

## Polymers

There are two **types of polymerisation: addition and condensation**

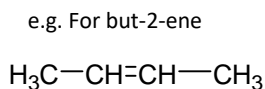
### Addition Polymerisation

An **addition polymer** forms when unsaturated monomers react to form a polymer  
Monomers contain C=C bonds

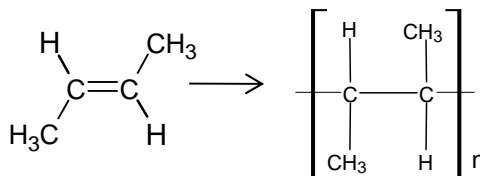
Poly(alkenes) are chemically inert due to the strong C-C and C-H bonds and **non-polar** nature of the bonds and therefore are non-biodegradable.

Chain forms when same basic unit is repeated over and over.

You should be able to draw the polymer repeating unit for any alkene



It is best to first draw out the monomer with groups of atoms arranged around the double bond



### Condensation Polymerisation

The two most common **types** of condensation polymers are **polyesters** and **polyamides** which involve the formation of an **ester** linkage or an **amide** linkage.

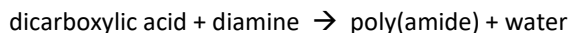
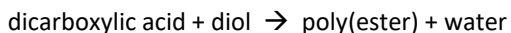
In condensation polymerisation there are two different monomers that add together and a small molecule is usually given off as a side-product e.g.  $\text{H}_2\text{O}$  or  $\text{HCl}$ .

The monomers usually have the same functional group on both ends of the molecule e.g. di-amine, di carboxylic acid, diol, diacyl chloride.

Forming polyesters and polyamide uses these reactions we met earlier in the course

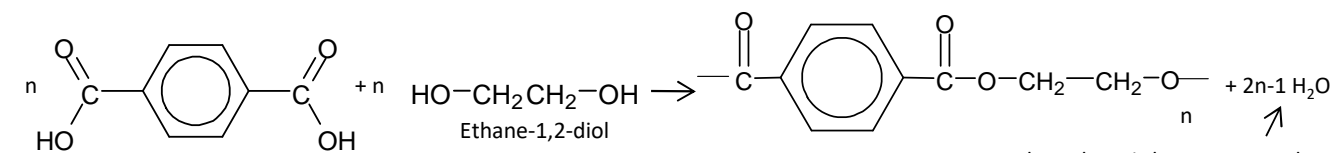


If we have the same functional group on each end of molecule we can make polymers so we have the analogous equations:



Using the carboxylic acid to make the ester or amide would need an acid catalyst and would only give an equilibrium mixture. The more reactive acyl chloride goes to completion and does not need a catalyst but does produce hazardous  $\text{HCl}$  fumes.

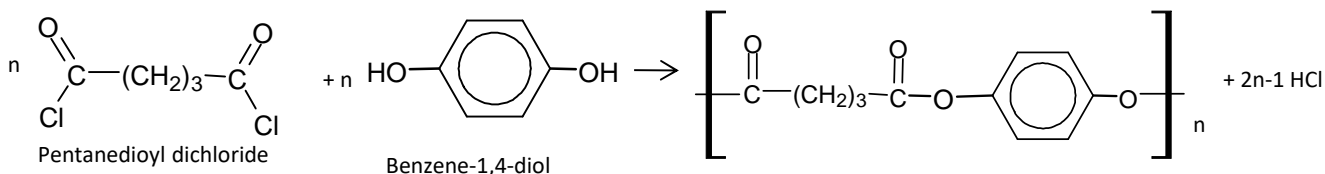
### Terylene- a common polyester



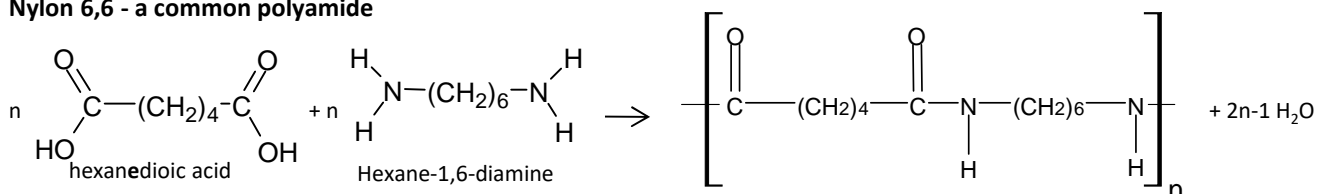
Benzene-1,4-dicarboxylic acid

Terylene fabric is used in clothing, tire cords

The -1 here is because at each end of the chain the H and OH are still present

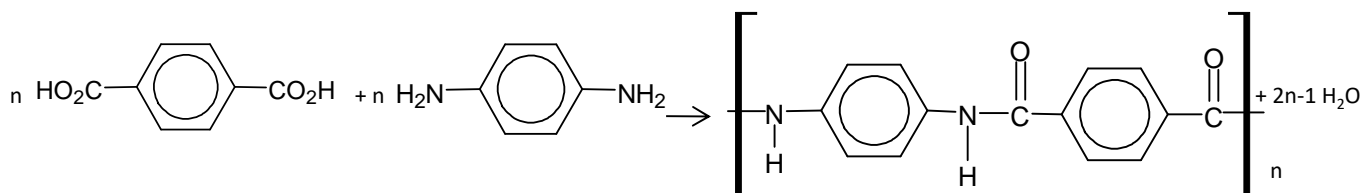


### Nylon 6,6 - a common polyamide



The 6,6 stands for 6 carbons in each of the monomers. Different length carbon chains produce different polyamides

### Kevlar- a common polyamide

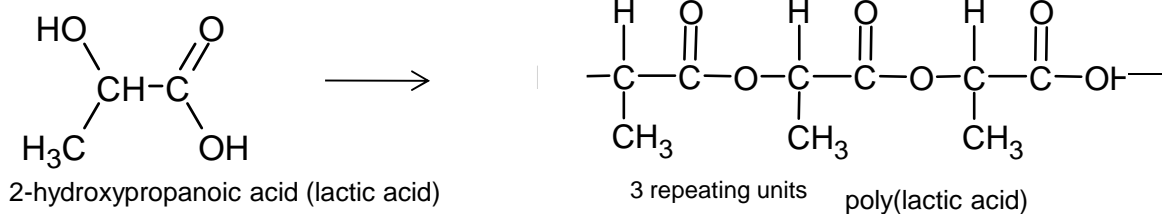
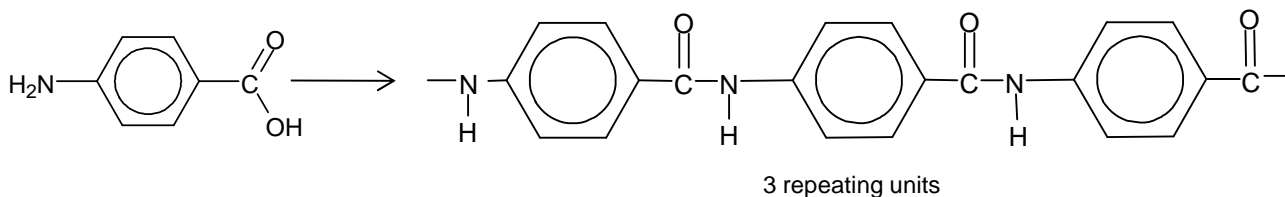
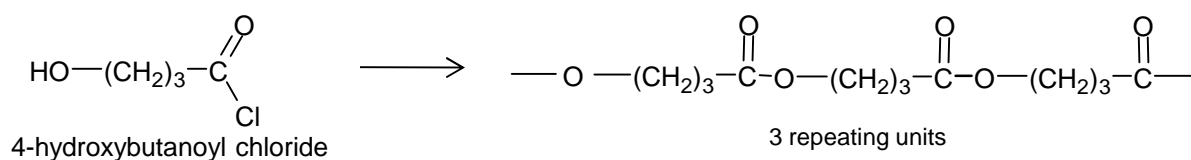


### Note on classification for condensation polymers

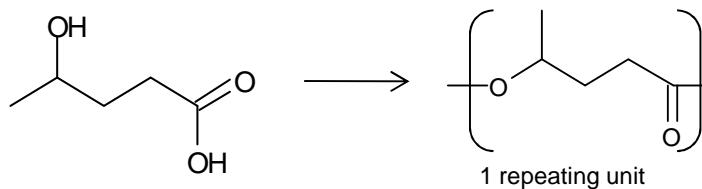
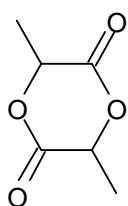
If asked for **type of polymer**: It is polyamide or polyester

Whereas **type of polymerisation** is **condensation**

It is also possible for polyamides and polyesters to form from **one** monomer, if that monomer contains both the functional groups needed to react

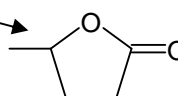


2 lactic acid molecules can also form a ring diester



It is possible for some of these compounds to form various cyclic esters under different conditions from forming the polymer.

You do not need to learn these but may be asked to deduce structures from information given



### Chemical reactivity of condensation polymers

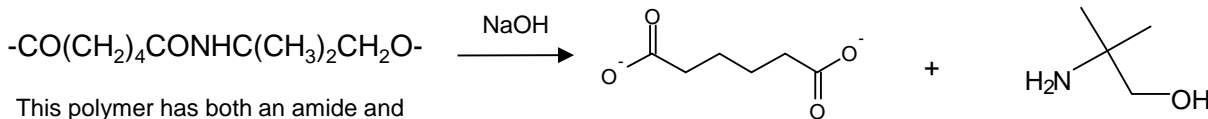
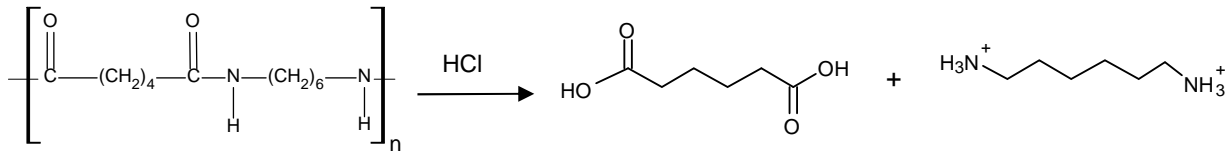
polyesters and polyamides can be broken down by **hydrolysis** and are, therefore, biodegradable

The reactivity can be explained by the presence of **polar bonds** which can attract attacking species such as nucleophiles and acids

### Hydrolysis

Polyesters and polyamides can be hydrolysed by acid and alkali

The hydrolysis will result in the original monomers forming- although the carboxylic acid or amine group will be in salt form depending on whether the conditions are alkaline or acidic



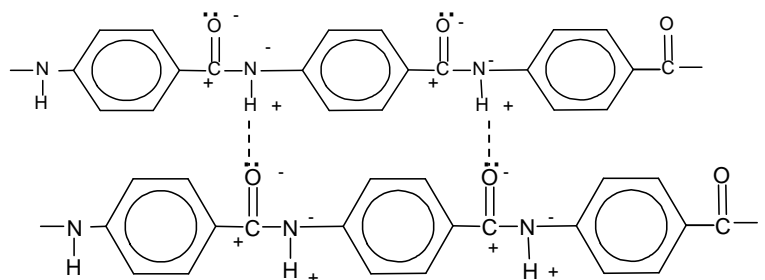
This polymer has both an amide and ester link

### Intermolecular bonding between condensation polymers chains

Polyesters have permanent dipole forces between the  $\text{C}^{\delta+}=\text{O}^{\delta-}$  groups in the different chains in addition to the van der Waals forces between the chains.

Polyamides (and proteins) have hydrogen bonding between the oxygen in  $\text{C}^{\delta+}=\text{O}^{\delta-}$  groups and the H in the  $\text{N}^{\delta-}-\text{H}^{\delta+}$  groups in the different chains in addition to the van der Waals forces.

Polyamides will therefore have higher melting points than polyesters.



### Disposal of Polymers

#### Landfill

The most common method of disposal of waste in UK

Many are now reaching capacity.

European regulations will mean councils are charged much more for using landfill.

Most polymers (polyalkenes) are non-biodegradable and take many years to break down.

Could use more biodegradable plastics, e.g. Polyamides and cellulose and starch based polymers to improve rates of decomposition

#### Incineration

Rubbish is burnt and energy produced is used to generate electricity.

Some toxins can be released on incineration. Modern incinerators can burn more efficiently and most toxins and pollutants can be removed. Greenhouse gases will still be emitted though.

Volume of rubbish is greatly reduced.

#### Recycling

Saves raw materials- nearly all polymers are formed from compounds sourced/produced from crude oil. Saves precious resources.

Polymers need collecting/ sorting- expensive process in terms of energy and manpower.

Polymers can only be recycled into the same type – so careful separation needs to be done.

Thermoplastic polymers can be melted down and reshaped