

# Condensation Polymers

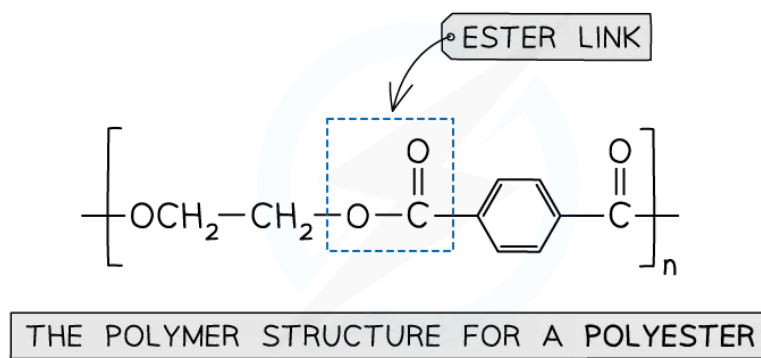
## What is condensation polymerisation?

- Condensation polymerisation is another type of reaction whereby a polymer is produced by repeated condensation reactions between monomers
- Natural condensation polymers are all formed by elimination of water
  - Although the process of condensation polymerisation involves the elimination of a small molecule
- Condensation polymers can be identified because the monomers are linked by ester or amide links
- Condensation polymers can be formed by:
  - Dicarboxylic acids and diols
  - Hydroxycarboxylic acids
  - Dicarboxylic acids and diamines
  - Amino acids

## What is polyester?

- Polyester is a polymer, most commonly formed by the condensation polymerisation of dicarboxylic acid monomers and diol monomers
- A polyester is produced by linking these monomers with ester bonds / links

### Ester Link in a Polyester



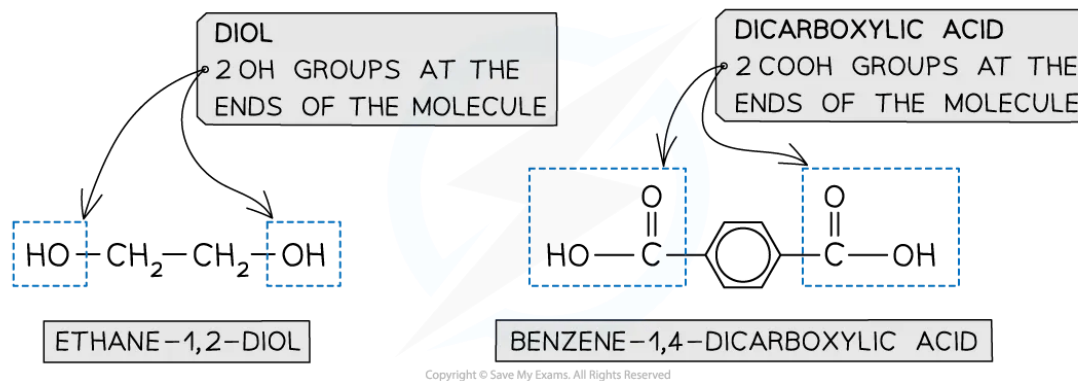
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*This polymer structure shows an ester functional group linking monomers together*

## Formation of polyesters using diols and dicarboxylic acids

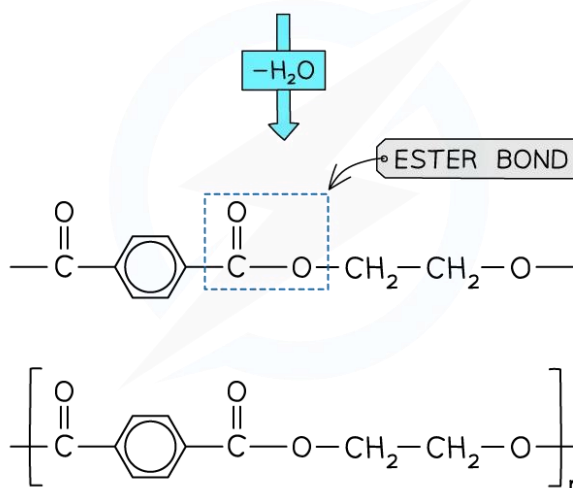
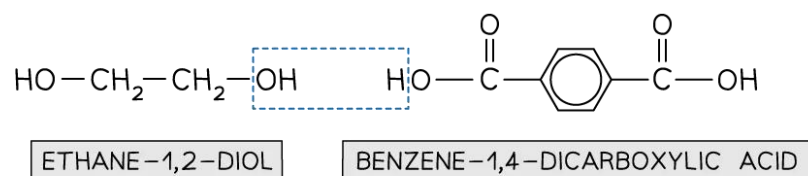
- A diol and a dicarboxylic acid are required to form a polyester
  - A diol contains two alcohol  $\text{-OH}$  groups
  - A dicarboxylic acid contains two carboxylic acid  $\text{-COOH}$  groups

## Diol and dicarboxylic acid monomer structures



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

- When the polyester is formed, one of the diol  $-\text{OH}$  groups and a hydrogen atom from one of the carboxylic acid  $-\text{COOH}$  groups are eliminated as a water molecule ( $\text{H}_2\text{O}$ )
- The resulting polymer is a polyester
  - For example, the polyester poly(ethylene terephthalate) or PET, which is sometimes known by its brand names of Terylene or Dacron
- **Formation of Poly(ethylene terephthalate)**



**THE POLYMER STRUCTURE FOR POLY(ETHYLENE TEREPHTHALATE) (PET)**

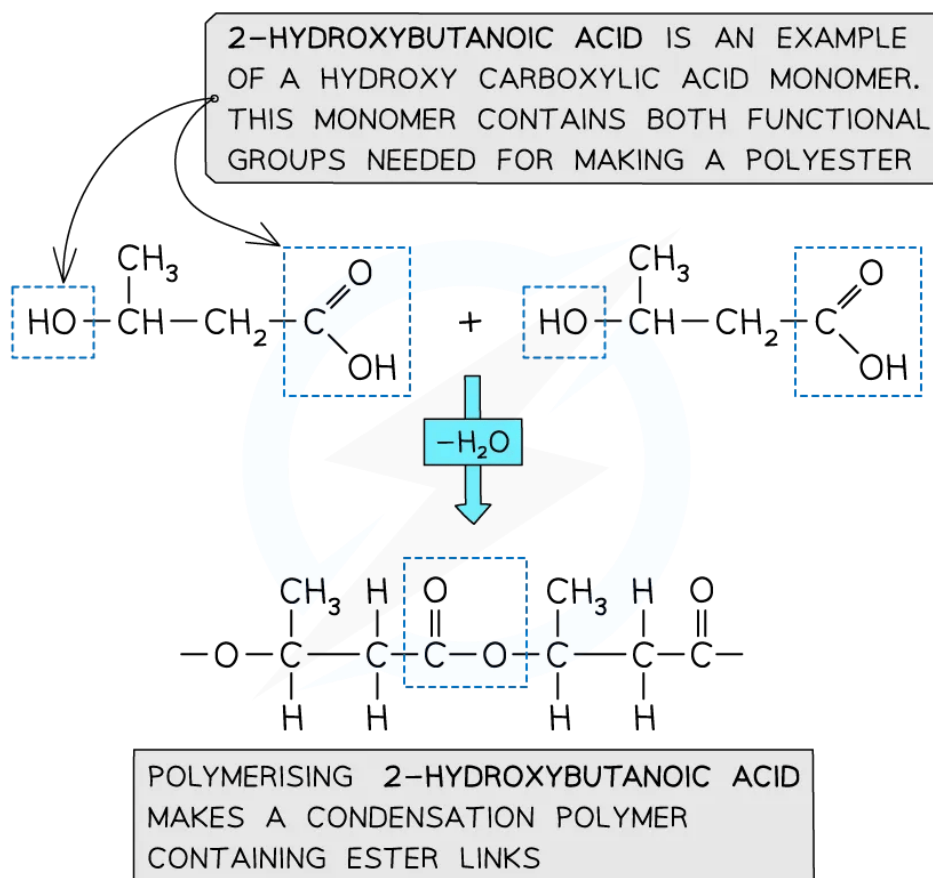
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The elimination of a water molecule in this condensation polymerisation forms the polyester called poly(ethylene terephthalate) (PET)

## Formation of polyesters using 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  $\text{-OH}$  group at one end of the molecule and a carboxylic acid  $\text{-COOH}$  group at the other end of the molecule

### Formation of polyesters from hydroxycarboxylic acids



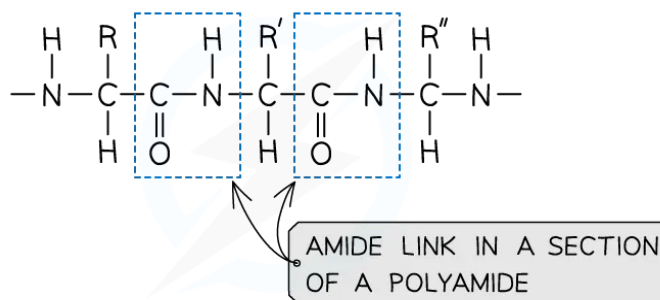
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*Both functional groups that are needed to form the ester link of the polyester come from the same monomer*

## What are polyamides?

- Polyamides are polymers where the repeating units are bonded together by amide links
- The formula of an amide group is  $\text{-CONH}$

## Amide links in Polyamides



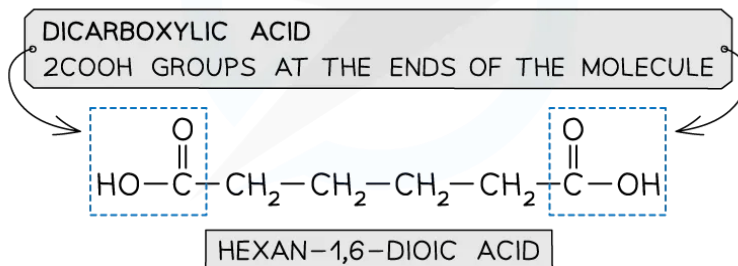
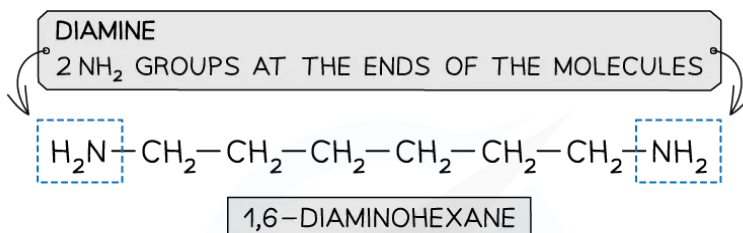
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An amide link - also known as a peptide link - is the key functional group in a polyamide

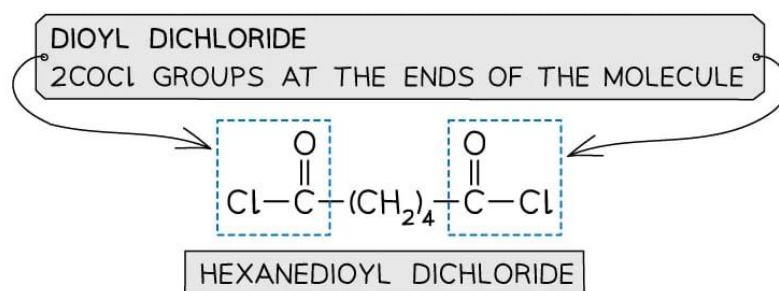
## Polyamide monomers

- A diamine and a dicarboxylic acid are required to form a polyamide
  - A diamine contains 2  $\text{---NH}_2$  groups
  - A dicarboxylic acid contains 2  $\text{---COOH}$  groups
- Dioyl dichlorides can also be used to react with the diamine instead of the acid
  - A dioyl chloride contains 2  $\text{---COCl}$  groups
  - This is a more reactive monomer but more expensive than dicarboxylic acid

## Polyamide monomers



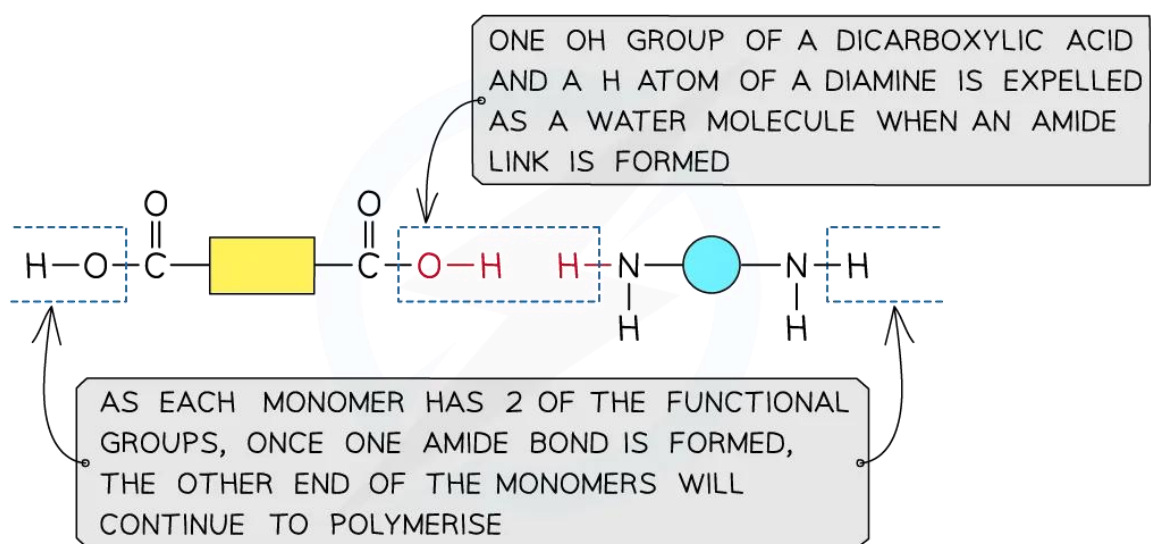
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*The monomers for making polyamides*

## Formation of polyamides

### Formation of Polyamides from Monomers

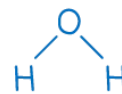
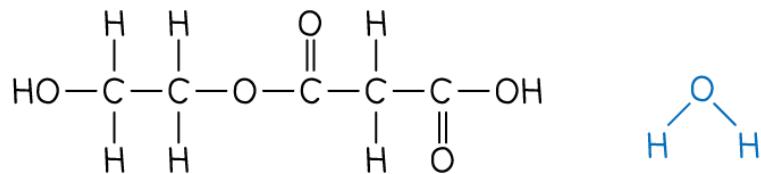


*This shows the elimination of a small molecule as the amide link forms*

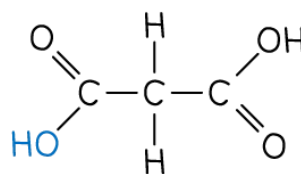
## Biodegradable polymers

- Both polyesters and polyamides can be broken down using hydrolysis reactions
- This is a major advantage over the addition polymers produced using alkene monomers (polyalkenes)
- When polyesters and polyamides are taken to landfill sites, they can be broken down easily and their products used for other applications
- Hydrolysis occurs during
  - Digestion
  - Decomposition
- Both condensation and hydrolysis reactions are controlled by enzymes

## Diagram to show hydrolysis of condensation polymers



HYDROLYSIS



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*Water is added which causes the polymer to break down into the original monomers*