Polymers and Life (PL)

Revision guide

Clarity, confidence, and top grades.

What this storyline covers

- Functional groups for polymers
- Addition and condensation polymers
- Acyl chlorides, esters and amides
- Acids, bases and amino acids
- Amino acids and proteins
- Enzymes and molecular recognition
- DNA and RNA
- Optical isomerism
- Structure determination: mass spectrometry and NMR

Required practicals in this storyline: paper chromatography of amino acids (**PAG6**), test-tube reactions of acids, amines and acyl chlorides (**PAG7**), and enzyme kinetics.



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i How to use this guide

Polymers and Life is the **largest storyline**, but it is built almost entirely from functional-group chemistry you already know. It develops **condensation polymers** (nylons and polyesters), the **acid–base chemistry of amino acids**, the structure of **proteins and DNA**, **enzymes**, **optical isomerism**, and the spectroscopic tools — mass spectrometry, infrared and **NMR** — for working out structures. Take it one section at a time.

How it is assessed

OCR B is context-led, so PL content can appear in **any** of the three written papers, in any context:

- **Paper 1** — Fundamentals of chemistry (110 marks)
- **Paper 2** — Scientific literacy, including the pre-release Advance Notice article (100 marks)
- **Paper 3** — Practical skills in chemistry (60 marks)

How to revise it

- Learn the **definitions in the teal boxes** word-for-word — they are marks you can guarantee.
- Practise **drawing polymers from monomers** and the reverse until it is automatic.
- Work through the **spectra** methodically: environments, then integration, then splitting.
- Use the **spec checklist** on the last page to confirm you can do every point.

1 Functional groups for polymers

Spec references: PL(k), PL(l).

Polymers and Life uses the families from What's in a Medicine? and adds several more, many with **two** functional groups so that they can form chains.

Family	Functional group	Example
Acyl chloride	–COCl	ethanoyl chloride, CH_3COCl
Primary amine	$-NH_2$	ethylamine, $CH_3CH_2NH_2$
Primary amide	$-CONH_2$	ethanamide, CH_3CONH_2
Secondary amide	–CONH– (N bonded to two C)	the link in nylon and proteins
Diol	two –OH groups	ethane-1,2-diol, $HOCH_2CH_2OH$
Dicarboxylic acid	two –COOH groups	hexanedioic acid, $HOOC(CH_2)_4COOH$
Diamine	two $-NH_2$ groups	1,6-diaminohexane, $H_2N(CH_2)_6NH_2$

Naming nylons

Nylons are named by the number of carbons in their monomers: **nylon-6,6** from a 6-carbon diamine and a 6-carbon dicarboxylic acid; **nylon-6,10** from a 6-carbon diamine and a 10-carbon diacid; **nylon-6** from a single 6-carbon monomer.

2 Addition and condensation polymers

Spec references: PL(o), PL(p).

Key definitions

- **Addition polymerisation** — monomers containing C=C double bonds join together with **no other product** (e.g. poly(ethene)).
- **Condensation polymerisation** — monomers, each with **two functional groups**, join with the **loss of a small molecule** (water or HCl) at every link.

- **Polyesters:** a **diol + a dicarboxylic acid** → polyester + water, joined by **ester** links.
- **Polyamides (nylons):** a **diamine + a dicarboxylic acid** (or a diacyl chloride) → polyamide + water (or HCl), joined by **amide** links.

Exam tip — monomers from a polymer, and back

To find the monomers of a condensation polymer, **cut each ester or amide link** and add back the small molecule: put **–OH** on the C=O side and **–H** on the O or N side. To draw the repeat unit from the monomers, join them and **remove one small molecule** at each new link.

3 Acyl chlorides, esters and amides

Spec references: PL(m), PL(n). Practical: PAG7.

Reactions of acyl chlorides PL(n)

Acyl chlorides (–COCl) are **very reactive**, which makes them useful for building esters and amides:

- with an **alcohol** → an **ester** + HCl
- with an **amine** (or ammonia) → an **amide** + HCl
- with **water** → a **carboxylic acid** + HCl

Hydrolysis of esters and amides PL(m)

- **Acid hydrolysis:** an **ester** + water → carboxylic acid + alcohol (reversible); an **amide** + water → carboxylic acid + an ammonium or amine salt.
- **Alkaline hydrolysis:** an **ester** + NaOH → the carboxylate **salt** + alcohol (this goes to completion); an **amide** + NaOH → the carboxylate salt + the amine (or ammonia).
- **Nylon** is a polyamide, so it is hydrolysed at its amide links, breaking the chain back into its monomers — the chemistry behind surgical stitches that dissolve.

4 Acids, bases and amino acids

Spec references: PL(h), PL(i), PL(j). Practical: PAG7.

Carboxylic acids PL(h)

Carboxylic acids are **weakly acidic** and react with:

- reactive **metals** → a salt + hydrogen
- **alkalis** → a salt + water
- **carbonates** → a salt + water + CO_2 (it fizzes — this distinguishes them from phenols, which do not react with carbonates)

Amines PL(j)

- Amines are **basic**: the **lone pair** on the nitrogen accepts a proton (H^+) to give a **cation**, for example $RNH_2 + H^+ \rightarrow RNH_3^+$.
- They react with acids to form salts.

Amino acids and zwitterions PL(i)

> **Key definition**
> An amino acid contains both an acidic **–COOH** group and a basic **$–NH_2$** group. A **zwitterion** is the form in which the –COOH has donated a proton to the $–NH_2$, giving **$–COO^-$** and **$–NH_3^+$** within the same molecule (overall neutral).

- The form depends on **pH**: in acid the $–NH_3^+$ cation predominates; in alkali the $–COO^-$ anion; near neutral, the zwitterion.

5 Amino acids and proteins

Spec references: PL(a), PL(b). Practical: paper chromatography (PAG6).

The peptide link PL(a)

- An amino acid has a central carbon carrying **$–NH_2$**, **–COOH**, **–H** and a side group **–R**.
- The **–COOH** of one amino acid and the **$–NH_2$** of another join by **condensation** (losing water) to form a **peptide link, –CONH–** (an amide link). Proteins are **condensation polymers** of amino acids.
- The peptide links can be **hydrolysed** (by acid or enzymes) back to the amino acids; the mixture is then separated and identified by **paper chromatography** (R_f values).

Protein structure PL(b)

Level	What it is	Held by
Primary	the sequence of amino acids	peptide (covalent) bonds
Secondary	regular folding (α-helix, β-pleated sheet)	hydrogen bonds along the backbone
Tertiary	the overall three-dimensional shape	intermolecular bonds between –R groups

- The **intermolecular bonds** between R groups (hydrogen bonds, ionic attractions and instantaneous dipole–induced dipole bonds) fix the shape, and the shape determines the protein's **properties and function**.

6 Enzymes and molecular recognition

Spec references: PL(e), PL(f), PL(g). Practical: enzyme kinetics.

Molecular recognition PL(e)

- A pharmacologically active molecule works because its shape and groups **fit a receptor site**. The **pharmacophore** is the part responsible for the biological activity; other groups modify it.
- Species interact in **three dimensions** — size, shape, bond formation and orientation all matter.

Enzymes as catalysts PL(f), PL(g)

- Enzymes are **protein catalysts** with a three-dimensional **active site** (part of the tertiary structure) that binds the substrate.
- **Rate against substrate concentration:** at **low** [substrate] the reaction is **first order** in substrate (rate ∝ [substrate]); at **high** [substrate] the active sites are saturated, so the reaction is **zero order** and the curve **levels off**.

Characteristics of enzyme catalysis: specificity (each enzyme fits one substrate), **temperature sensitivity** and **pH sensitivity** (the enzyme denatures away from its optimum, changing the active site), and **competitive inhibition** (a similar molecule blocks the active site).

7 DNA and RNA

Spec references: PL(c), PL(d). The monomers are given on the Data Sheet.

Nucleotides and the backbone PL(c)

- DNA and RNA are **condensation polymers** of **nucleotides**. Each nucleotide has three parts: a **phosphate**, a **sugar** (deoxyribose in DNA, ribose in RNA) and a **base**.
- The phosphate units join by condensation with the sugar to form the **phosphate–sugar backbone**; the bases join by condensation to the sugar.

Base pairing and the genetic code PL(c), PL(d)

- Two DNA strands pair through **hydrogen bonding** between complementary bases (A with T, C with G), forming the **double helix**.
- The specific base pairing allows accurate **replication** of the genetic information.
- The base sequence in **DNA encodes RNA**, whose base **triplets code for the amino acid sequence** in a protein.

8 Optical isomerism

Spec reference: PL(q).

Key definitions

- A **chiral centre** is a carbon atom bonded to **four different groups**.
- **Enantiomers** are the two optical isomers: **non-superimposable mirror images** of each other, like a left and a right hand.

- A molecule with a chiral centre is **chiral** and exists as two enantiomers. To show them, draw the central carbon with its four groups, then draw its mirror image.
- Enantiomers have **identical** physical and chemical properties except that they **rotate plane-polarised light** in opposite directions, and they may behave differently in biological systems.
- Many amino acids contain a chiral centre, which is why optical isomerism matters in Polymers and Life.

9 Structure determination: mass spectrometry and NMR

Spec references: PL(r), PL(s), PL(t).

Mass spectrometry, further PL(r)

- A **high-resolution** M^+ value (measured to several decimal places) gives the exact **molecular formula**, because formulae with the same nominal mass have slightly different exact masses.
- The **mass differences** between peaks show the **groups lost** as fragments (as in What's in a Medicine?).

Proton (^{1}H) NMR PL(s)

- The **chemical shift** (δ, in ppm) shows the **environment** of each hydrogen; the **number of peaks** equals the number of different hydrogen environments.

- The **integration** (relative peak areas) gives the **ratio** of hydrogen atoms in each environment.
- **Splitting (the n + 1 rule):** a signal is split by its neighbouring hydrogens — **n** equivalent neighbours give **n + 1** lines (singlet, doublet, triplet, quartet). Splitting beyond quartets is not required.

Carbon-13 (^{13}C) NMR and combined analysis PL(s), PL(t)

- **Carbon-13 NMR** shows the number of different **carbon environments** (one peak each). Assessed spectra are **proton-decoupled**, so the peaks are single lines.
- **Combining techniques:** use **mass spectrometry** (molecular mass and fragments), **infrared** (functional groups) and **NMR** (carbon and hydrogen environments) together to deduce a full structure.

P Required practicals in this storyline

These PAG activities are most likely to be examined in Paper 3, but the techniques can appear in any paper.

Activity	What to be able to do
Paper chromatography (PAG6)	separate a mixture of amino acids, locate the spots (e.g. with ninhydrin) and identify them by their R_f values
Test-tube reactions (PAG7)	carry out reactions of carboxylic acids (with metals, alkalis and carbonates), amines (with acids) and acyl chlorides (with amines and alcohols), and the hydrolysis of an ester or amide such as nylon
Enzyme kinetics	investigate how the rate of an enzyme-catalysed reaction varies with substrate concentration, temperature and pH

Exam tip — reading a structure from spectra

Work in order: use the **mass spectrum** for the molecular mass and formula, **infrared** for the functional groups, then **NMR** — count environments for the number of peaks, use **integration** for the ratio, and the **n + 1 rule** for the splitting.

Spec coverage checklist — can you do every point?

Every assessable learning outcome for Polymers and Life, with where it is covered in this guide. Tick each one once you can do it confidently.

PL(a)	Amino acid structure, the peptide link, proteins as condensation polymers, and paper chromatography — §5
PL(b)	Primary, secondary and tertiary structure of proteins and the role of intermolecular bonds — §5
PL(c)	DNA and RNA as condensation polymers of nucleotides; the phosphate–sugar backbone and double helix — §7
PL(d)	Hydrogen bonding in base pairing, replication, and how DNA codes for protein — §7
PL(e)	Molecular recognition: the pharmacophore, receptor sites and three-dimensional interaction — §6
PL(f)	The rate–substrate concentration curve for an enzyme reaction — §6
PL(g)	Characteristics of enzyme catalysis and the active site — §6
PL(h)	Acidity of carboxylic acids and their reactions with metals, alkalis and carbonates — §4
PL(i)	Acid–base properties of amino acids and zwitterions — §4
PL(j)	The basic nature of the amino group and the reaction of amines with acids — §4
PL(k)	Formulae and naming of the polymer-related families, including nylons — §1
PL(l)	Formulae for primary and secondary amides — §1
PL(m)	Hydrolysis of esters and amides by acid and alkali, including salt formation — §3
PL(n)	Reactions of acyl chlorides with amines and alcohols — §3
PL(o)	The difference between addition and condensation polymerisation — §2
PL(p)	Relating a condensation polymer to its monomers and vice versa — §2
PL(q)	Optical isomerism: chiral centres and enantiomers as mirror images — §8
PL(r)	High-resolution mass spectra and mass differences between peaks — §9
PL(s)	Proton and carbon-13 NMR for structure determination — §9
PL(t)	Combining mass spectrometry, infrared and NMR to determine structure — §9