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.

polyester: -C(=O)-OH + H-O- → -C(=O)-O- + H_2O

polyamide: -C(=O)-OH + H-N(H)- → -C(=O)-NH- + H_2O

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

Polyamides

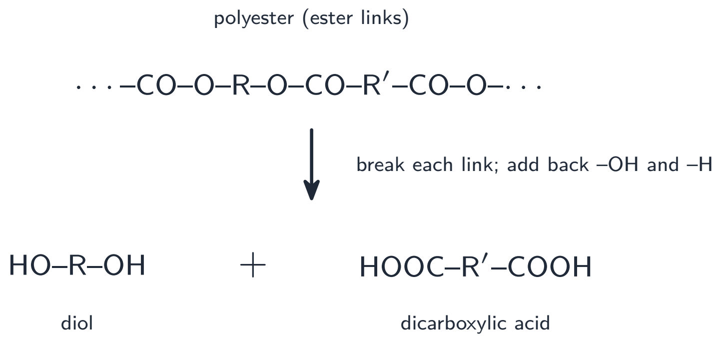
A **polyamide** 聚酰胺 has many amide links. You can make one from:

- a **diamine** 二胺 (two $–NH_2$ groups) and a dicarboxylic acid or a dioyl 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)

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 C=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 → 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 C=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 $C = C$ gives addition; two functional groups give condensation.
- Polyesters and polyamides are **hydrolysable** (more degradable); addition polymers are not.