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ANSWER BOOK

Condensation polymers and the disposal of polymers

Carbonyls and carboxylic acids · Unit C20

AQA 3.3.12.1, 3.3.12.2 · OCR A 6.2.3

19 questions · 61 marks

NAVY EDITION

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SECTION A · Short, 1 to 2 marks

A1 CPD-Q8

B1 nylon chains are held by hydrogen bonds between N–H and C=O groups on neighbouring chains. **B1** poly(ethene) chains are held only by weaker van der Waals forces, so less energy is needed to separate them. [2]

A2 CPD-Q13

B1 PVC contains chlorine, so burning it produces hydrogen chloride. **B1** HCl is toxic and acidic, so it has to be removed from the waste gases, for example by a base, adding cost. [2]

A3 CPD-Q15

B1 landfill waste is compacted, dry and short of oxygen. **B1** so few microorganisms are active to catalyse the hydrolysis of the ester links. [2]

SECTION B · Standard, 3 to 5 marks

B1 CPD-Q3

B1 hexanedioic acid, $HOOC(CH_2)_4COOH$; allow hexanedioyl dichloride, $ClOC(CH_2)_4COCl$. **B1** the other monomer is hexane-1,6-diamine, $H_2N(CH_2)_6NH_2$. **B1** hydrolysis gives hexanedioic acid, $HOOC(CH_2)_4COOH$. **B1** and the hexane-1,6-diammonium ion, as its chloride, because the amine groups are protonated by the acid. [4]

B2 CPD-Q4

B1 $-OCCH_2CH_2COOCH_2CH_2O-$, one residue of each monomer. **B1** the ester link drawn in full with C=O displayed, and an open bond at each end; ends closed with H or OH are not credited. **B1** the polymer is a polyester. **B1** the small molecule lost is water, two per repeating unit, one per ester link. [4]

B3 CPD-Q11

B1 addition monomers have a C=C bond, while condensation monomers have two functional groups each. **B1** addition gives no other product, while condensation loses a small molecule such as water or HCl at each link. **B1** an addition polymer's main chain is carbon only, while a condensation polymer's chain contains ester or amide links with O or N. **B1** condensation polymers can be hydrolysed and are biodegradable, while addition polymers are not. [4]

B4 CPD-Q19

B1 propenamide undergoes addition polymerisation, through its C=C bond. **B1** its repeating unit is $-CH_2CH(CONH_2)-$, with the amide group as a side chain. **B1** 4-aminobutanoic acid undergoes condensation polymerisation, its NH_2 reacting with the COOH of the next molecule to give a polyamide. **B1** its repeating unit is $-NH(CH_2)_3CO-$, and water is lost at each link. [4]

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B5 CPD-Q2 **B1** monomers with two functional groups join into a polymer with the loss of a small molecule, such as water, at each link. **B1** a polyester has ester links, –COO–. **B1** a polyamide has amide links, –CONH–. [3]

B6 CPD-Q5 **B1** pentanedioic acid, $HOOC(CH_2)_3COOH$; allow its diacyl chloride. **B1** the other monomer is ethane-1,2-diol, $HOCH_2CH_2OH$. **B1** the polymer is a polyester, because the links are ester links, –COO–. [3]

B7 CPD-Q6 **B1** Kevlar is a polyamide whose chains contain N–H and C=O groups in the amide links. **B1** hydrogen bonds form between the N–H of one chain and the C=O oxygen of a neighbouring chain. **B1** the chains are straight and rigid because of the 1,4-linked benzene rings, so they pack closely and many hydrogen bonds form along their length. [3]

B8 CPD-Q7 **B1** the ester links in a polyester contain a polar C=O bond with a δ+ carbon. **B1** water or hydroxide ions attack that carbon as nucleophiles, so the links can be hydrolysed, catalysed by enzymes from microorganisms. **B1** poly(ethene) has only strong, non-polar C–C and C–H bonds, so there is no site for attack. [3]

B9 CPD-Q9 **M1** the repeating unit is $C_{10}H_8O_4$. **M1** Mr of the unit = (10 × 12.0) + (8 × 1.0) + (4 × 16.0) = 192.0. **A1** number of units = 38 400 ÷ 192.0 = 200, a whole number with no unit; allow 2.00×10^2. [3]

B10 CPD-Q10 **M1** amount of repeating units = 2000 ÷ 226.0 = 8.850 mol. **M1** two water molecules are lost per repeating unit, so 17.70 mol of water. **A1** mass of water = 17.70 × 18.0 = 319 g, to 3 significant figures. [3]

B11 CPD-Q14 **B1** it is a polyester, because the OH of one molecule reacts with the COOH of the next. **B1** the repeating unit is $–OCH_2CH_2CH_2CO–$. **B1** it is biodegradable, because its ester links can be hydrolysed. [3]

B12 CPD-Q16 **B1** one product is ethane-1,2-diol, $HOCH_2CH_2OH$. **B1** the other is the sodium salt of benzene-1,4-dicarboxylic acid, $NaOOCC_6H_4COONa$. **B1** adding a strong acid protonates the carboxylate ions, giving benzene-1,4-dicarboxylic acid. [3]

B13 CPD-Q18 **B1** the chains contain a few C=O groups, which absorb ultraviolet light. **B1** the energy absorbed breaks chain bonds next to the C=O groups, so the polymer breaks into small fragments. **B1** buried in landfill, no light reaches the bag, so the bonds are not broken. [3]

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B14 CPD-Q20 **M1** amount of repeating units = 2400 ÷ 192.0 = 12.5 mol. **M1** each repeating unit gives one molecule of ethane-1,2-diol, so 12.5 mol of diol forms. **A1** mass = 12.5 × 62.0 = 775 g, to 3 significant figures. [3]

B15 CPD-Q21 **B1** the link that repeats along the chain is –CONH–, the amide link, so the polymer is a polyamide. **B1** the repeating unit –NH(CH$_2$)$_5$CO– holds one residue only, with the N at one end and the C=O at the other, so every monomer molecule must carry both an NH$_2$ group and a COOH group, and one kind of molecule is enough. **B1** the monomer is 6-aminohexanoic acid, H$_2$N(CH$_2$)$_5$COOH, and a molecule of water is lost as each amide link forms, which makes the polymerisation a condensation. [3]

SECTION C · Long, 6 marks or more

C1 CPD-Q12 **Indicative content** [6]

B1 poly(ethene) has a chain of C–C and C–H bonds only, strong and non-polar, so it is chemically inert and is not biodegraded; in landfill it persists for centuries. **B1** the polyester chain contains ester links, whose δ+ carbonyl carbon is attacked by water, acids and alkalis, so the polymer can be hydrolysed. **B1** hydrolysis breaks the polyester back into its diol and its dicarboxylic acid, or its salt in alkali, so it can be chemically recycled to monomer or biodegraded. **B1** in a dry, oxygen-poor landfill even a polyester breaks down slowly, so the gain depends on where the used bags are sent. **B1** the hydrolysis that helps disposal can weaken a polyester bag in use, in contact with damp, acidic or alkaline goods, while poly(ethene) is unaffected by them. **B1** both polymers can be burned to release energy, giving carbon dioxide, so a justified conclusion favours the polyester only if its waste is hydrolysed or composted rather than buried.

Levels

Level 3 (5–6 marks) the inert C–C chain of poly(ethene) and the hydrolysable ester link of the polyester are both explained, the hydrolysis products are named, and the two bags are compared in landfill, incineration and recycling; the judgement allows for how slowly even a polyester breaks down when buried, or for the weakening of the bag in use.

Level 2 (3–4 marks) the ester link is said to be hydrolysed and poly(ethene) to be non-biodegradable, and some disposal routes are compared; the answer usually stops short of the products of hydrolysis or of any drawback of the polyester, so its verdict is one-sided.

Level 1 (1–2 marks) the polyester bag is preferred because it is 'natural' or 'rots', or poly(ethene) is said to break down slowly, with no mention of the ester link or of the bonds in either chain.

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