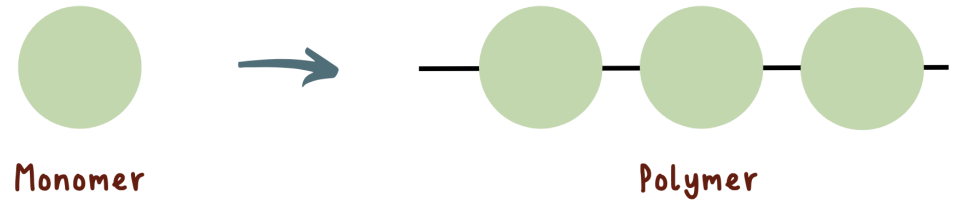
CAIE IGCSE Chemistry

11.8 Polymers

Notes

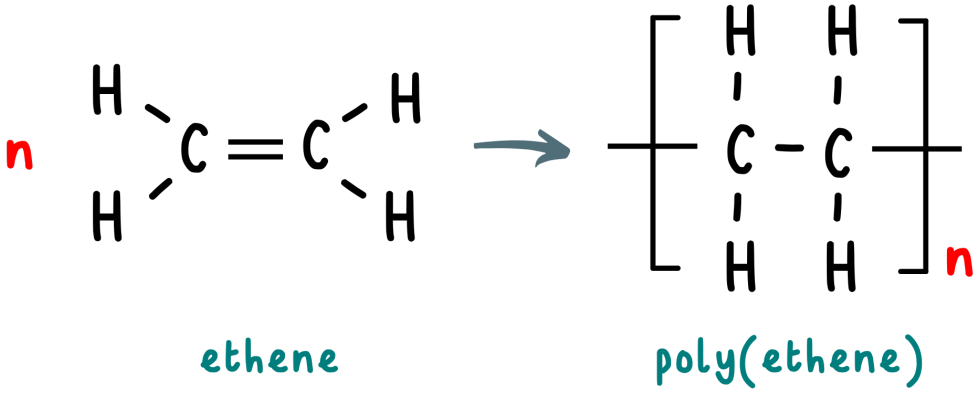
Define polymers…

- Polymers are large molecules built up from many smaller molecules, known as monomers, joined together by covalent bonds.
- 'Poly' means many, 'mono' means one.



Describe the formation of poly(ethene) as an example of addition polymerisation using ethene monomers

- Addition polymerisation occurs when unsaturated monomers (alkenes) bond together to form a long chain polymer through addition reactions.
- Poly(ethene) is an addition polymer made up of many ethene monomers joined together:
    - The double carbon=carbon bond in the ethene monomers is broken into a single covalent bond to allow the many monomers to join together by covalent bonds.
    - The formation of poly(ethene) is represented by the structure of the ethene monomer with *n* standing for the number of repeating units in the polymer.
    - Poly(ethene) is shown by its repeat unit with the outer bonds extended and square brackets around it with an n in the corner since drawing the entire long-chain molecule would be difficult.



State that plastics are made from…

- Plastics are made from polymers

Describe how the properties of plastics have implications for their disposal

- The disposal of plastics can be difficult because of the following properties:
    - Non-biodegradable plastics: Can take thousands of years to decompose so will build up in waste sites
    - Chemically unreactive: Microorganisms/decomposers are unable to break down the material
    - Mixed with other materials: Difficult to recycle into its constituent parts

Describe the environmental challenges caused by plastics, limited to:

(a) Disposal in landfill sites

- Non-biodegradable plastics are disposed in landfill sites, where they continue to build up and accumulate as they are unable to be broken down by decomposers

(b) Accumulation in oceans

- Plastics also end up in oceans due to improper disposal where they accumulate and cause harm to aquatic life, ending up in the food chains and causing biological harm

(c) Formation of toxic gases from burning

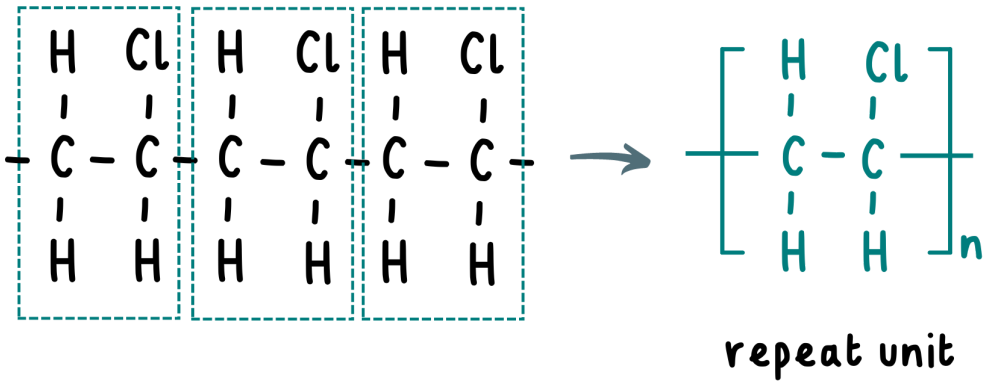
- Incinerating plastics is done to release thermal energy which can be used to generate electricity
- But in burning the polymers there are environmental challenges such as:
    - Carbon dioxide, a greenhouse gas, is released
    - Plastics that contain chlorine, such as PVC, burn and release toxic hydrogen chloride gas
    - Carbon monoxide, a toxic gas, is released into the atmosphere if incomplete combustion is done

(Extended only) Identify the repeat units and/or linkages in addition polymers and in condensation polymers

- As mentioned above, repeat units are used to represent polymers as drawing the entire long chain molecule would be difficult

Addition polymers

- Addition polymers are formed from many unsaturated monomers (contain a C=C double bond)
- To identify the repeat unit of an addition polymer:

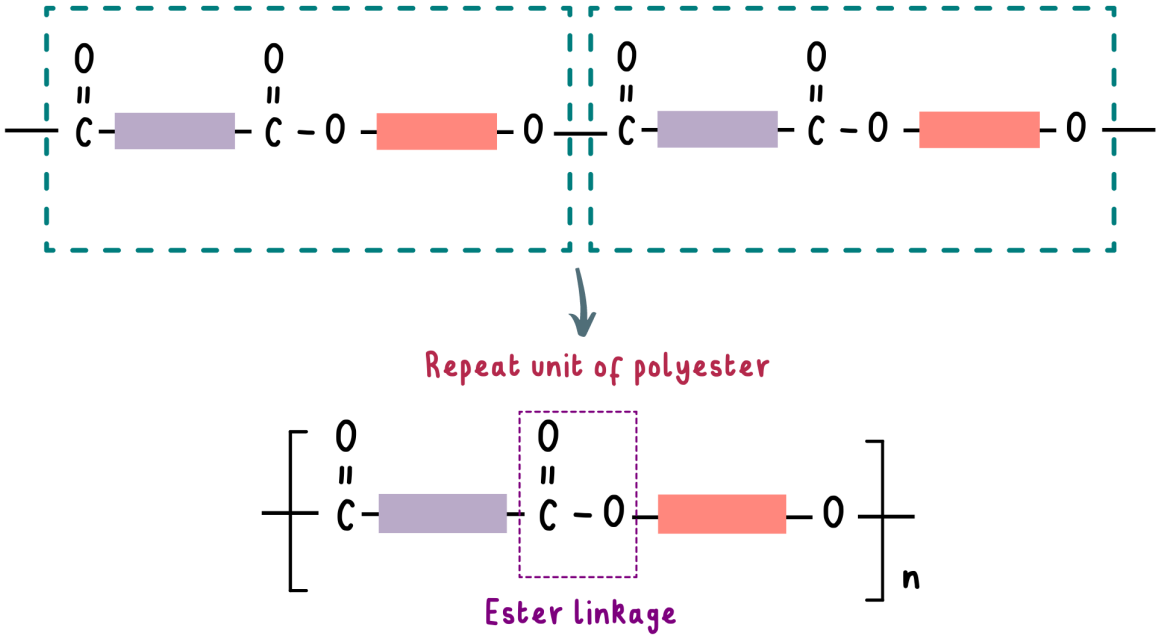


1. Spot which group is being repeated in the long-chain molecule and circle
2. Draw one diagram of the group that was repeated and extend the continued bond on either side of the carbon atoms
3. Draw square brackets around the repeat unit and add a small *n* on the lower right hand corner to represent the number of repeating units in the polymer chain.

Condensation polymers

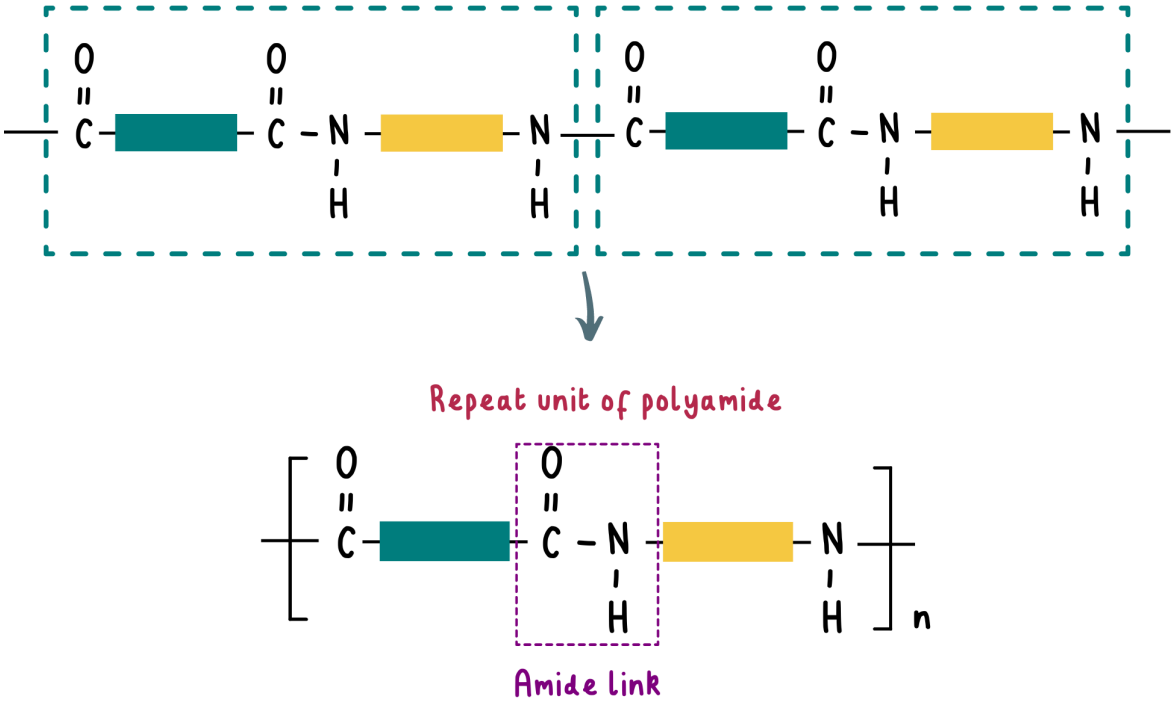
- Condensation polymers are formed from monomers with two functional groups such as:
    - Dicarboxylic acids and diols will form polyesters and have an ester linkage in each repeat unit
        - The ester linkage is -COO-
    - Dicarboxylic acids and diamines will form polyamides and have an amide linkage in each repeat unit
        - The amide linkage is -CONH-

To identify the repeat unit and ester linkage of a polyester



1. Spot which group is being repeated in the long-chain molecule and circle
2. Draw one diagram of the group that was repeated and extend the continued bond on either side of the carbon atoms
3. Draw square brackets around the repeat unit and add a small *n* on the lower right hand corner to represent the number of repeating units in the polymer chain.
4. A repeat unit of a polyester will have a -C=O and an -O- on either side
5. The ester linkage is circled in the diagram
6. The purple and orange rectangles represent any length and type of carbon chain in the dicarboxylic acid and diol

To identify the repeat unit and ester linkage of a polyamide



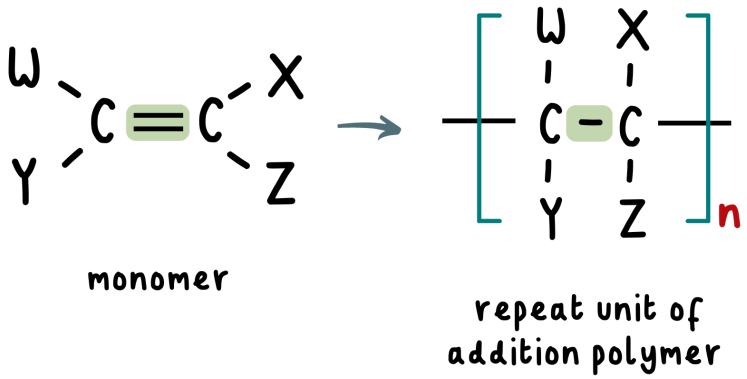
1. Spot which group is being repeated in the long-chain molecule and circle
2. Draw one diagram of the group that was repeated and extend the continued bond on either side of the carbon atoms
3. Draw square brackets around the repeat unit and add a small *n* on the lower right hand corner to represent the number of repeating units in the polymer chain.
4. A repeat unit of a polyamide will have a -C=O and a -NH- on either side
5. The amide linkage is circled in the diagram
6. The green and yellow rectangles represent any length and type of carbon chain in the dicarboxylic acid and diamine

(Extended only) Deduce the structure or repeat unit of an addition polymer from a given alkene and vice versa

Addition polymers

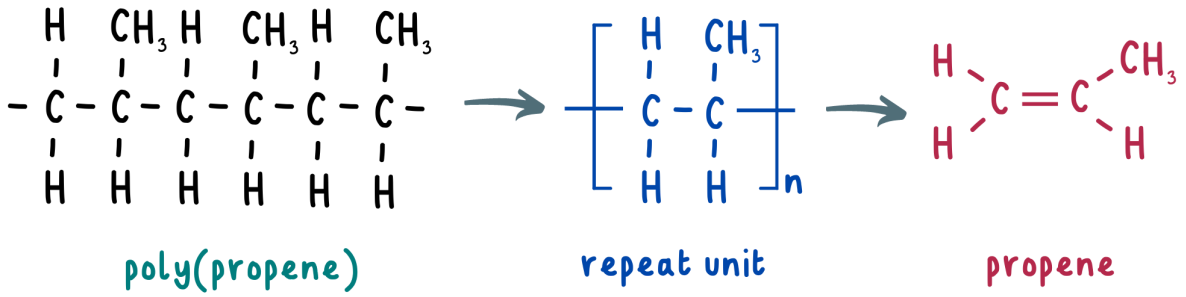
- Addition polymers are formed from many unsaturated monomers (contain a C=C double bond)

Drawing the repeat unit of an addition polymer from a given alkene



1. Replace the double C=C bond to a single C-C covalent bond
2. Both carbon atoms now have another bond that can be formed (carbon atoms have 4 bonds) so this is drawn on either side of the repeat unit extended out of the square brackets
3. An *n* is written on the lower right hand corner of the square brackets to represent the number of repeat units in the polymer

Drawing the alkene monomer of an addition polymer from its structure/repeat unit

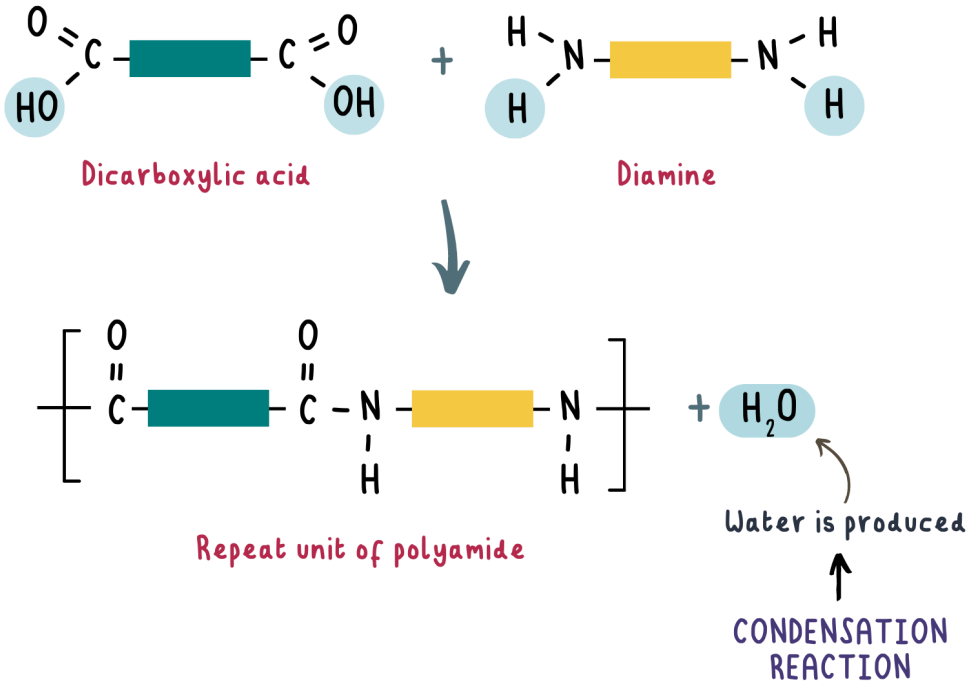


1. Identify the repeat unit in the polymer structure and draw it separately
2. Replace the single C-C covalent bond with a double C=C bond to convert it to its alkene
3. Erase the square brackets and carbon extended bonds to ensure each carbon only has 4 bonds.

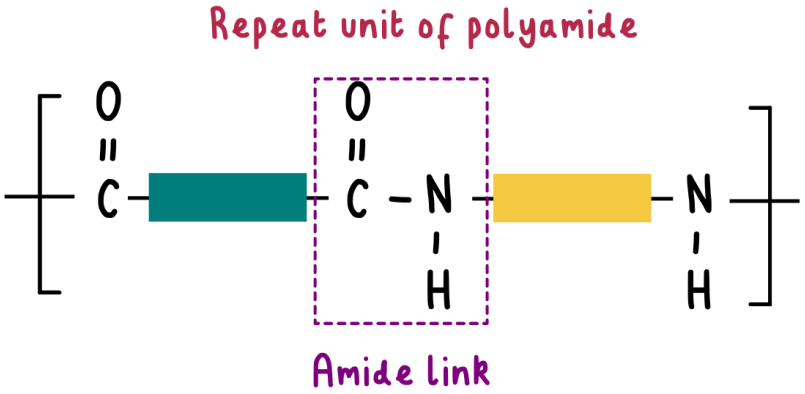
(Extended only) Deduce the structure or repeat unit of a condensation polymer from given monomers and vice versa, limited to:

(a) Polyamides from a dicarboxylic acid and a diamine

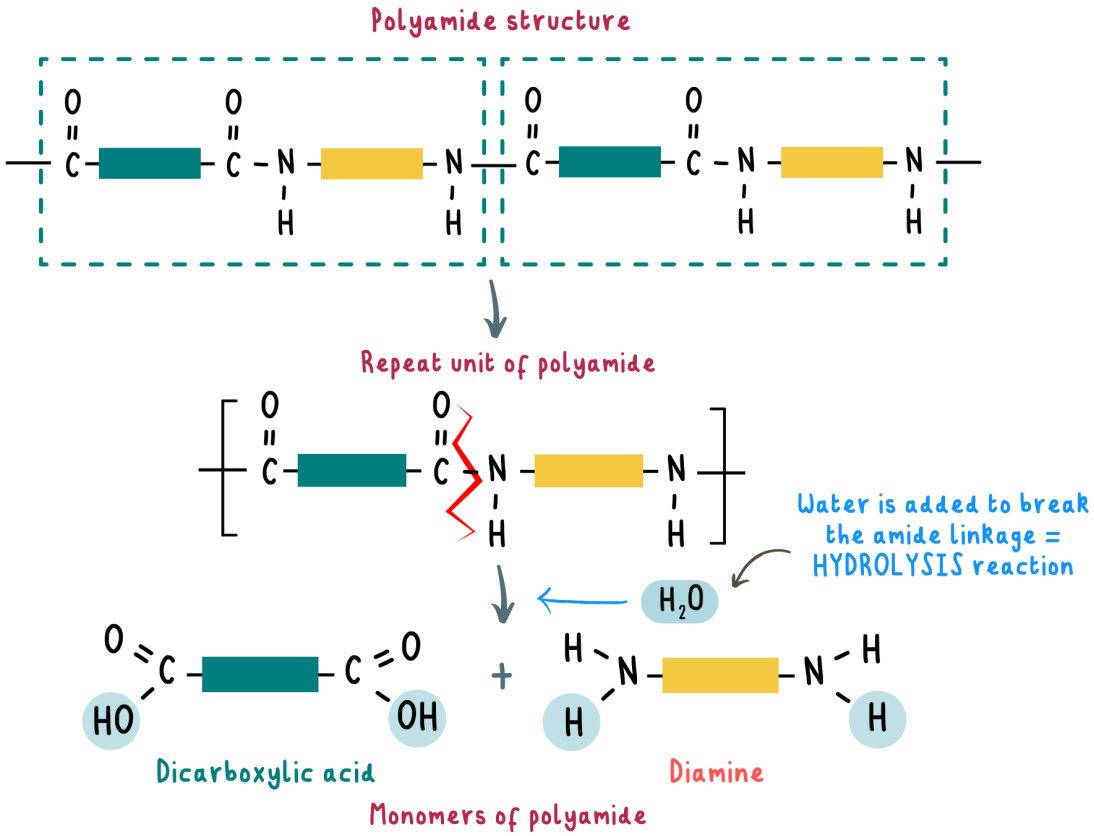
Drawing the repeat unit/structure of a polyamide from its monomers



- The hydroxyl groups (-OH) on either side of the dicarboxylic acid is removed and combined with the H atoms that are removed from the amine groups ($-NH_2$) on either side of the diamine to form water
- The remaining monomers are joined together by an amide linkage



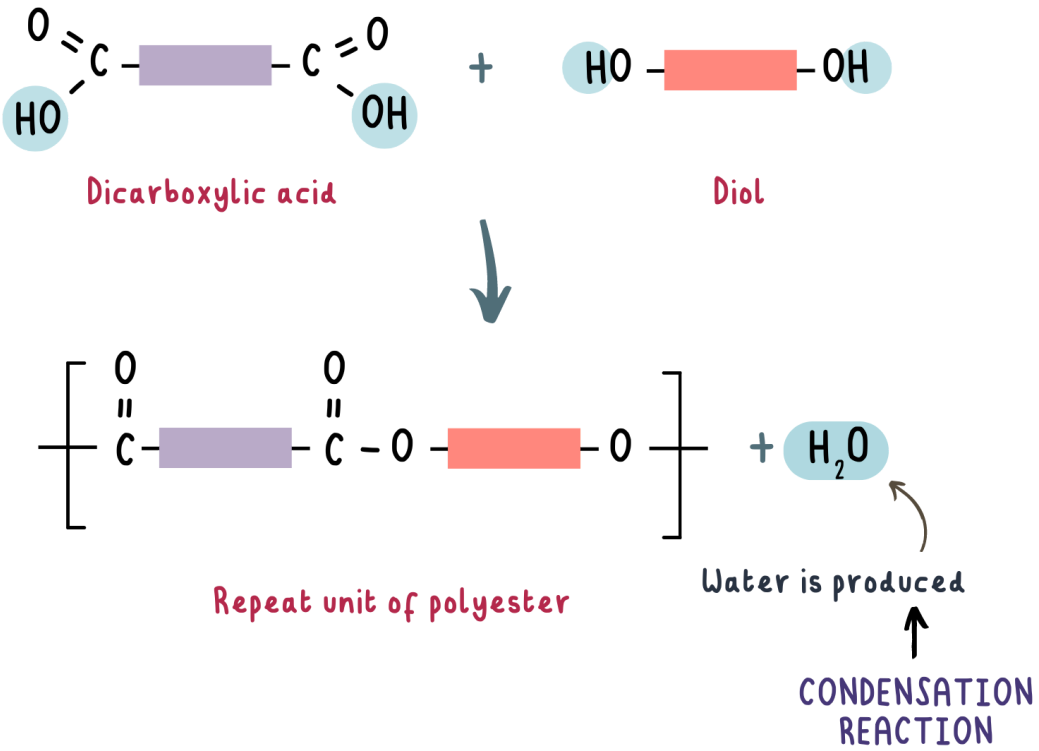
Drawing the monomers from the structure/repeat unit of a polyamide



1. Identify the repeat unit in the polyamide structure and draw it separately
2. The amide linkage is broken by the addition of water (hydrolysis reaction)
3. The monomers are separated into dicarboxylic acid (with a carboxyl group on either end of the molecule) and a diamine (with an amine group on either end of the molecule)

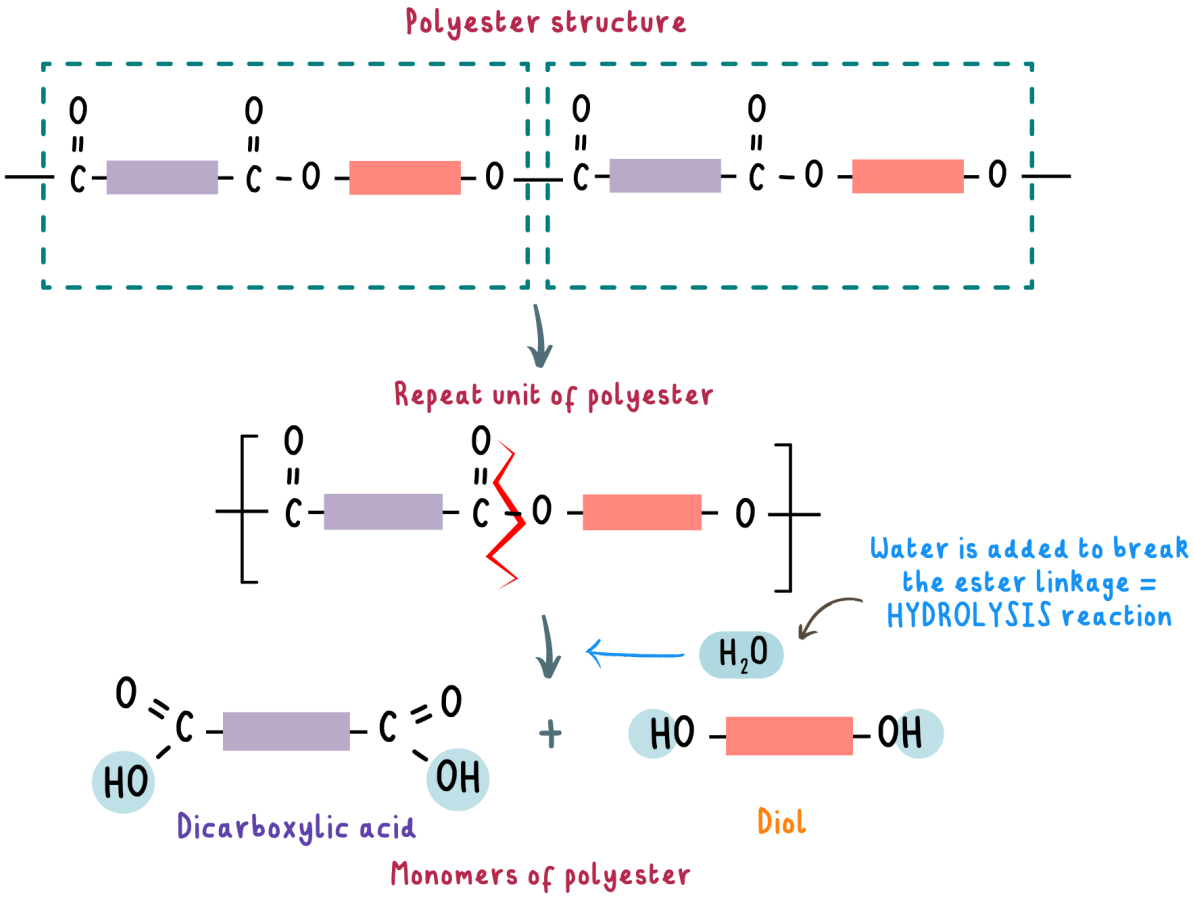
(b) Polyesters from a dicarboxylic acid and a diol

Drawing the repeat unit/structure of a polyester from its monomers



- The -OH on either side of the dicarboxylic acid is removed and combined with the H atoms that are removed from the hydroxyl groups on either side of the diol to form water
- The remaining monomers are joined together by an ester linkage

Drawing the monomers from the structure/repeat unit of a polyester



1. Identify the repeat unit in the polyester structure and draw it separately
2. The ester linkage is broken by the addition of water (hydrolysis reaction)
3. The monomers are separated into dicarboxylic acid (with a carboxyl group on either end of the molecule) and a diol (with a hydroxyl group on either end of the molecule)

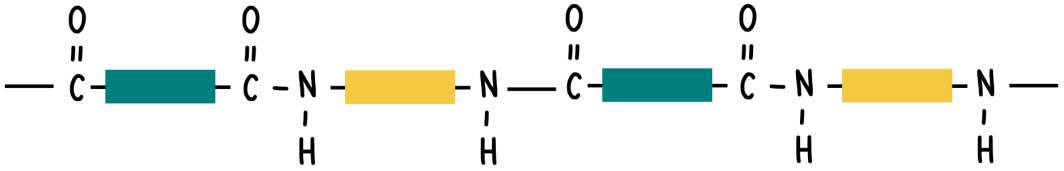
(Extended only) Describe the differences between addition and condensation polymerisation

Addition polymerisation	**Condensation polymerisation**
Forms a polymer from alkene monomers	Forms a polymer by reacting compounds with two different functional groups together
The C=C bond is removed from the monomers to form a saturated polymer	A small molecule such as water is produced
Addition polymers are long chains of C-C single bonds	Condensation polymers can be polyesters with ester linkages or polyamides with amide linkages

(Extended only) Describe and draw the structure of:

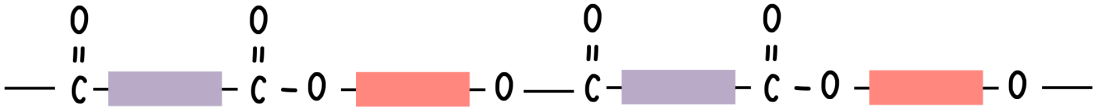
(a) Nylon, a polyamide

- Nylon is a type of polyamide formed from a dicarboxylic acid and diamine by condensation polymerisation
- The structure of nylon is represented as:



(b) PET, a polyester (The full name for PET, polyethylene terephthalate, is not required)

- PET is a type of polyester formed from a dicarboxylic acid and diol by condensation polymerisation
- The structure of PET is represented as:

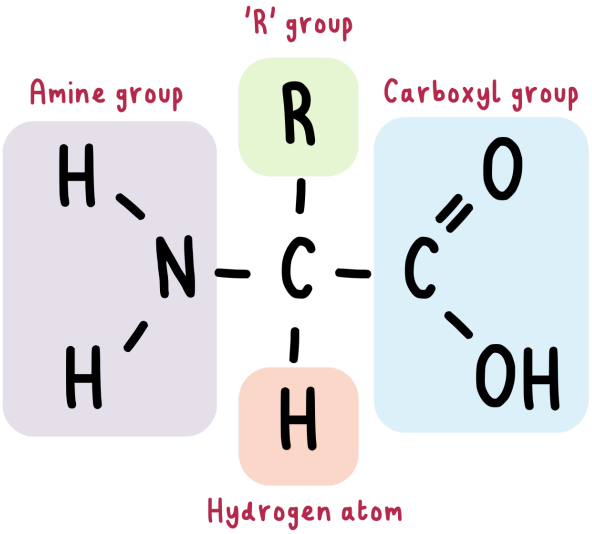


(Extended only) State that PET can be

- PET can be converted back into monomers (dicarboxylic acid and diol) through hydrolysis and re-polymerisation

(Extended only) Describe proteins as natural polyamides and that they are formed from amino acid monomers with the general structure

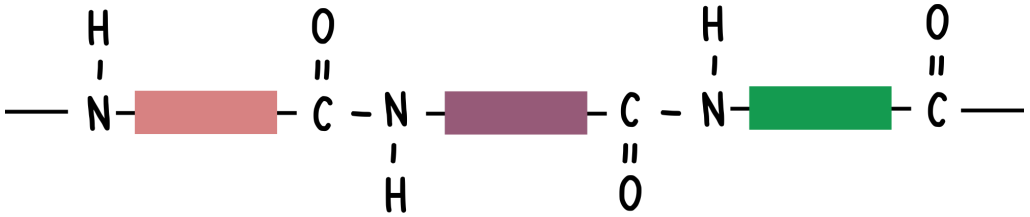
- Proteins are natural polyamides
- They are formed from amino acid monomers
- Amino acids have the general structure:



  - A central carbon atom is bonded to:
    - An amine ($-NH_2$) group
    - A carboxyl (-COOH) group
    - An 'R' group- any side group
    - A hydrogen atom

(Extended only) Describe and draw the structure of proteins as:

- The general structure of proteins can be drawn as:



  - The rectangles represent the different types of amino acids (have same general structure but different 'R' groups
  - Proteins are joined together like polyamides with amide linkages