

Condensation polymers

Condensation polymers form when many **monomers** join together by eliminating small molecules such as water or hydrogen chloride. They can be found in nature in **proteins** or they can be synthesised. Examples include **polyesters** – such as poly(ethylene terephthalate) (PET) used in bottles – and **polyamides** such as Kevlar used in bulletproof vests.

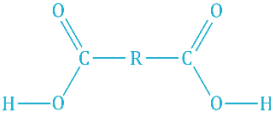
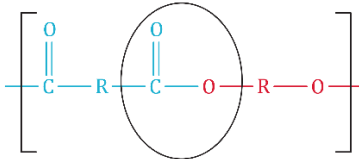
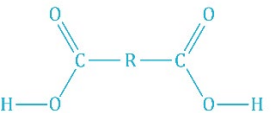
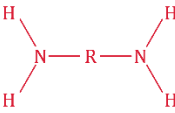
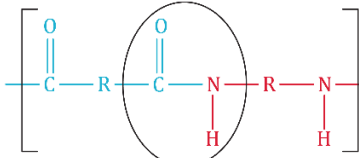
Lightweight, strong and flexible, these versatile materials shape industries from fashion to engineering. Understanding their structure, synthesis and properties highlights chemistry's role in innovation and sustainability, helping us appreciate their benefits and environmental impact.

Did you know ...?

Kevlar is a **polyamide** and is five times stronger than steel by weight, making it ideal for bulletproof vests. It can also withstand extreme heat and is used in spacecraft components.

Synthesising condensation polymers

Condensation polymers are **macromolecules** made from monomers which have two functional groups. The functional groups at each end of the molecule undergo a **condensation reaction** to form strong **covalent bonds**, releasing small by-products such as water. **Polyesters** are formed by reacting diols and dicarboxylic acids, while **polyamides** result from the reaction of diamines and dicarboxylic acids (see table).

Monomer 1	Monomer 2	Repeating unit
 Dicarboxylic acid	 Diol	 Polyester (ester bond circled)
 Dicarboxylic acid	 Diamine	 Polyamide (amide bond circled)

The **repeating unit** is formed from one of each original **monomer**, while each end of the **repeating unit** joins with another **repeating unit** to create another **ester** or **amide bond** between the molecules. Two molecules of water are formed during the formation of one repeating unit.

Polyamide chains also occur in **proteins**, through a condensation reaction between the -COOH and -NH_2 group present in **amino acids**. This links amino acids together into a **peptide chain**.

Did you know ...?

Spider silk is a natural **polyamide**. Scientists have studied it to create synthetic materials, mimicking its incredible strength and elasticity.

Physical properties

The physical properties of **condensation polymers** are shaped by strong **intermolecular forces**. **Polyamides**, such as nylon, form **hydrogen bonds** between chains due to the presence of -NH and -C=O groups. This gives them strength and flexibility.

Polyesters also exhibit **permanent dipole–dipole interactions**, contributing to their durability. These forces explain the versatility of condensation polymers in applications ranging from clothing to engineering materials.

Did you know ...?

Toothbrush bristles are often made of nylon, a **polyamide**, and during the second world war parachutes were made of nylon too.

Environmental impact

Unlike **addition polymers**, **condensation polymers** contain bonds that can be **hydrolysed** back into the original **monomers**, making them more **biodegradable** and therefore more eco-friendly than **addition polymers**. Recycling is also more feasible for polymers like poly(ethylene terephthalate) (PET), used to make bottles and textiles. However, overuse and improper disposal still contribute to environmental issues, emphasising the importance of **sustainable practices** in polymer production and use.