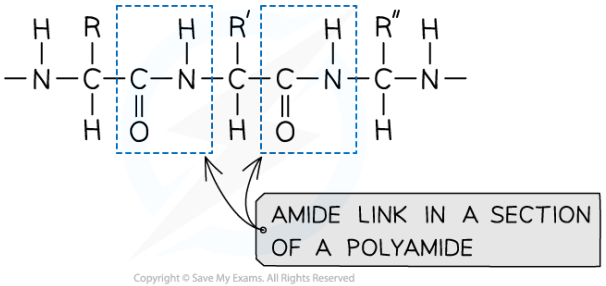
Example polyester structure



Polyesters contain the ester link

- If there is an amide link, the polymer is a polyamide (formed by condensation polymerisation)

Example polyamide structure



Polyamides contain the amide or peptide link

- In condensation polymerisation, the monomers either contain:

- 2 monomers each with the same functional group, such as a diamine with a dicarboxylic acid or
- One single monomer that has both of the functional groups needed for polymerisation, such as an aminocarboxylic acid

Your notes

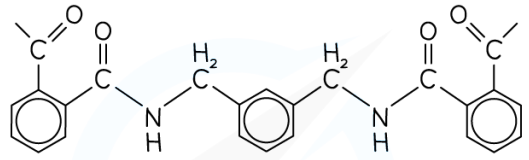
Examiner Tips and Tricks

- Remember: in condensation polymerisation, a small molecule is expelled as a result of the 2 monomers joining together.
- When a dioic acid and diamine polymerise, a water molecule is expelled
  - OH from acid and H from the amine
- When a dioyl chloride and diamine are polymerised, a hydrochloric acid molecule is expelled
  - Cl from the chloride and H from the amine

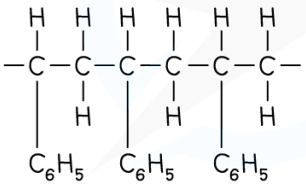
Worked Example

Draw the repeating unit and identify the monomers used to make the following polymers

a)

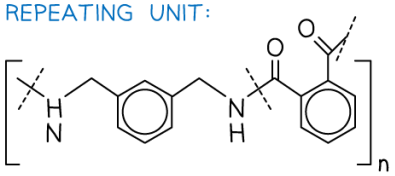


b)

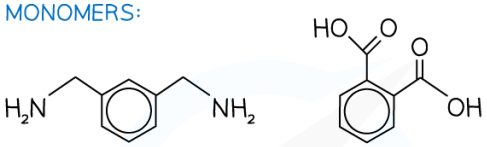


Answer:

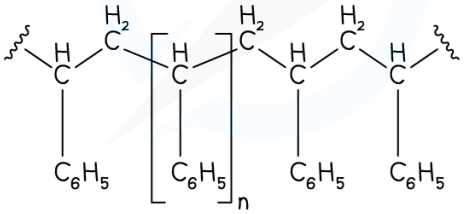
a) REPEATING UNIT:



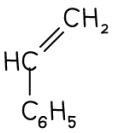
a) MONOMERS:



b) REPEATING UNIT:



b) MONOMERS:



Your notes

Identifying Monomers in Condensation Polymers

- When a section of polymer is presented, the monomers can be identified by considering the small molecules expelled from the monomers
- If a water molecule is expelled, the -OH must have been from an acid group
- The hydrogen atom may be from an amine group of a monomer.
- If the molecule was hydrochloric acid (HCl), a dioyl chloride monomer may have been used