Cambridge (CIE) IGCSE Chemistry

Your notes

Polymers

Contents

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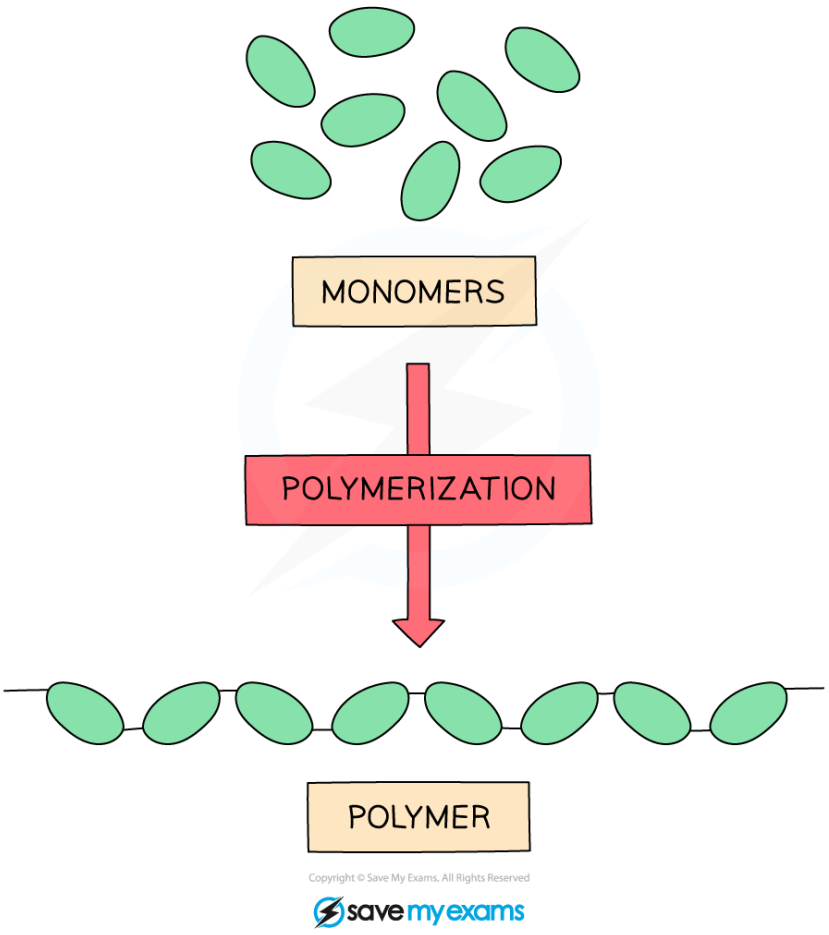
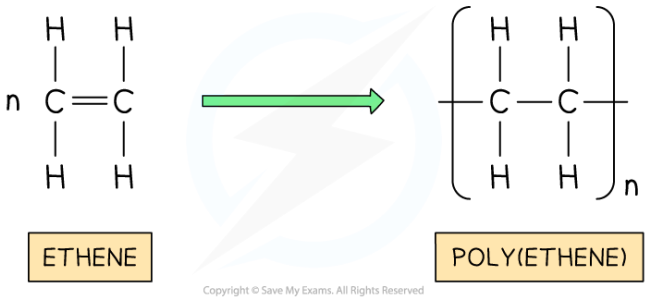
Polymers: the basics

- Polymers are large molecules built by linking 50 or more smaller molecules called **monomers**
- Each repeat unit is connected to the adjacent units via **covalent bonds**
- Examples of polymers include PVC and nylon



Many monomers join together to form a polymer

- Poly(ethene) is formed by the addition polymerisation of ethene monomers
- Addition polymerisation involves the addition of many monomers to make a long chained polymer
- In this case, many ethene monomers join together due to the carbon carbon double bond breaking



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Poly(ethene) is formed by addition polymerisation using ethene monomers

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Addition polymers

Extended tier only

- Addition polymers are formed by the joining up of many monomers and only occur in monomers that contain **C=C bonds**
- One of the bonds in each C=C bond breaks and forms a bond with the adjacent monomer
- The polymer formed will only contain single bonds
- Many polymers can be made by the addition of alkene monomers
- Others are made from alkene monomers with different atoms attached to the monomer such as chlorine or a hydroxyl group
- The name of the polymer is deduced by putting the name of the **monomer** in brackets and adding poly- as the **prefix**
- For example if propene is the alkene monomer used, then the name is **poly(propene)**
- Poly(ethene) is formed by the addition polymerisation of **ethene monomers**

Deducing the polymer from the monomer

- Polymer molecules are very large compared with most other molecule
- **Repeat units** are used when displaying the formula
- To draw a repeat unit:
  - Change the double bond in the monomer to a **single bond** in the repeat unit
  - Add a continuation bond to each end of the repeat unit
    - The bonds on either side of the polymer must **extend** outside the brackets (these are called extension or continuation bonds)
  - A small **subscript** n is written on the bottom right hand side to indicate a large number of repeat units
  - Add on the rest of the groups in the **same order** that they surrounded the double bond in the monomer

Examples of some addition polymers

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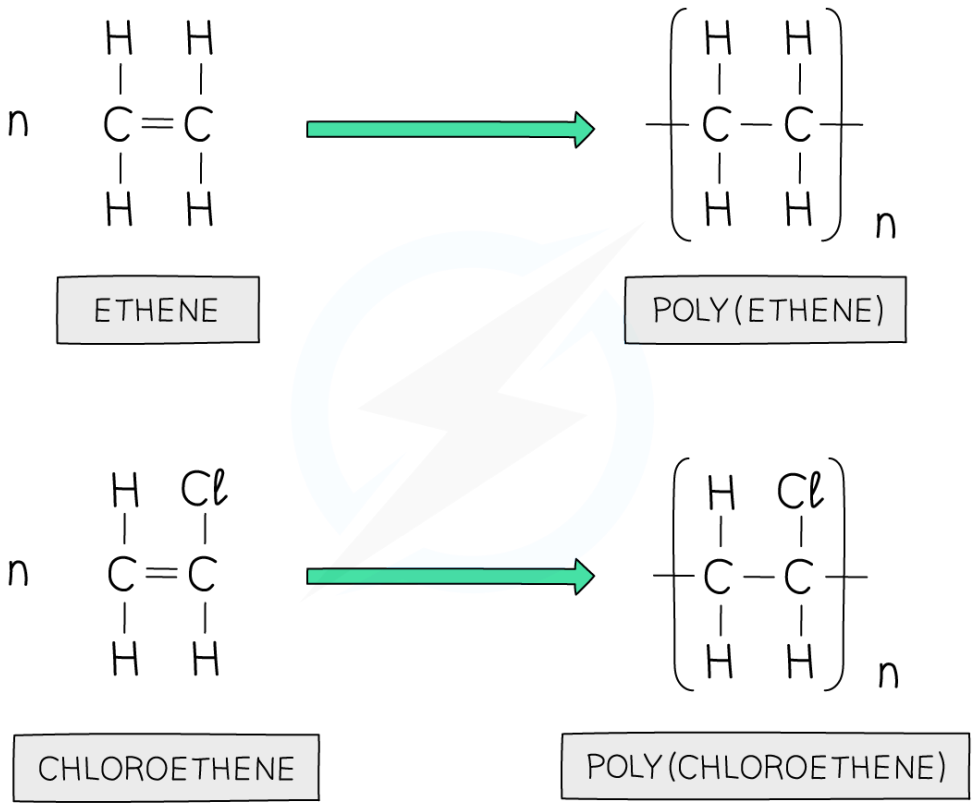

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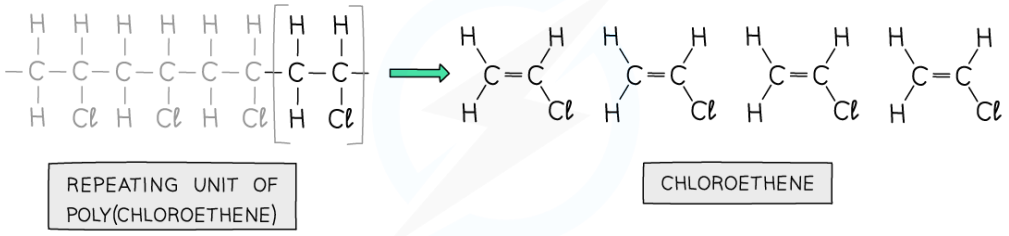
The repeat unit for the polymer should have an n in the bottom right hand corner

Deducing the monomer from the polymer

- To deduce the monomer from the polymer:
- Identify the repeating unit in the polymer
- Change the single bond in the repeat unit to a **double bond** in the monomer
- Remove the bond from each end of the repeat unit



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Th monomer has been identified, a double bond added and the atoms drawn in

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Examiner Tips and Tricks

You could be asked to draw the repeat unit for any given monomer and vice versa.

You would only need to draw the structure of one monomer if you have been given the polymer.

Condensation polymers

Extended tier only

- Condensation polymers are formed when two **different monomers** are linked together with the removal of a small molecule, usually water
- This is a key difference between condensation polymers and addition polymers:
  - Addition polymerisation forms the polymer molecule **only**
  - Condensation polymerisation forms the polymer molecule and one water molecule per linkage
- The monomers have **two** functional groups present, one on each end
- The functional groups at the ends of one monomer react with the functional group on the end of the other monomer, in so doing creating long chains of alternating monomers, forming the polymer

Forming nylon

- Nylon is a **polyamide** made from **dicarboxylic acid** monomers (a carboxylic with a -COOH group at either end) and **diamines** (an amine with an $-NH_2$ group at either end)
- Each -COOH group reacts with another $-NH_2$ group on another monomer
- An **amide linkage** is formed with the subsequent loss of one water molecule per link

Forming nylon

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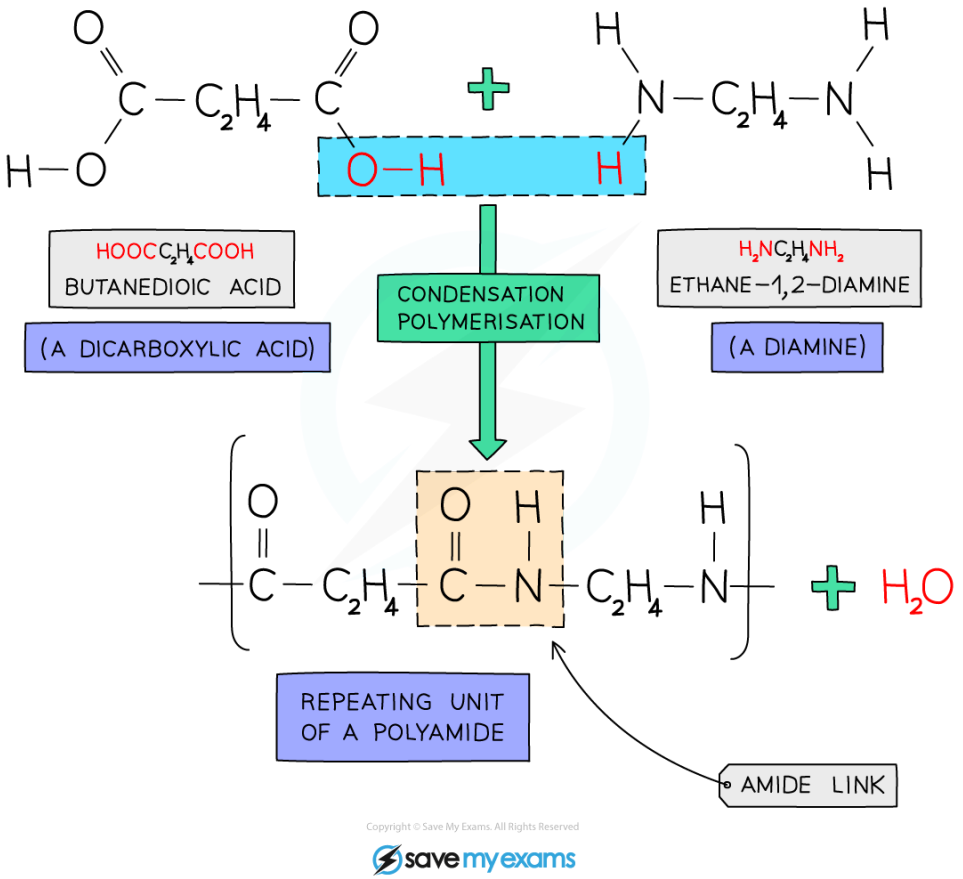

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Nylon is a polyamide formed from a dicarboxylic acid and a diamine

- The structure of nylon can be represented by drawing out the polymer using boxes to represent the carbon chains

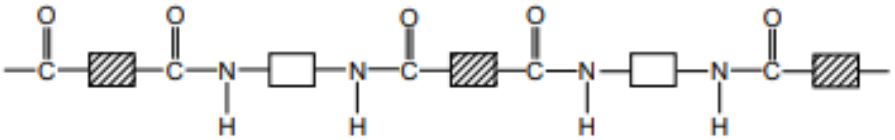


Diagram showing a section of nylon

Forming polyesters

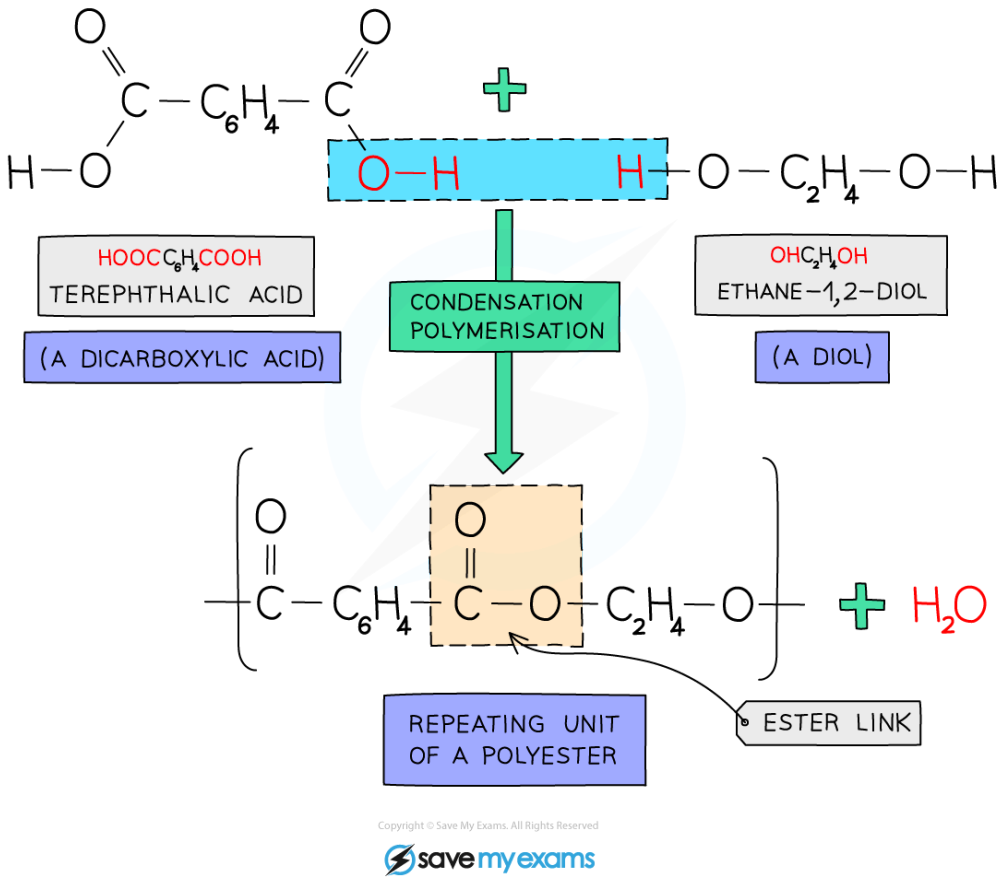
- **PET** or polyethylene terephthalate to give its full name, is a **polyester** made from **dicarboxylic** acid monomers (a carboxylic with a -COOH group at either end) and **diols** (alcohol with an -OH group at either end)
- Each -COOH group reacts with another -OH group on another monomer
- An **ester linkage** is formed with the subsequent loss of one water molecule per link

Your notes

- For every ester linkage formed in condensation polymerisation, one molecule of water is formed from the combination of a **proton** (H^+) and a **hydroxyl** ion (OH^-)
- **PET** is also used in synthetic fibres as is sold under the trade name of **terylene**

Your notes

Forming PET



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PET is a polyester formed from a dicarboxylic acid and a diol

- The structure of PET can be represented by drawing out the polymer using boxes to represent the carbon chains
- This can be done for all polyesters

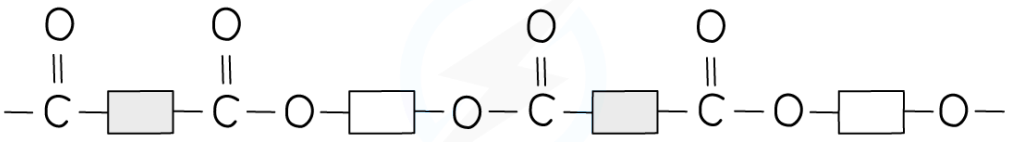

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Diagram showing a section of PET

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Examiner Tips and Tricks

You don't need to know the detailed chemical structure of PET, just the symbolic drawing showing the alternating blocks and the linking ester group. Be careful not to exactly repeat the linking group in nylon or PET; the link alternates by reversing the order of the atoms, rather like a mirror image.

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Plastics & their disposal

- Plastics are made from polymers
- Many polymers are chemically unreactive, which means that they are **non-biodegradable**
- This means that the disposal of plastics can cause environmental issues

Incineration

- Polymers release a lot of heat energy when they burn and produce carbon dioxide, which is a greenhouse gas that contributes to climate change
- Some polymers release **toxic fumes** when they burn
  - An example of this is poly(vinylchloride), which releases toxic hydrogen chloride gas when burned
- If incinerated by incomplete combustion, carbon monoxide will be produced which is a toxic gas

Polluting oceans

- Plastic waste is **accumulating in oceans** and causing huge disruptions to marine life

Landfills

- Waste polymers are disposed of in landfill sites
  - But, this takes up valuable land
- Most polymers are non-biodegradable
  - This means that micro-organisms, such as decomposers, cannot break them down
  - This causes sites to quickly fill up

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Disposal of polymers is an environmental problem

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PET re-polymerisation

Extended tier only

- PET stands for polyethylene terephthalate
  - This is a common polymer used to make things like plastic bottles
- It is a condensation polymer consisting of repeating ester units
  - So, PET is a type of polyester, like terylene
- One of the problems with recycling polymers is that the conditions needed to break them down, which are usually high temperatures and pressures, can degrade the monomers making them unusable for re-polymerisation
- PET is relatively easy to convert back into the monomers
- It can be depolymerised either using enzymes or by chemical methods
- Enzymes present in microbes breakdown the PET into the original monomers
- The same can be achieved using solvents a catalyst and mild heating
- The monomers are recovered and be **re-polymerised** into new PET
- This saves on resources and energy, reducing the carbon footprint of the production process

The re-polymerisation of PET

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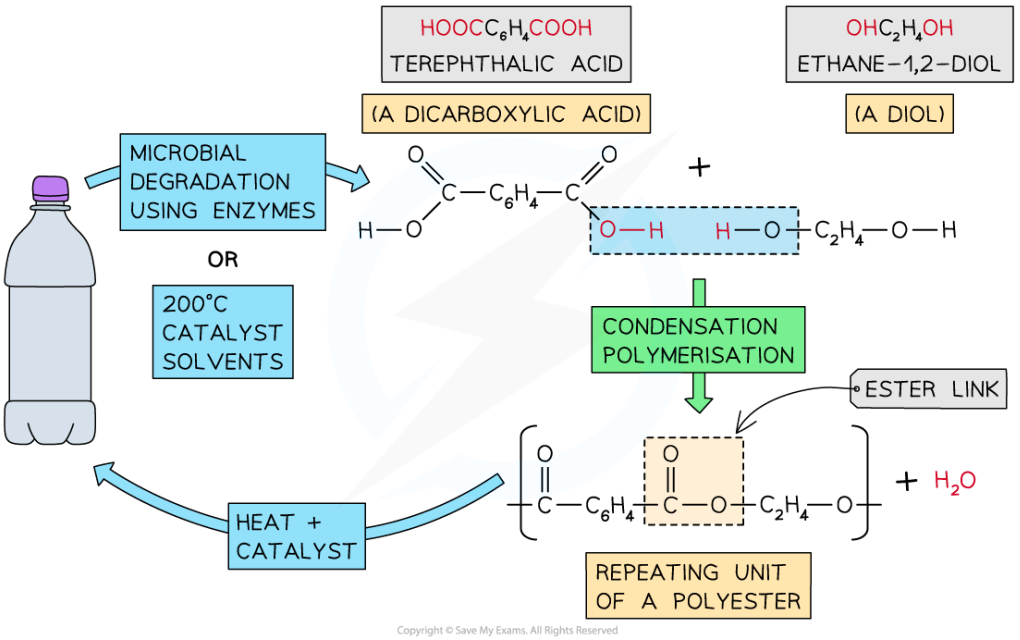


The breakdown of PET into its two monomers takes place using enzymes or chemical catalysts and mild conditions

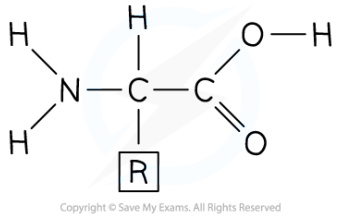
Your notes

Your notes

Proteins

Extended tier only

- Proteins are an example of **condensation** polymers
- They are formed from **amino acid** monomers joined together by **amide** links
- Amino acids are small molecules containing **NH_2** and **COOH** functional groups
- Due to containing amide links and being found in biological systems, proteins are known as **natural polyamides**
- In proteins, the amide links are known as peptide links
- There are **twenty** common amino acids, each differing by their side chain, represented by R



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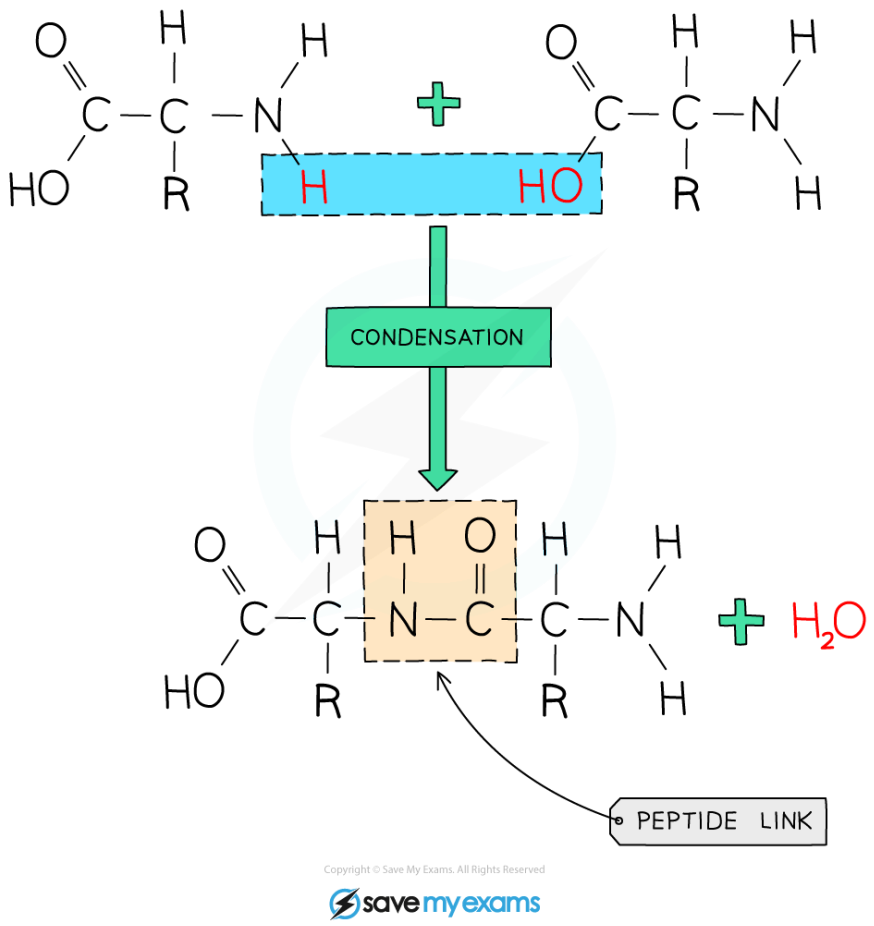
General structure of an amino acid

- Proteins can contain between 60 and 600 of these amino acids in different orders
- These are the monomers which polymerise to form the protein

The formation of a protein



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A protein is produced by a condensation polymerisation reaction

- The structure of proteins can be represented using the following diagram whereby the boxes represent the carbon chains

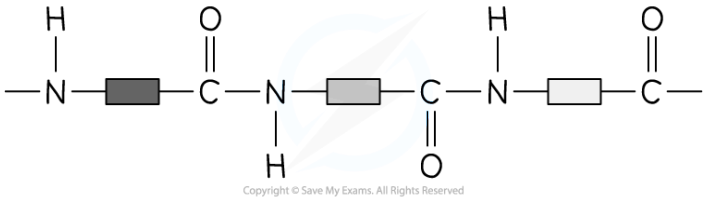

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Diagram showing a section of protein

Examiner Tips and Tricks

For your exam, you are only required to draw proteins using the boxes representing the carbon chains.

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