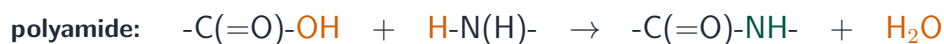


Polymerisation

A-Level Chemistry

Condensation polymerisation

In **condensation polymerisation** 缩合聚合, monomers join into a long chain **and** a small molecule (such as water or HCl) is lost each time a new bond forms. Each monomer needs **two** reactive groups, so the chain can grow at both ends.



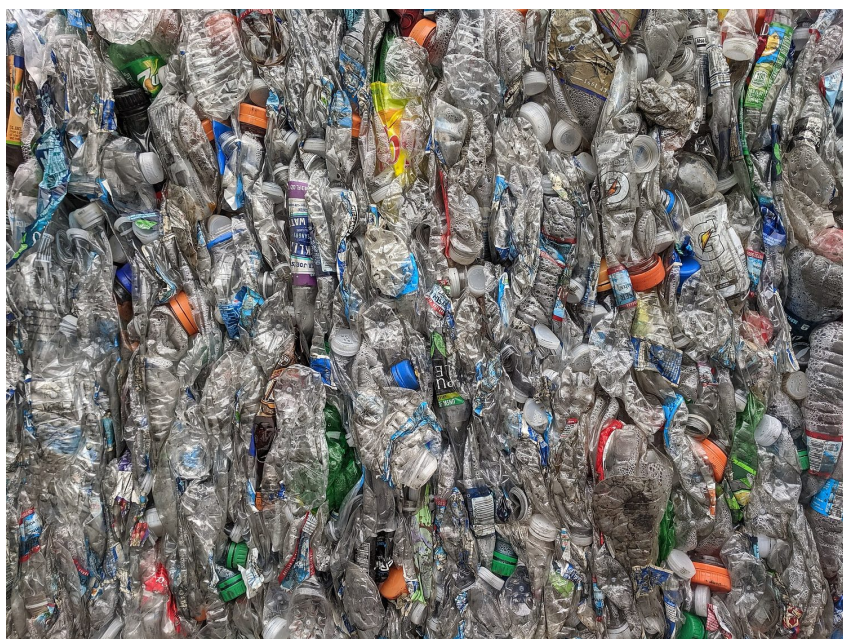
every new **ester or amide link** loses a **small molecule** (condensation)

*Condensation links: a polyester forms ester links and a polyamide forms amide links;
each new link releases a small molecule (here water)*

Polyesters

A **polyester** 聚酯 has many ester links along its chain. You can make one from:

- a **diol** 二醇 (two -OH groups) and a **dicarboxylic acid** 二羧酸 (two -COOH groups), or a dioyl chloride.
- a single hydroxycarboxylic acid, which has both an -OH and a -COOH .



PET drinks bottles are made of a polyester—a condensation polymer, collected here for recycling

Image: Grendelkhan, CC BY-SA 4.0 (commons.wikimedia.org)

Polyamides

A **polyamide** 聚酰胺 has many amide links. You can make one from:

- a **diamine** 二胺 (two -NH_2 groups) and a dicarboxylic acid or a diacyl chloride.
- a single aminocarboxylic acid, or from **amino acids** 氨基酸 joining together (proteins are natural polyamides).

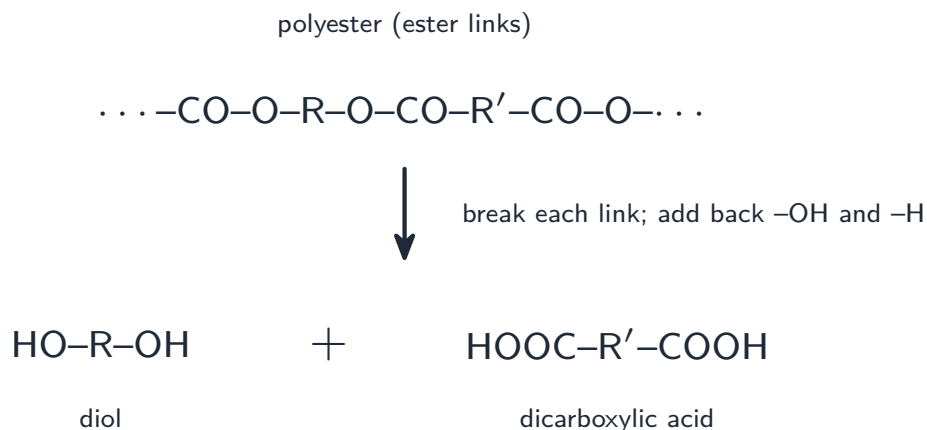


The "nylon rope trick": nylon (a polyamide) forms where two reactant solutions meet, so a single long thread can be pulled out (it is pink here from an added indicator)

Image: Thctamm, CC BY-SA 3.0 (commons.wikimedia.org)

Repeat units and monomers

The **repeat unit** 重复单元 of a condensation polymer contains parts of **both** monomers, minus the atoms lost as the small molecule. To find the **monomers** 单体 from a section of polymer, break the chain at each ester or amide link, then add back -OH and -H (or -Cl).



To find the monomers, break the chain at each link and add back -OH and -H to the cut ends —here giving the diol and the dicarboxylic acid

Worked example. A polymer chain contains repeating -CONH- links. Name the type of polymer, identify the monomers, and give the small molecule lost. A -CONH- link is an **amide**, so this is a **polyamide** made by **condensation** polymerisation. To find the monomers, break the chain at **each** amide link and give the cut ends their atoms back: the carbon side takes -OH , making a **dicarboxylic acid**, and the nitrogen side takes -H , making a **diamine**. The small molecule lost at each link is **water** (or HCl , if an acyl dichloride was used in place of the acid). Each monomer must have **two** functional groups, or the chain could never keep growing - if the monomer you propose has only one, you have broken the chain in the wrong place.

Predicting the type of polymerisation

Clue	Type
the monomer has a $\text{C}=\text{C}$ double bond, and nothing else is lost	addition polymerisation 加成聚合
each monomer has two functional groups, and a small molecule is lost; the chain has ester or amide links	condensation polymerisation

addition polymerisation

- monomer has a **C=C**
 - the double bond opens and the monomers join
 - **nothing else** is lost
- e.g. ethene $\rightarrow$ poly(ethene)

condensation polymerisation

- each monomer has **two** functional groups
 - a **small molecule** (H_2O or HCl) is lost
 - ester or amide links form
- e.g. a polyester or polyamide

The two kinds of polymerisation: addition opens a $\text{C}=\text{C}$ and loses nothing; condensation joins two-group monomers and loses a small molecule

Degradable polymers

- **poly(alkene)s** 聚烯烃 are chemically inert —they have only strong, non-polar C–C and C–H bonds, so they are hard to **biodegrade** 可生物降解 and last a long time.
- some polymers are made so that light can break them down (they are photodegradable).
- polyesters and polyamides **are** biodegradable, because their ester and amide links can be broken by acidic or alkaline **hydrolysis** 水解.

Exam tips

- **Condensation polymers** (polyesters, polyamides) form with **loss of a small molecule** (H_2O or HCl) —draw the repeat unit and the lost molecule.
- Identify the **monomers from the polymer** by breaking the ester or amide link — a common question.
- **Predict the type** from the monomers: a $\text{C}=\text{C}$ gives addition; two functional groups give condensation.
- Polyesters and polyamides are **hydrolysable** (more degradable); addition polymers are not.