Polyamides and polyesters

This tutorial utilises the same reaction we saw in the amine and amide tutorial but in this section it is called **condensation polymerisation**. The products are either polyamides or polyesters.

The starting materials are either ‘diols’ (molecules with an OH at each end) or ‘diamines’ (molecules with an NH₂ at each end) reacting with dicarboxylic acids (molecules with a COOH at each end).

**Edexcel** and **AQA**: you can use diacyl chlorides instead of the dicarboxylic acids.

**Polyamides**

Polyamide formation is very similar to the amide formation in the amines and amides tutorial but using molecules with two NH₂ groups and two carboxylic acid groups (these are the **monomers**).

The reason for the molecules with the two functional groups is so that the amide formed can react again at either end. In the examples above, once the amide is formed, that’s it, it can’t react further.

![](image)

In this example, the product has an acid group at one end and an amine group at the other, therefore it can do the same reaction again and again….and again. So, all you need to do is remove H₂O to form the amide group.

You can of course replace the acid with an acyl chloride and do the same reaction.

To form the amide, all you have to do is remove an H from the NH₂ and the OH from the acid to form the H₂O.

**How to draw the polymer**

You can’t just draw the product like in the diagram above. When it is a polymer you need to show that it is repeating. So this means you need to draw it like:

![](image)

Comparing the structure to that in the previous diagram above, we can see that H₂O has been removed again: the OH from the carbonyl group and an H from the NH₂. This is just to show the part of the polymer that is repeating.
If you imagine taking the whole unit above in the brackets and adding it to the right hand side of the NH, then another amide group is formed, which is correct.

The little ‘n’ is just there to show that it is a polymer and that there could be any number of these units together.

**Note:** if they ask for the repeating unit, then you don’t need to draw in the brackets and the n.

**Polyamide examples**

**Nylon-6,6**

Starting with H₂N-(CH₂)₆-NH₂ and HOOC-(CH₂)₆-COOH produces a polyamide that is given the name nylon. Because both of the monomers have 6 carbons, it is called *nylon-6,6*, which is used in clothes.

**Kevlar**

Here is the repeat unit for Kevlar. Hopefully you can work out what we started with. Kevlar is used in bullet proof vests:

![Kevlar repeat unit](image)

**Polyesters**

This is identical to the polyamide stuff above. The only difference is that we are starting with a ‘diol’ (a molecule with two alcohol groups) rather than a diamine.

![Polyester reaction](image)

**Polyester examples**

**Terylene**

Polyesters tend to be used in clothes. Here is the repeat unit for Terylene:

![Terylene repeat unit](image)
Edexcel: probably don’t need to know the name ‘Terylene’ but this is the example they mention in the specification.

OCR: you also need to know the structure of polylactic acid, which comes from the monomer 2-hydroxypropanoic acid reacting with itself. Below is the structure when two of these molecules are joined together:

But as it is reacting with itself, the repeat unit is actually:

**Breaking the polymer (hydrolysis)**

Again this is covered in the amino acid tutorial. You need to do the opposite i.e. add water to break the amide bond.

The bond formed when making the amide is the C-N bond, therefore this is the bond that is broken to go back the way:

As the diagram shows, you need to add the ‘OH’ to the carbonyl group, the ‘H’ to the NH group and break the C-N bond.

**Note:** polyester hydrolysis is the same as above, except swap an O for the NH and break the C-O bond.

**Acid and base hydrolysis**

As with the amino acid tutorial, when hydrolysing these polymers, either acid or base is used. This means you need to know how the products react with acid and base:

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amine + acid → NH₃
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carboxylic acid + base → COO⁻
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So the products formed are not quite as simple as in the amide hydrolysis example above. You have to take the conditions into account.

**Polyamide hydrolysis**: amine and carboxylic acid formed. Under acidic conditions you will get the + charge on the NH$_3$. Under basic conditions you will get the – charge on the acid group.

**Polyester hydrolysis**: alcohol and carboxylic acid formed. The alcohol will remain under acidic or basic conditions. But under basic conditions the – charge has to go on the carboxylic acid again.

**Condensation v addition**

At AS, you will have looked at addition polymers where you start with an alkene and simply break the double bond and add lots of them together.

They are quite keen on comparing the two types of polymers due to their environmental impact.

As condensation polymers can be hydrolysed, then they are classed as biodegradable, which is good. But the addition polymers can’t be broken easily. Therefore they need to be burned (but could release toxic gases), recycled or taken to landfill sites.

**Uses**

It was mentioned above that condensation polymers are used a lot in clothes. They do have other uses as shown with Kevlar depending on the structure.

In comparison to addition polymers, condensation polymers can pack closer together and the polyamides can hydrogen bond, both of which make them more rigid.