Polyesters and polyamides

AQA 7405 · A level

Show your working where needed. Check the worked answers when you finish.

Name _____ Date _____

1. Read two polymer chains

Chain A contains …-CH_2CH_2-O-C(=O)-CH_2-C(=O)-O-CH_2CH_2-…

Chain B contains …-CH_2CH_2-NH-C(=O)-CH_2-C(=O)-NH-CH_2CH_2-…

Copy the linking group in each chain. Name each link and classify its polymer.

2. From two monomers to one repeat

Write one repeat unit of the polyester formed from $HOCH_2CH_2OH$ and $HOOCCH_2CH_2COOH$. Show the continuation bond at each end.

3. Find a diamine and diacid

Use the polyamide repeat -[NH-CH_2-CH_2-NH-C(=O)-CH_2-C(=O)]-. Give condensed structures for the diamine and dicarboxylic acid that could make it.

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4. Two polymerisation reactions

Propene gives polymer P. A mixture of a diol and a dicarboxylic acid gives polymer Q. Explain what happens to the reacting bonds or groups, name each type of polymerisation and state any other product.

5. Calculate a repeat-unit mass

$HO(CH_2)_3OH$ has M_r 76 and $HOOC(CH_2)_2COOH$ has M_r 118. Calculate M_r for one long-chain polyester repeat containing one fragment of each monomer. Use $M_r(H_2O) = 18$ and ignore end groups.

6. Use alkaline hydrolysis

Give both organic products from complete hydrolysis of -[O-CH_2-CH_2-O-C(=O)-CH_2-CH_2-C(=O)]- with hot excess aqueous NaOH. Show the charge or counter-ions of any salt.

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7. Use acidic hydrolysis

Draw the organic products of completely hydrolysing -[NH-CH_2-CH_2-NH-C(=O)-CH_2-C(=O)]- with excess hot dilute HCl. Include any charges in the final mixture.

8. Explain two material properties

A polyamide has N-H and C=O in each repeat. A polyalkene contains only C and H. Explain why the polyamide can show stronger attractions between chains and why it can be hydrolysed.

9. Extra challenge · Calculate a polymer yield from a repeat

$HO(CH_2)_4OH$ (M_r 90) and $HOOC(CH_2)_2COOH$ (M_r 118) form a polyester. Draw a repeat unit and calculate the mass of polyester expected from 0.100 mol of each monomer. Ignore end groups and use $M_r(H_2O)$ = 18.

Hot aqueous NaOH is then added to the polymer. Give both organic products and explain why carrying out the same treatment on a polyalkene leaves its backbone intact.

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Worked answers

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1. Read two polymer chains

A contains ester links, -C(=O)-O-, and is a polyester. B contains amide links, -C(=O)-NH-, and is a polyamide.

2. From two monomers to one repeat

-[O-CH_2-CH_2-O-C(=O)-CH_2-CH_2-C(=O)]-. The last carbonyl carbon bonds to the oxygen of the next unit.

3. Find a diamine and diacid

$H_2NCH_2CH_2NH_2$ and $HOOCCH_2COOH$. Restore H at each amide nitrogen and OH at each acyl carbon when separating the monomer fragments.

4. Two polymerisation reactions

Propene forms P by addition polymerisation. Its C=C bond becomes a C-C bond in the chain and all the monomer atoms are retained.

Alcohol and carboxylic acid groups form ester links in Q by condensation polymerisation. Each new link releases a water molecule.

5. Calculate a repeat-unit mass

76 + 118 − 2 × 18 = 158. A repeat containing one diol fragment and one diacid fragment accounts for two ester links when the chain is extended.

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Worked answers

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6. Use alkaline hydrolysis

$HOCH_2CH_2OH$ and $^-O\text{-}C(=O)\text{-}CH_2\text{-}CH_2\text{-}C(=O)\text{-}O^-$ with two Na^+ counter-ions. Both acid-derived groups are carboxylate groups in the alkaline solution.

7. Use acidic hydrolysis

$HOOCCH_2COOH$ and $[H_3N\text{-}CH_2\text{-}CH_2\text{-}NH_3]^{2+}$ form. Both amino groups of the diamine are protonated in excess acid. Two Cl^- ions balance each diammonium ion.

8. Explain two material properties

Polyamide chains can form intermolecular hydrogen bonds between N-H and C=O. The polyalkene has mainly London forces between chains. Hydrolysis can break the amide link in the polyamide. The polyalkene has a C-C backbone with no such link.

9. Extra challenge · Calculate a polymer yield from a repeat

The repeat is $\text{-}[O\text{-}(CH_2)_4\text{-}O\text{-}C(=O)\text{-}CH_2CH_2\text{-}C(=O)]\text{-}$. Each pair of monomers contributes 90 + 118 − 2 × 18 = 172 g per mole of repeats, so the expected mass is 17.2 g.

The products are $HO(CH_2)_4OH$ and $^-OOCCH_2CH_2COO^-$ with two Na^+ counter-ions. Cleaving an ester link restores an alcohol group and a carboxylate group. A polyalkene has no ester groups in its backbone.

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