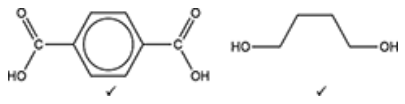
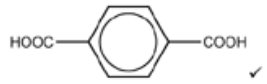
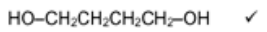
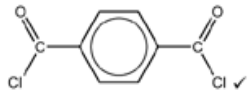
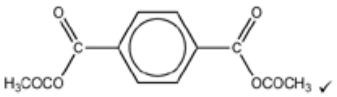
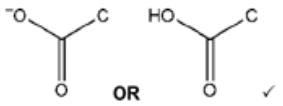
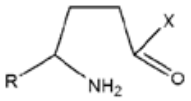
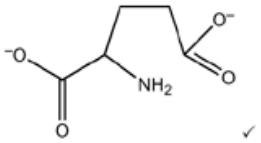
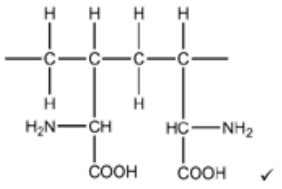
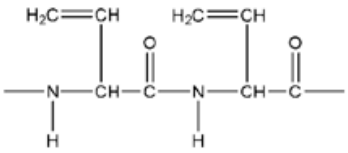
Mark scheme

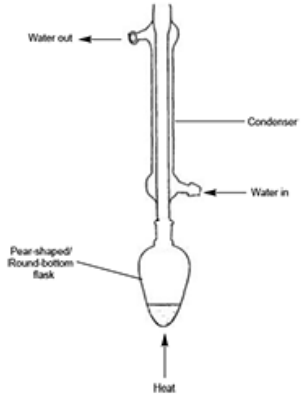
Question			Answer/Indicative content	Marks	Guidance
1			Idea that reflux is used to prevent loss by evaporation ✓ e.g. prevents reaction mixture boiling dry e.g. prevents loss of (volatile) compounds / products / reactants e.g. prevent methanol escaping	1	**IGNORE** responses related to rate of reaction **IGNORE** responses related to ensuring complete reaction **DO NOT ALLOW** reference to incorrect reaction e.g. oxidation, combustion (flammability) **Examiner's Comments** An unfamiliar question that proved challenging with only around a fifth of candidates obtaining the mark for correctly suggesting that reflux would prevent loss of volatile compounds. Many candidatessuggested that reflux ensures the reaction goes to completion but here this was insufficient asesterification is an equilibrium reaction and additional information in (b)(i) indicates that there isunreacted compound **G** present. It was necessary to focus on the purpose for reflux rather than other ways of heating a reaction, such asthe energy needed to break bonds or speed up the rate of reaction. Some less successful responseslinked to oxidation reactions, presumably as they understand the importance of either reflux or distillationin this context. For example, 'reflux is required for complete oxidation' or 'if distillation had been used analdehyde would have been formed'.
			Total	**1**	
2	a		 ✓ ✓	2	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous e.g. **ALLOW**

					 ✓  ✓ **ALLOW** Diacyl chloride:  **ALLOW** a diacid anhydride of benzene-1,4-dicarboxylic acid, e.g.  **DO NOT ALLOW** incorrect connectivity on OH **BUT ALLOW ECF** on subsequent structures **ALLOW** correct Kekulé representation of benzene **Examiner's Comments** The majority scored both marks here. A few drew the diacyl dichloride, but these were in the minority. A small minority only lost one mark, usually for incorrect connectivity on -OH groups. Some other errors seen included missing a carbon from alcohol, missing hydrogens on carbon if not drawn skeletally, carboxylic acid groups added directly on to the benzene ring with a pentavalent carbon atom or omitting the circle in the benzene ring.
	b		**Hydrolysis of ester:** Methanol / CH_3-OH ✓ **Formation of carboxylate / carboxylic acid from hydrolysis of ester or amide:**	4	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **DO NOT ALLOW** incorrect connectivity on OH **…BUT ALLOW ECF** on subsequent structures **DO NOT ALLOW** CH_3O^- (Na^+) **OR** sodium methoxide

			 ✓ *C=O of Carboxylate or carboxylic acid group must be attached to a C But ignore rest of molecule* **Hydrolysis of amide:** Breaks amide bond in ring to give: ✓  *Where R can be H or any other structure For X, ignore group attached to C=O* **Correct hydrolysis product:**  ✓		**ALLOW** $-COO^-Na^+$ **OR** $-COONa$ **DO NOT ALLOW** esters or amides **ALLOW** NH_3^+ **IGNORE** missing Hs on carbon chain Must be completely correct structure **ALLOW** $-COO^-Na^+$ **OR** $-COONa$ **Examiner's Comments** Just over a quarter of candidates were able to gain all 4 marks. The successful candidates clearly identified where theester and amide would be hydrolysed on the structure provided, helping them draw out the correct products. This question differentiated well. Most were able to gain some credit for hydrolysing the ester to give methanol and a carboxylate or carboxylic acid, leaving the amide bond and ring intact. However, some lost the first mark for giving the methoxide ion, assuming that the alkaline conditions are capable of deprotonating the alcohol group. Lower attaining candidates often broke other C-C bonds in the ring forming a range of products. A few displayed the structure as $C=O^-Na^+$ and some also protonated the amine group either with the ring intact or broken.
			Total	**6**	
3	a		**IF** answer on answer line = 73518 **AWARD** 3 marks **IF** answer on answer line = 73500 **AWARD** 2 marks --- M_r of amino acid = 165 ✓ M_r of 500 molecules = 500 × 165 = 82500 ✓ M_r of polymer = 82500 – (499 × 18) = 73518 ✓ *(final answer must be given to nearest whole number)*	3	**ALLOW ECF** from incorrect M_r of amino acid **Alternative method:** Mr of repeat unit = 147 ✓ 147 x 500 = 73500 ✓ 73500 + 18 = 73518 ✓ **Common error for 2 marks** 36518 Use of Mr 91 82500 Not shown 165 in working **Common error for 1 mark** 45500 Use of Mr 91

					Examiner's Comments Most candidates managed to score at least one mark here, either for correctly determining the molar mass of the monomer, the repeat unit in the polymer or alternatively they multiplied a molar mass by500. Many candidates gained 2 marks for either 73500 or 82500 but then struggled to account for thewater lost. Some candidates lost marks due to errors in calculating the molar mass of the monomer or some tried toincorporate the use of Avogadro's constant into the calculation. Many misunderstood what atoms wouldbe lost during polymerisation. For example, a common incorrect response seen was found by subtracting2 from the correct molar mass giving 163, followed by multiplication by 500 to give 81500 and finallyadding of 2 to give 81502. Some struggled to understand what was meant by nearest whole number,e.g. rounding 73518 to 74000 or 82500 to 80000.
	b		**Addition polymer**  **Condensation polymer**  Amide link ✓ 2 repeat units of correct polymer ✓	3	For **BOTH** structures, **ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous 'End bonds' **MUST** be shown (with either a solid or dashed line) **BUT ALLOW ECF IF** end bonds omitted in both structures **DO NOT ALLOW** more than 2 repeat units **BUT ALLOW ECF** in subsequent structure **IGNORE** connectivity of side groups in both diagrams --- **CARE: ALLOW** any consistent repeat unit: side groups can alternate or be on opposite sides of chain **ALLOW** NH in amide link i.e. without

					bond shown **ALLOW** −NH− at either end **IGNORE** brackets **IGNORE** *n* or subscript numbers **ALLOW** C_2H_3 as side chain for condensation polymer **ALLOW** 1 mark if correct structures given by wrong way round **Examiner's Comments** In general, candidates found it easier to give the correct addition polymer rather than the condensation polymer. Some lost the mark for using molecular formula on side chains rather than displaying thesection correctly. The condensation polymer was generally less well answered, with candidates oftenstruggling to give a correct amide bond – many had an oxygen atom retained between the carbonylcarbon and the amine group's nitrogen atom, giving C–O–N. Another common error was the omission ofhydrogen atoms from nitrogen or from the carbon attached to C_2H_3. Just over a quarter of candidates didnot score any marks. Some candidates drew ester linkages instead of amide linkages and struggled toinclude the side chains i.e. trying to incorporate the alkene into the main polymer chain.
			Total	**6**	
4			**A**	1	**ALLOW** HC*l* **Examiner's Comments** The vast majority of candidates gave the correct option A, HC*l*. The most common incorrect response was B i.e. H_2O.
			Total	**1**	
5		i		2 (AO 3.3 ×2)	For open system, **DO NOT ALLOW**



Reaction apparatus (Labels NOT required)

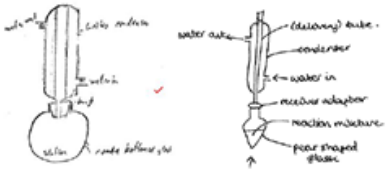
flask
AND upright condenser
AND open system at top ✓
(Could be labelled)

Labels AND direction of water flow

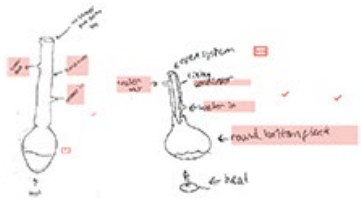
Pear-shaped/round-bottom flask
AND condenser
AND water in at bottom and out at top ✓

Heat **NOT** required

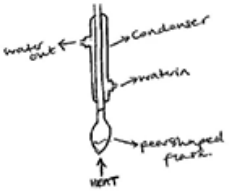
DO NOT ALLOW flask, conical flask, volumetric flask
DO NOT ALLOW thermometer
DO NOT ALLOW condensing tube as label

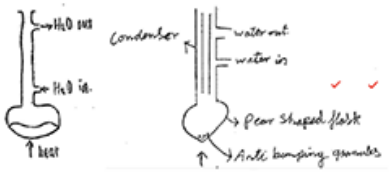


For open system, ALLOW label. e.g. 'open at top'

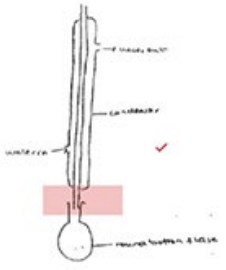


ALLOW line across flask





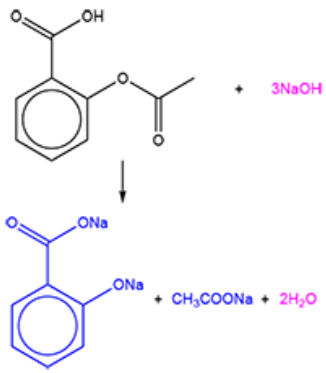
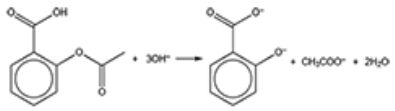
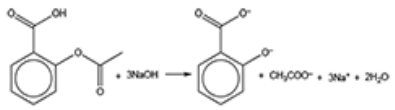
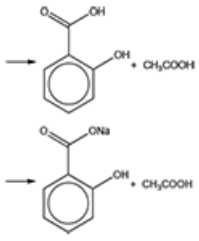
ALLOW small gap between flask and condenser **BOD**, e.g.

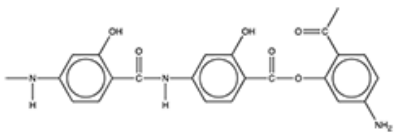


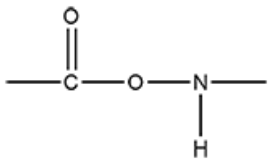
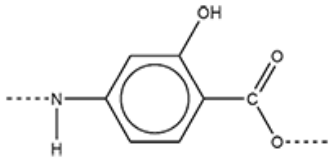
If in doubt, ask Team Leader

Examiner's Comments

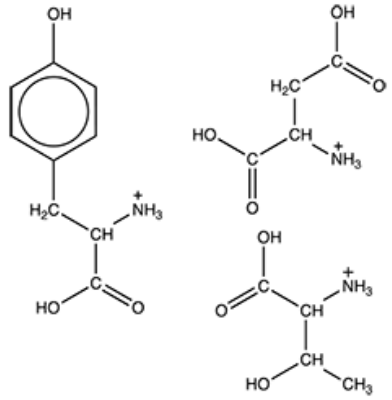
Most candidates drew a diagram that looked like a vertical condenser above

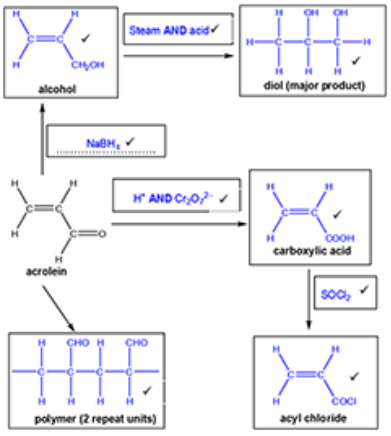
					a flask. The quality of the diagrams was not very good. Candidates then needed to label their diagram. Errors included a bung or thermometer inserted at the top of the condenser and water flowing the wrong way in the condenser. For labelling, candidates were expected to use scientific terminology. Responses such as 'condensation tube' and vague terms such as 'flask' were not credited. These labels were often omitted. A significant number drew a set up for distillation instead of reflux.
		ii	 Organic products ✓ ✓ ***2 marks*** 3NaOH AND $2H_2O$ ✓ ***1 mark*** NOTE: ALLOW O^-Na^+ for ONa throughout **SCROLL DOWN FOR PRODUCTS**	3 (AO 2.6 ×3)	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **IGNORE** annotations of provided structure of aspirin at top left **ALLOW** equation with 3OH– **OR** 3NaOH giving anions for organic products, i.e.  **OR**  **ALLOW** 1 of the 2 organic products mark for BOTH structures as COOH and OH (or mixture) e.g  **Examiner's Comments**

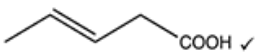
					This question was the hardest part of Question 5 and about half the candidates were not given any marks. Some drew the sodium carboxylate salt of aspirin structure, leaving the ester link intact. A large number of candidates realised that the ester would be hydrolysed. Sometimes the sodium salts were often not shown and, even they were shown, the phenol group was often shown intact. The hardest mark was the formation of $2H_2O$ and a large number of candidates showed the more intuitive but incorrect '$3H_2O$' instead.
			Total	**5**	
6		i	 Section contains A displayed amide linkage between 2 benzene rings ✓ A displayed ester linkage between 2 benzene rings ✓ Section with at least **one** 'end bond' and correct positioning of all 3 groups on **each** benzene ✓	3 (AO1.2 ×2) (AO3.2)	**Marking point 3 is dependent on first 2 marks** Check bonding around **each** benzene so C=O position 1, C-O position 2 and C-NH position 4. **ALLOW** 'end bonds' (with either a solid or dashed line') **OR** terminal ends e.g. -O- or -OH **ALLOW** any combination of 'end bonds' as showing a section not a repeat unit **IGNORE** connectivity of OH and NH_2 groups to benzene **Examiner's Comments** This was a demanding question with just over a third of candidates not scoring marks. However, many

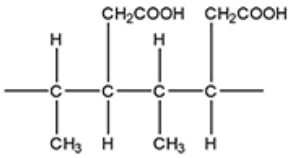
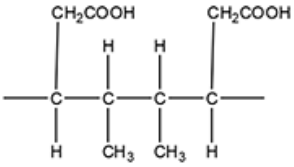
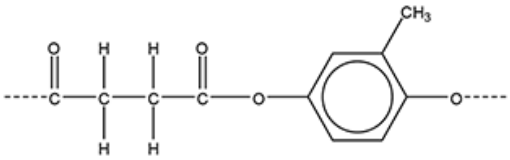
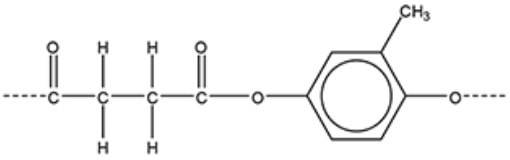
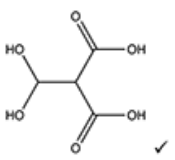
					candidates were able to gain a mark for either showing the displayed ester or amide link between two benzene rings. Some candidates recognised that at least 3 PAS units would be needed to show both the amide and ester links appropriately. Few responses were able to show a section of polymer that contained correct amide and ester linkages, the correct substituent groups and at least one end bond. The most common reason why candidates did not secure all 3 marks was omission of the OH group on one or more benzene rings of PAS. This question was more challenging as candidates needed to show a polymer section. Many gave 2 'end bonds' as they would for a repeat unit but this was not sufficient here due to the many different possible combinations, we could not make assumptions about what would be next. A common incorrect response was:  Furthermore, many candidates just gave 1 benzene ring, like this: 
		ii	**FIRST CHECK ANSWER ON THE ANSWER LINE** **If answer = 2.36×10^{22} award 3 marks** **Calculate moles of PAS:** 300 mg of PAS contains $\frac{300 \times 10^{-3}}{153}$ **OR** 1.96.... × 10^{-}	3 (AO3.1 ×2) (AO3.2 ×1)	**ALLOW 3SF** up to calculator value throughout **IGNORE** rounding errors past **3SF** **If there is an alternative answer, apply ECF throughout. Steps can be carried out in any order.** **Calculator values:**

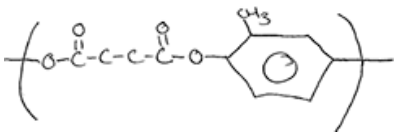
			^{3} (mol) ✓ **Daily dose of PAS:** *n*(PAS) for 20.0 kg child = 20 × 1.96…. × 10^{-3} (mol) **OR** 0.0392..... (mol) ✓ **Use of Avogadro's constant:** Number of PAS molecules = 0.0392..... × 6.02 × 10^{23} = 2.36 × 10^{22} ✓		1.960784314 x 10^{-3} 0.03921568627 **Common alternative method:** m(PAS) for 20.0 kg child = 0.3 x 20 **OR** 6.0 (g) ✓ n(PAS) for 20.0 kg child = 6/153 **OR** 0.0392…(mol**)** ✓ **Examiner's Comments** Nearly half the candidates were able to correctly calculate the number of PAS molecules in the maximum daily dosage. Some struggled with conversion from mg to g. Some made errors calculating the molar masses or did not calculate moles at all. Most were confident to multiply by N_A at the end. As with other calculations some lost marks for significant figures and rounding errors.
			Total	**6**	
7		i	16 ✓	1 (AO2.6)	**Examiner's Comments** This question was challenging for even the most able candidates with very few obtaining the correct answer of 16. Many identified the four chiral centres in compound E, often labelling these with an asterisk. However, only a small proportion were able to predict that there would be 16 possible optical isomers. Most provided an answer of four corresponding to the number of chiral centres or eight considering that each chiral centre would result in two optical isomers. They struggled to see that they needed 2^{n} in this case where n represents the number of chiral centres. Candidates have probably seen very few, if any, examples of

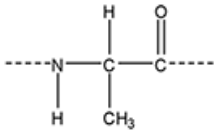
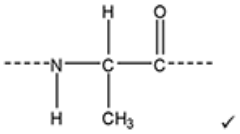
					chiral compounds with more than two chiral centres.
		ii	 **1 mark** for each **correct** structure with • **Either** NH_3^+ **OR** NH_2 ✓✓✓ **1 mark** for • **all 3 correct** structures with NH_3^+ ✓	4 (AO2.5 ×4)	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **IGNORE** connectivity **ALLOW** + charge on H of NH_3 group, i.e. NH_3^+ If structures are shown with NH_3 groups (without the + charge) **OR** as NH_2^+ groups allow **ECF** for subsequent use. **ALLOW** structures shown as correctly balanced salts, e.g NH_3Cl **OR** $NH_3^+Cl^-$ all marks can be awarded. **Examiner's Comments** A significant number of candidates did not attempt this question despite similar questions appearing in previous exam series. However, approximately a quarter of candidates scored all 4 marks. Some lost the final mark for not protonating the amine groups as required as under acidic conditions. A very common error was to hydrolyse the amides to give acyl chlorides or even aldehydes rather than carboxylic acids. Lower scoring candidates often had incomplete hydrolysis or no hydrolysis at all with just changes to acid/amine/phenol functional groups, e.g. protonation of amine to form salts or swapping or OH groups for Cl. Candidates need to check their answers carefully for missing or extra Hs as this lost marks. It was much easier to mark candidates' work presented with structures with a similar arrangement to compound E.
			Total	**5**	

8			 **Only possible alternative that can gain credit:** Reaction with $NaCN/H^+$ 	9 (AO1.2 ×4) (AO2.5 ×5)	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **ALLOW** Correct names instead of formula for all reagents throughout e.g. For H^+ and $Cr_2O_7^{2-}$, **ALLOW** acidified dichromate For Steam and acid • For steam, **ALLOW** $H_2O(g)$ **OR** H_2O with T ≥ 100°C • For acid, **ALLOW** H^+ **OR** H_2SO_4 **OR** H_3PO_4 • Note both needed for 1 mark. **ALLOW** either way round. For $NaBH_4$ • **IGNORE** water / aqueous /acid • **ALLOW** $LiAlH_4$ For $SOCl_2$, **ALLOW** PCl_5 **OR** $COCl_2$ • **IGNORE** H^+ OR HCl For H^+ and $Cr_2O_7^{2-}$, **ALLOW** H_2SO_4 **AND** $K_2Cr_2O_7$ **OR** $Na_2Cr_2O_7$ **ALLOW** Tollens' reagent **IGNORE** connectivity except **DO NOT ALLOW** -COH for aldehyde For polymer **ALLOW** alternating side chains. **IGNORE** brackets and use of 'n' 'End bonds' **MUST** be shown (solid or dotted) **IF** $NaCN/H^+$ reacted with acrolein instead of $NaBH_4$ • No mark for NaCN/H+ **OR** HCN • Unsaturated alcohol award mark for product as shown • Final product must have CN hydrolysed as shown **<u>Examiner's Comments</u>** This question discriminated well. Many

					candidates were able to demonstrate an excellent knowledge of organic reactions and it was not uncommon to see scores of at least 7 marks. This question identified which candidates had learned their synthetic routes including necessary reagents and conditions. Marks were often lost for small details such as missing Hs (check all Cs have four bonds) or not specifying that steam is required for hydration of alkenes or missing the acid needed for oxidation. Many suggested the use of NaOH or just a mixture of acids to product the diol. The minor 1,3-diol or 1,1-diol product was often seen. The sequence leading to an acyl chloride from acrolein was usually the most well answered. However, quite a few tried to use HCl to make the acyl chloride. Many lost marks for the polymer for incorrect connectivity on the aldehyde, e.g. -COH or attempting to make a polymer via connection of the aldehyde group. **OCR support** This topic guide provides a summary of synthetic routes. Copies of the summary posters without the conditions can be found on Teach Cambridge. This should be used in conjunction with the organic synthesis topic exploration pack.
			Total	**9**	
9	a	i	**Pent-3-enoic acid**  **2 repeat units of polymer**	2 (AO1.2) (AO2.5)	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **ALLOW** either the *E* or *Z* isomer **ALLOW ECF** from pent-2-enoic acid **OR** pent-4-enoic acid **ONLY** **For repeat unit,**

			 ✓		• 'side bonds' required on either side of repeat unit from C atoms • **2** repeat units required **IGNORE** connectivity of CH_2COOH in polymer **IGNORE** brackets **IGNORE** *n* --- **ALLOW** any consistent repeat unit: CH_2COOH and CH_3 groups can alternate or be on opposite sides of chain e.g. 
		ii	 ester link ✓ **ONE** repeat units of correct polymer ✓	2 (AO1.2) (AO2.5)	end –O– may be at either side e.g.  **ALLOW** CH_3 to be on position 2 or 3 of the aromatic ring 'End bonds' **MUST** be shown (do not have to be dotted) **IGNORE** brackets **IGNORE** *n*
		iii	 ✓	1 (AO3.2)	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **Examiner's Comments** Most candidates were given at least 1

					mark with many correctly drawing the structure of pent-3-enoic acid. Common errors included drawing pent-2-enoic acid or propenoic acid, suggesting a lack of knowledge of prefixes. The second mark required candidates to draw two repeat units, frequently candidates tried to draw repeat units linking the carboxylic acid groups rather than identifying that it is the carbon-carbon double bond that breaks. This question differentiated well. Candidates who scored 1 mark had often shown an ester link but their structure was missing hydrogen atoms from the carbon chain (as shown in exemplar 1) or the methyl group was missing from the ring. **Exemplar 1**  This type of response was seen frequently by examiners. The candidate has correctly drawn the ester link but has omitted the hydrogen atoms from the carbon chain. This question proved difficult for candidates with the majority of candidates not scoring the mark. A significant proportion of candidate had identified the monomer but drew structures that combined skeletal and displayed formulae. This resulted in ambiguous structures being given that had missing hydrogen atoms on the carbons. **Drawing of organic structures** Candidates need practice at drawing structures that are not ambiguous. They should check the number of bonds on each atom and make sure the appropriate number of hydrogen atoms are drawn.
	b	i		1 (AO2.5)	end –N– may be at either side e.g.

			 ✓ **ONE** repeat unit **ONLY**		 ✓ 'End bonds' **MUST** be shown (do not have to be dotted) **IGNORE** brackets **IGNORE** *n*
		ii	**IF** answer on answer line = 28418, **AWARD** 2 marks **IF** answer on answer line = 28400, **AWARD** 1 mark **----------** M_r of 400 molecules = 400 × 89 = 35600 ✓ M_r of polymer = 35600 − (399 × 18) = 28418 ✓	2 (AO2.2×2)	**ALLOW ECF** from incorrect repeat unit in 19di **ALLOW ECF** from incorrect M_r of 400 repeat units Alternative method based on repeat unit: M_r of 400 repeat units = 400 × 71 = 28400 ✓ M_r of polymer = 28400 + 1 + 17 = 28418 ✓ **<u>Examiner's Comments</u>** Few candidates were given the mark for this question. Frequently candidates drew structures with two repeat units or the did not remove the oxygen atom from the OH group. A variety of responses were seen in this demanding question. In general candidates adopted one of two approaches. The most common was to multiply the Mr of the repeat unit by 200 and then add the mass of H and OH at each end of the polymer. The other approach used the Mr of the monomer by 200 and then subtract the mass of the 199 water molecules removed in the polymerisation. Many

					candidates were successful with the first step of their approach, but the best responses included the second step taking into account the Mr of water. A significant number of candidates used an incorrect value for the Mr.
			Total	**8**	
10			B	1 (AO1.2)	**Examiner's Comments** Most candidates correctly identified B as one of the products. These candidates often drew out the structures of butyl propanoate and the product options to aid in their selection.
			Total	**1**	