3.12 Polymers

Condensation polymerisation:

- This is the joining of 2 monomers while eliminating a small molecule - H_2O or HCl
- The functional group on one monomer joins with a different functional group in another molecule.

There are 2 types of condensation polymerisations covered:

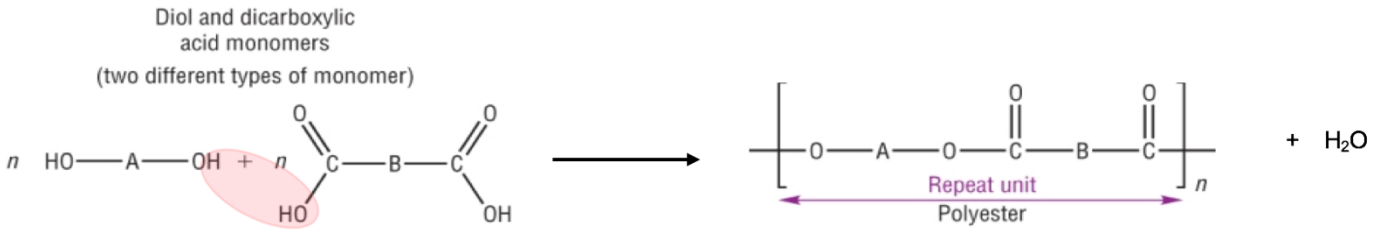
1) **Polyesters - from alcohols and carboxylic acids**
2) **Polyamides - from amines and carboxylic acids**

1) polyesters:

- A polyester is made by condensing an alcohol and carboxylic acid.
- The joining link is an **ester** functional group, hence poly**ester**.
- A polyester is can be made in one of 2 ways:

a) 2 monomers: A Diol and a Dicarboxylic acid:

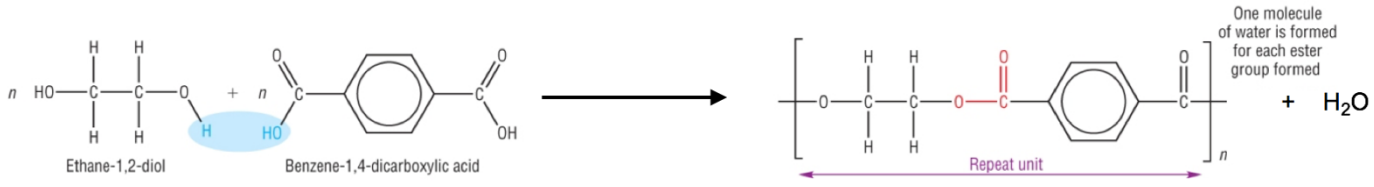
- As with esters, the OH from the carboxylic acid is lost with the H from the alcohol.



- It is described as a **condensation reaction** as **water** is eliminated as the **ester link** is formed.
- A repeat unit is one section of the polymer that repeats.

Example:

- Terylene is made from the reaction between the monomers ethane-1,2-diol and benzene-1,4-dicarboxylic acid.



Uses:

- Plastic bottles
- Clothing
- Carpets

Questions:

For each of the following questions, write out the monomers, then a repeat unit of the polymer:

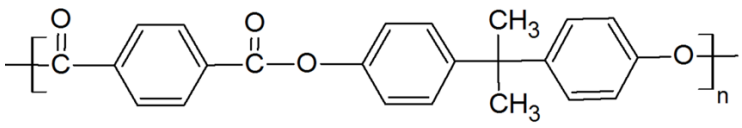
1) Ethanedioc acid and butan-1,4-diol:

Monomers	Polymer

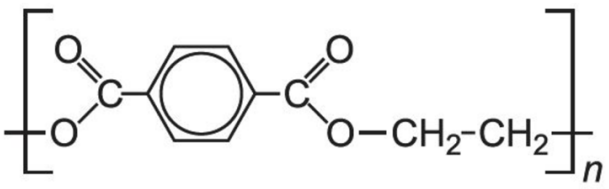
2) Propanedioc acid and ethan-1,2-diol:

Monomers	Polymer

3) Draw the monomers that make the following condensation polymer:

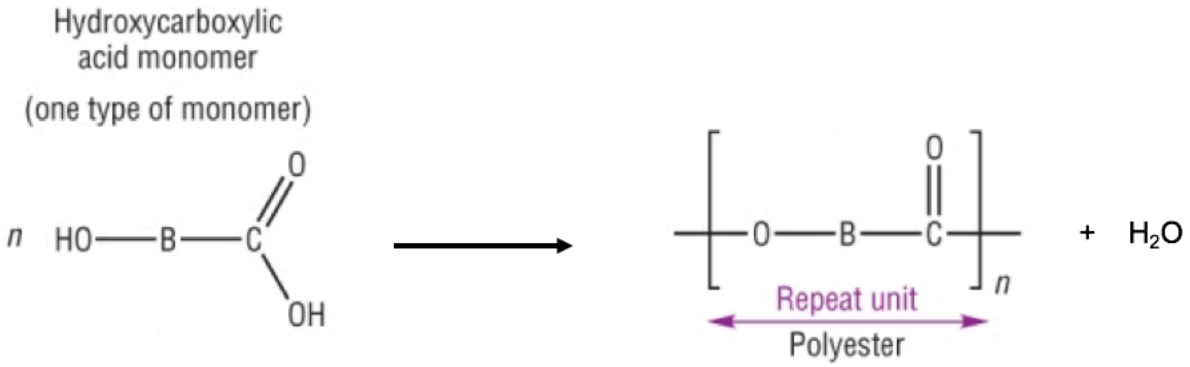
Monomers	Polymer
	

4) Challenging:
Draw the acyl chloride and diol that made the following condensation polymer:

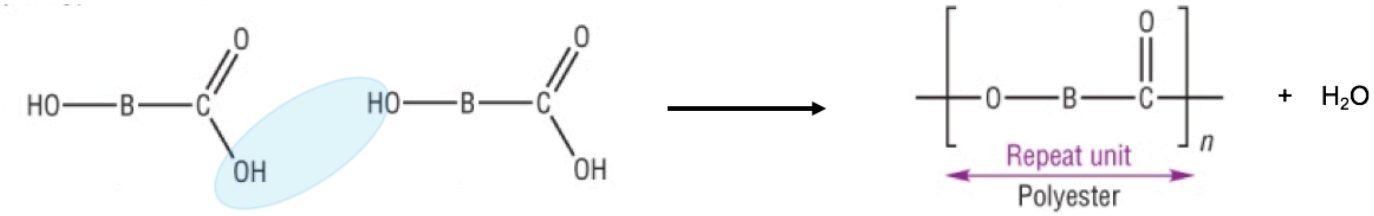
Monomers	Polymer
	

b) 1 monomer: Hydroxycarboxylic acid

- As before, the carboxylic acid loses the OH, the alcohol loses the H.
- The difference this time is that the 2 functional groups are in the same molecule.



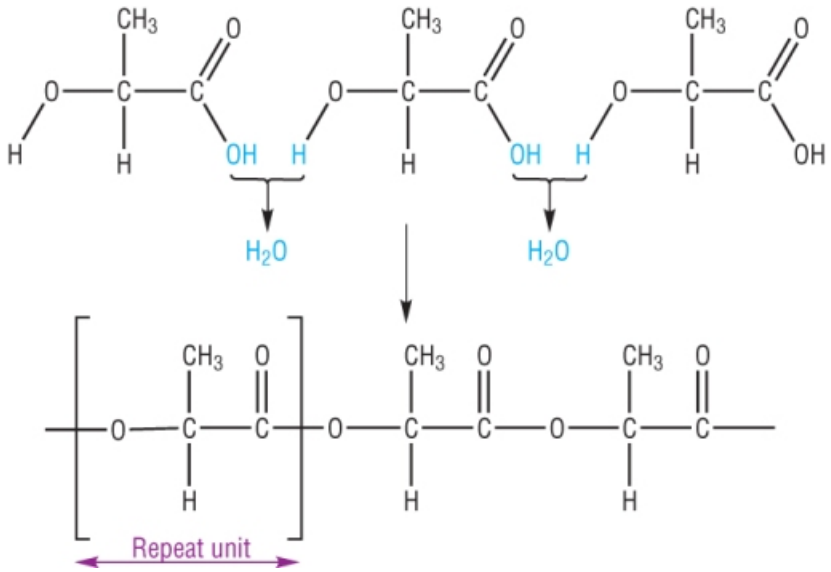
- It is probably easier to see written as:



- It is still a **condensation reaction** as **water** is eliminated as the **ester link** is formed.
- A repeat unit is one section of the polymer that repeats.

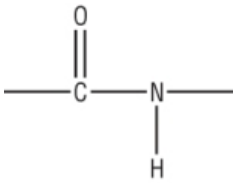
Example:

- Poly(lactic acid), PLA is made from the reaction between the same monomer containing an **OH** and a **COOH** group.



2) Polyamides:

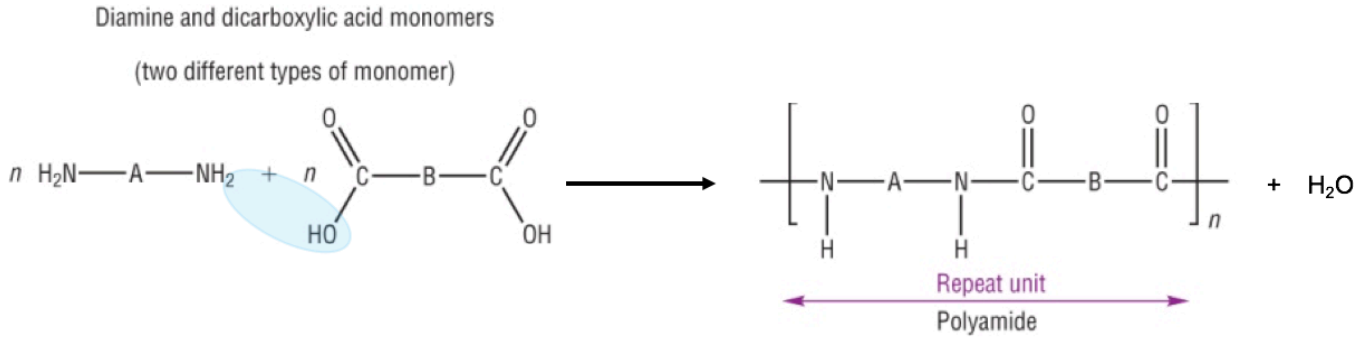
- **Polyamides** are made by an **amine / carboxylic acid** condensation reaction.
- The resulting link is an **amide** functional group, hence the poly**amide**



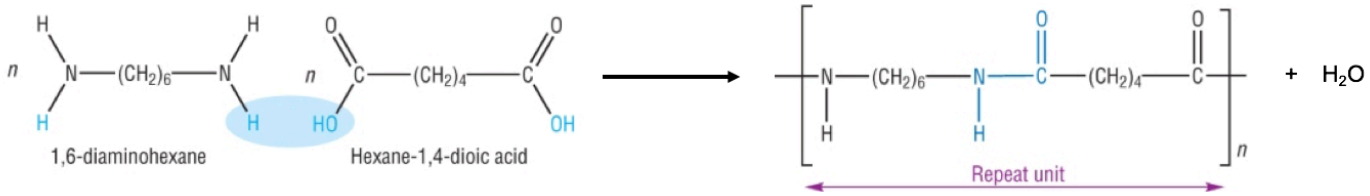
- A poly**amide** can be made in one of 2 ways:

a) 2 monomers: Diamine and Dicarboxylic acids-

- As with amides, the OH from the carboxylic acid is lost with the H from the amine.
- It is a **condensation reaction** as **water** is eliminated as the **amide link** is formed.
- A repeat unit is one section of the polymer that repeats.



Example: Nylon 6,6:



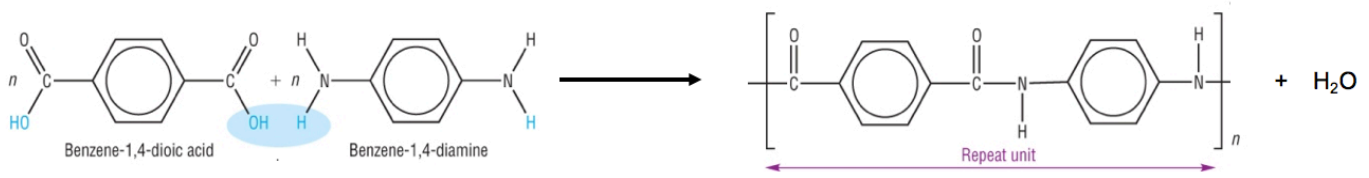
- Nylon is made from the reaction between the monomers 1,6-diaminohexanel and hexane-1,4-dioic acid.
- Nylon 6,6 is a strong material, resistant to abraision.

Uses:

- Clothing
- Carpets
- Rope
- Parachutes

Example: Kevlar:

- Another is **kevlar** - very strong polymer used in fire and bullet proof vest and crash helmets:



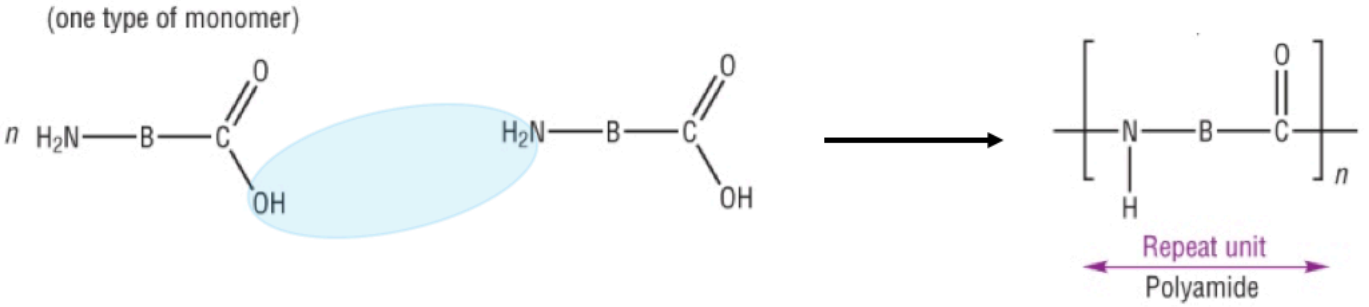
- Kevlar is made from the reaction between the monomers benzene - 1,4 - dioic acid and benzene – 1,4 – diamine.
- The polymer molecules are flat so can pack closely together.
- It can H bond between the N and the H in the amide linkage group
- Very strong material.

Uses:

- Bullet proof vests
- Crash helmets
- Fire resistant material

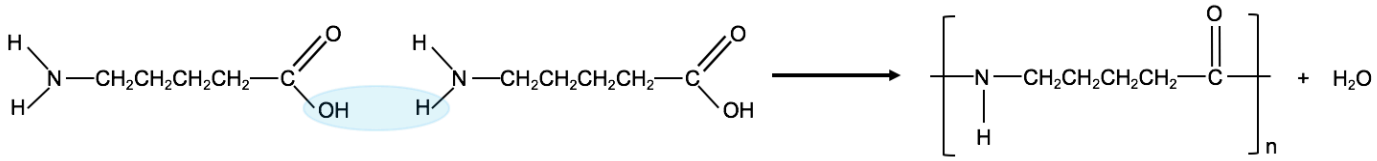
b) 1 monomer: Hydroxycarboxylic acid / Amino acids:

- A monomer with an amine group at one end and a carboxylic acid group at the other.
- These can:
  - Hydroxycarboxylic acids – where the COOH and the NH_2 are joined to different carbon
  - Amino acids – where the COOH and the NH_2 are joined to the same carbon



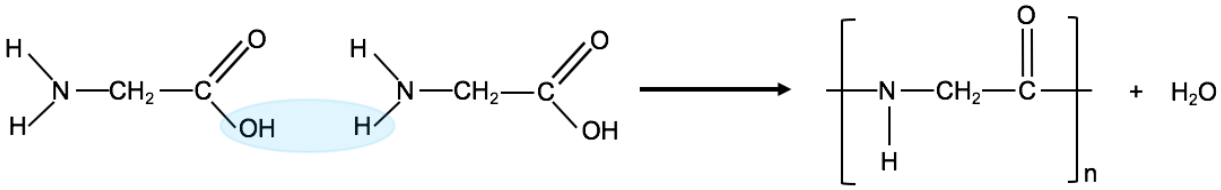
Example: Nylon 6:

- From a hydroxycarboxylic acid, 5 amino pentanoic acid:

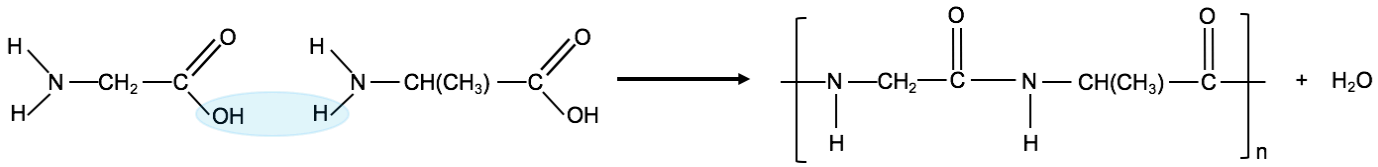


Example: Polypeptides and proteins

- From amino acids:
  - Same amino acid:



  - Different amino acids:



- It is still a **condensation reaction** as **water** is eliminated as the **amide link** is formed.
- A repeat unit is one section of the polymer that repeats.
- Polypeptides and proteins from amino acids will be covered in more detail in 3.13/

Questions:

For each of the following questions, write out the monomers, then a repeat unit of the polymer:

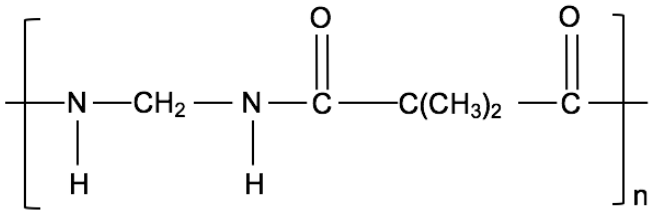
1) Ethanedioc acid and butan-1,4-diamine:

Monomers	Polymer

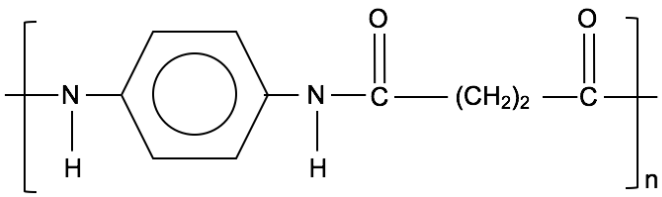
2) Propanedioc acid and ethan-1,2-diamine:

Monomers	Polymer

3) Draw the monomers that make the following condensation polymer:

Monomers	Polymer
	

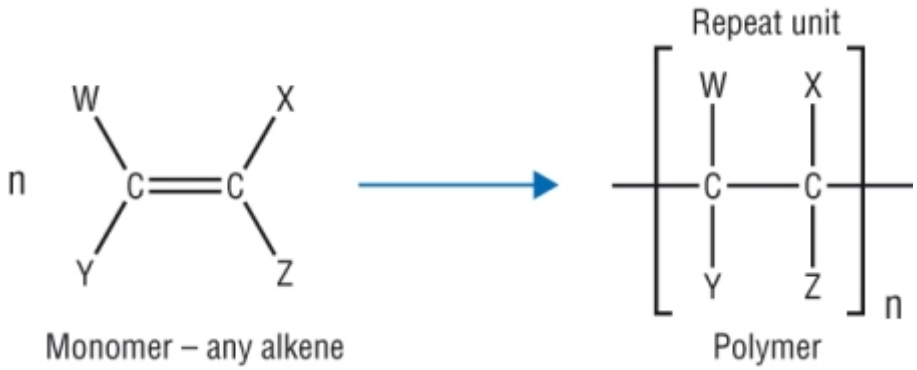
4) Challenging:
Draw the acyl chloride and diamine that made the following condensation polymer:

Monomers	Polymer
	

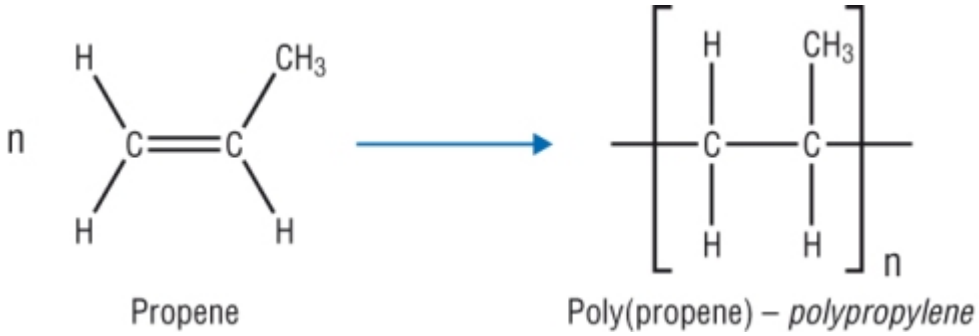
AS Recap:

Addition polymers:

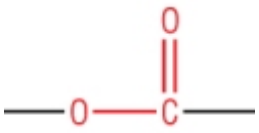
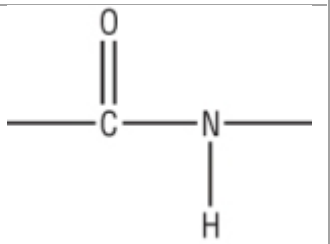
- This was covered in AS:



- These are made from one monomer only - containing a C=C
- Only one product is formed.
- Using different alkene molecules, different addition polymers can be made:



Comparison of addition and condensation polymers:

	Addition polymerisation	**Condensation polymerisation**	
		Polyester	**Polyamide**
Functional groups	**C=C**	**COOH / OH**	**COOH / NH_2**
No monomers	1	1 or 2	1 or 2
Products	poly(alkene)	polyester + water / HCl	polyamide + water / HCl
linkage	C-C		
Physical properties	→ Increase in rigidity →		
	→ Increase in intermolecular forces between chains →		
	VDW between chains	Permanent dipole between chains	H bonding between chains

Breaking down polymers

Addition polymers: Cannot be broken down as they are chemically inert – **Non-biodegradable**

Condensation polymers: Can be hydrolysed - **Biodegradable**

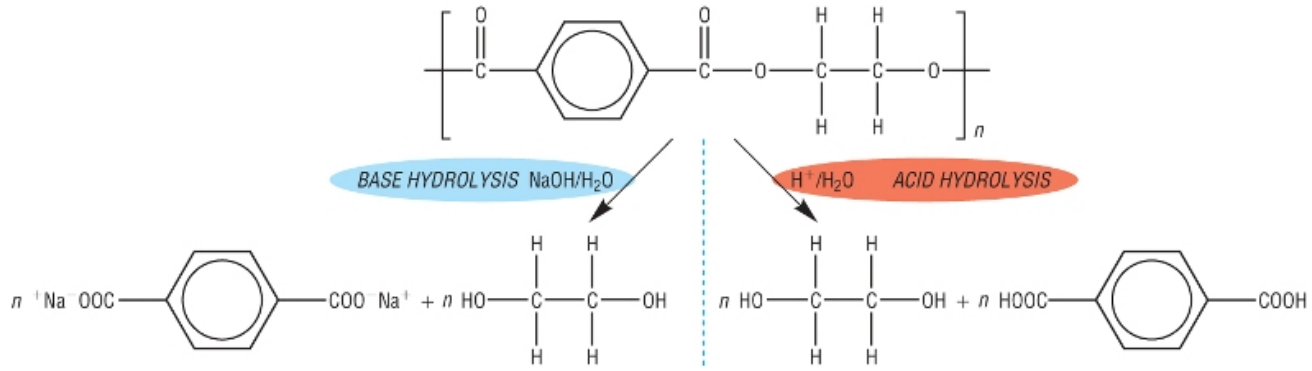
- If condensation **polymerisation eliminate water,** then they can be **hydrolysed with the addition of water**
- 2 condensation polymers have been covered and both can be hydrolysed:

Definitions:

> ***Hydrolysis:***
>
> ***The breaking of a bond using water***

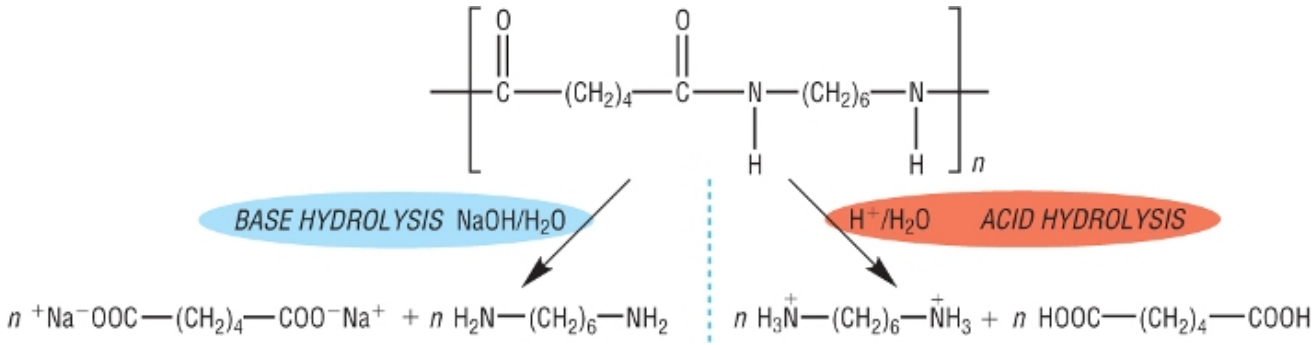
1) Hydrolysis of polyesters:

- In carbonyl compounds we saw that esters can be hydrolysed in acidic or basic conditions.
- This gave the corresponding alcohol and carboxylic acid (or salt of acid - base)
- **Poly**esters can be hydrolysed in exactly the same way with **hot aqueous acid / aqueous alkali**.
- The monomers making up the polymer are produced (or salt if base hydrolysis used):



2) Hydrolysis of polyamides:

- **Poly**esters can also be hydrolysed with **hot aqueous acid / aqueous alkali**.
- The monomers making up the polymer are produced - ammonium in acidic conditions - carboxylate salts in basic:



Degradable polymers:

- Most plastic packaging is addition polymers which will not degrade in landfill sites.
- Environmental demand has produced biodegradable plastics.
- These have polar bonds that will hydrolyse similar to polyesters and polyamides.
- A polymer based on tapioca starch will decompose in 28 days when buried.

Methods of disposal:

Land fill - burying:

- Advantage:
  - Cheap

- Disadvantages:
  - Non-biodegradable does not decompose
  - Requires land
  - Decomposition of degradable waste often produces CH_4, a greenhouse gas
  - Decomposition releases water soluble toxins → water supply

Combustion:

- Advantage:
  - Produces heat energy

- Disadvantage:
  - CO_2 released – greenhouse gas
  - CO released – toxic
  - C released – aggravates respiratory problems
  - Styrene can produce toxic styrene vapour
  - Chlorinated polymers release HCl gas which would need to be removed

Sort and recycle

- Advantages:
  - Remoulded
  - Conserves oil reserves – long polymers can be 'cracked' into shorter molecules and reused
  - Saves energy from oil refining
  - Waste not going to landfill
  - CO_2 not emitted

- Disadvantage:
  - Collection and transporting requires man power – expensive
  - Polymers cannot be separated by machinery – man power – expensive
  - Often cannot be re used as same plastic – used to make other polymer material

Questions:

1) State the type of polymerisation that occurs between the following molecules:

a) Ethene

b) Ethane-1,2-dicarboxylic acid & Propan-1,3-diol

c) Phenylethene

d) 3-hydroxy propanoic acid

e) Propane-1,3-dicarboxylic acid & Ethan-1,2-diamine

f) 4-amino butanoic acid

2) Draw a repeat unit for the polymer formed for polymers formed in question 1:

a)	b)
c)	d)
e)	f)

3) Name the strongest intermolecular forces that exist between the polymer chains in 1(&2):

a)	b)	c)
d)	e)	f)

4) State and explain which of the polymers in question 1 are biodegradable:

5) Draw the products for the acid hydrolysis, using HCl, of the biodegradable polymers outlined in question 4:

6) Draw the products for the base hydrolysis, using NaOH, of the biodegradable polymers outlined in question 4:

7) For each method of disposal, state and explain one advantage and one disadvantage:

Method of disposal	Advantage	Disadvantage