9701 CHEMISTRY · TOPICS 20 & 34 · AS + A LEVEL

Polymerisation

01 · THE TWO TYPES

	Addition	Condensation
monomer	C=C	two functional groups
small molecule lost	none	H_2O or HCl
backbone	C–C only	contains O or N
hydrolysable	no	yes

02 · ADDITION POLYMERS

The π bond opens and the monomers join end to end: n CH_2=CHR → –(CH_2–CHR)$_n$–.

Common ones: poly(ethene) for bags and bottles, poly(propene) for crates and rope, poly(chloroethene) or PVC for pipes and cable, poly(phenylethene) for packaging, PTFE for non-stick coatings.

03 · DRAWING A REPEAT UNIT

From monomer to polymer
1 · Open the C=C into a single bond.
2 · Draw bonds extending through the brackets on both sides.
3 · Write n outside the bracket.

From polymer to monomer
Find the repeating pattern, take one unit, and put the double bond back between the two backbone carbons.

04 · POLYESTERS A2

Made from a **diol + a dicarboxylic acid** (or its diacyl chloride), losing water at each link. The link is –COO–.

Terylene (PET) comes from ethane-1,2-diol and benzene-1,4-dicarboxylic acid. A single monomer carrying both an –OH and a –COOH can also self-polymerise.

05 · POLYAMIDES A2

Made from a **diamine + a dicarboxylic acid**, losing water. The link is the amide –CONH–.

Nylon-6,6 comes from 1,6-diaminohexane and hexanedioic acid; Kevlar uses aromatic monomers, and its flat, hydrogen-bonded, aligned chains make it exceptionally strong for its mass. Proteins are natural polyamides.

06 · IDENTIFYING MONOMERS A2

Cut the chain **through the link**, then add back what was lost.

Ester link –CO–O– → break between C and O, add –OH to each side.

Amide link –CO–NH– → break between C and N, give the acid an –OH and the amine an –H.

07 · HYDROLYSIS OF CONDENSATION POLYMERS

The ester and amide links can be broken by acid or alkali, so these polymers are **degradable** — the basis of both biodegradable plastics and chemical recycling back to monomers.

Addition polymers have an unreactive C–C backbone with no polar bond for a nucleophile to attack, so they persist in the environment for centuries.

08 · PROPERTIES FROM STRUCTURE

Longer, unbranched chains pack closely, so London forces are stronger and the polymer is denser, stiffer and higher melting — high-density poly(ethene) against the low-density branched form.

Polar links allow hydrogen bonding between chains, which is why nylon and Kevlar are strong fibres while poly(ethene) is not.

09 · DISPOSAL

Landfill — cheap but wasteful of land and of the oil the plastic came from. **Incineration** — recovers energy, but PVC releases HCl and incomplete burning releases CO and dioxins, so the gases must be scrubbed.

Recycling — mechanical (sort, melt, remould) or chemical (break back to monomers or feedstock). Sorting mixed plastics is the practical difficulty.

10 · WORKED EXAMPLE — DEDUCE THE MONOMERS

A polymer has the repeating section –NH(CH_2)$_6$NHCO(CH_2)$_4$CO–

Two amide links → polyamide → cut each –CO–NH–

Amine fragment: $H_2N(CH_2)_6NH_2$
Acid fragment: $HOOC(CH_2)_4COOH$

→ 1,6-diaminohexane and hexanedioic acid: **nylon-6,6**.

11 · WORKED EXAMPLE — POLYESTER

Draw the repeat unit from ethane-1,2-diol and benzene-1,4-dicarboxylic acid.

Join –OH to –COOH, losing H_2O at each end: –O–CH_2CH_2–O–CO–C_6H_4–CO–

Two water molecules are lost per repeat unit, and bonds must extend through the brackets on both sides.

12 · POLYMERS TO KNOW

Polymer	Type	Monomer
poly(ethene)	addition	ethene
PVC	addition	chloroethene
PTFE	addition	tetrafluoroethene
Terylene	polyester	diol + dioic acid
nylon-6,6	polyamide	diamine + dioic acid
protein	polyamide	amino acids

13 · HYDROLYSIS EQUATIONS

Polyester + NaOH(aq)
→ the diol + the sodium salt of the diacid

Polyamide + dilute HCl
→ the dioic acid + the ammonium salt of the diamine

Acid and alkali give different forms of the same two fragments, so read the conditions before answering.

MARKS LOST HERE

— Leaving the double bond in an addition repeat unit, or forgetting the bonds through the brackets.

— Cutting a condensation polymer in the wrong place, so the fragments come out missing –OH or –H.

— Saying addition polymerisation releases water.

— Describing addition polymers as biodegradable.