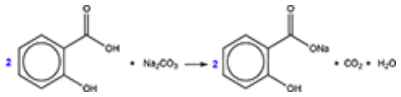
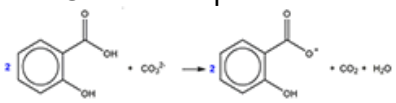
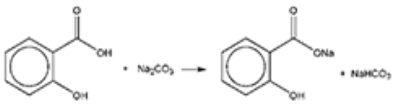
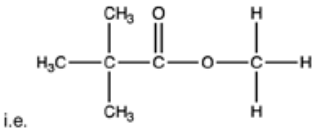
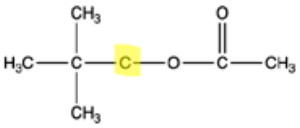
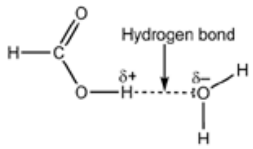
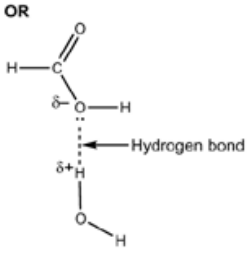
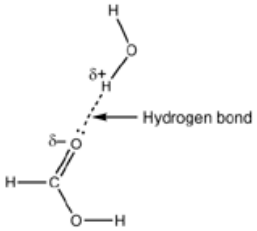
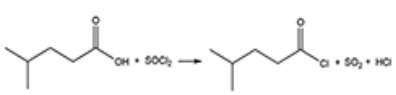
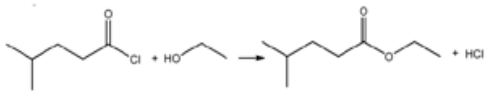
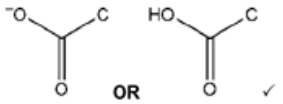
Mark scheme

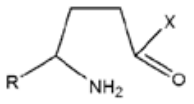
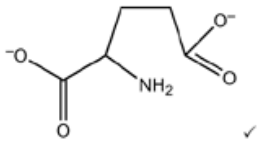
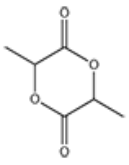
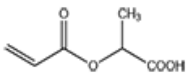
Question			Answer/Indicative content	Marks	Guidance
1		i	**Reaction with H_2SO_4** $Na_2CO_3 + H_2SO_4 \rightarrow Na_2SO_4 + CO_2 + H_2O$ ✓ **Reaction with excess G**  Correct organic product structure ✓ Correct balanced equation ✓	3	**ALLOW** multiples in both equations **IGNORE** state symbols **ALLOW** $Na_2CO_3 + 2H_2SO_4 \rightarrow 2NaHSO_4 + CO_2 + H_2O$ **ALLOW** ionic equation $CO_3^{2-} + 2H^+ \rightarrow CO_2 + H_2O$ **ALLOW** H_2CO_3 instead of $CO_2 + H_2O$ **ALLOW** $-COO^-$ (Na^+) for product structure mark **ALLOW** ionic equation  **ALLOW**  **ALLOW** H_2CO_3 instead of $CO_2 + H_2O$ **ALLOW** correct Kekulé representation of benzene **Examiner's Comments** Another fairly challenging question, however most secured at least one mark for giving an equation for the reaction of sulfuric acid with sodium carbonate. Less confident candidates struggled to gain any marks as they were unable to give correct formula for sodium sulfate, giving $NaSO_4$ for example. Although many attempted the equation showing the reaction of compound **G** with sodium carbonate, only some correctly identified that only the carboxyl group would react, not the phenol. A small minority of students were able to balance the second equation gaining all 3 marks.
		ii	(NaOH) reacts with phenol / -OH (in compound G / H) **OR** (NaOH) would hydrolyse the ester / compound H	1	**IGNORE** comment about whether it improves or not **DO NOT ALLOW** (NaOH) reacts with alcohol **Examiner's Comments** The best responses correctly identified that using sodium hydroxide was not an improvement and

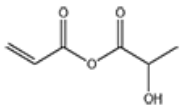
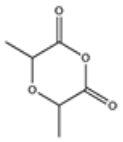
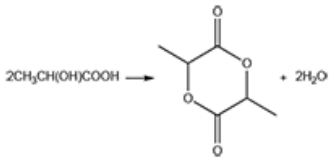
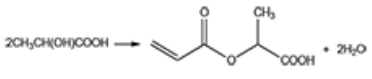
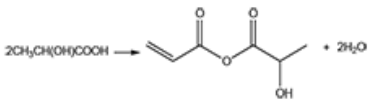
					explained this either bystating that it would react with the phenol group or hydrolyse the ester group in compound **H**. However, most candidates appeared not to consider a reaction with **H** in their answer. Many focused on the neutralisation of sulfuric acid in a similar way to sodium carbonate and gave responses such as: • stronger base • no effervescence so harder to see when completely reacted • no CO_2 produced so easier/safer/higher atom economy/less waste • requires double the moles compared to Na_2SO_4 to react
			Total	**4**	
2			**Mark organic product first:** A correct ester of $(CH_3)_3COH$ ✓ e.g. $(CH_3)_3COOCCH_3$ **Reagent and/or catalyst:** Reagent to match ester shown suitable carboxylic acid **AND** acid / H^+ catalyst, e.g. CH_3COOH/H_2SO_4 **OR** suitable acyl chloride e.g. CH_3COCl **OR** suitable acid anhydride e.g. $(CH_3CO)_2O$ ✓	2	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **IGNORE** additional byproducts e.g. H_2O, HCl or carboxylic acid (from acid anhydride) **For 2 marks**, the reagent must be consistent with the product given e.g. $(CH_3)_3COOCCH_3$ then correct reagent is CH_3COOH / H_2SO_4 **ALLOW** 1 mark if correct reagents given but no or incorrect organic product shown **ALLOW** 1 mark if ester is given with an R group i.e. $(CH_3)_3COOCR$ **AND** reagent is consistent e.g. RCOOH **OR** just states 'carboxylic acid and acid' **ALLOW** names of reagents e.g. ethanoic acid and sulfuric acid. **DO NOT ALLOW** other additional reagents e.g. $Cr_2O_7^{2-}$ **IGNORE** concentration e.g. dilute/concentrated **IGNORE** conditions e.g. reflux/distillation **IGNORE** use of acid catalyst with acyl chloride or acid anhydride **<u>Examiner's Comments</u>** Once again, more than half scored both marks here but candidates found it more challenging than Question 17 (c). Many stated 'carboxylic acid' but did not identify the specific example to use to give their product. A common error was to omit the acid

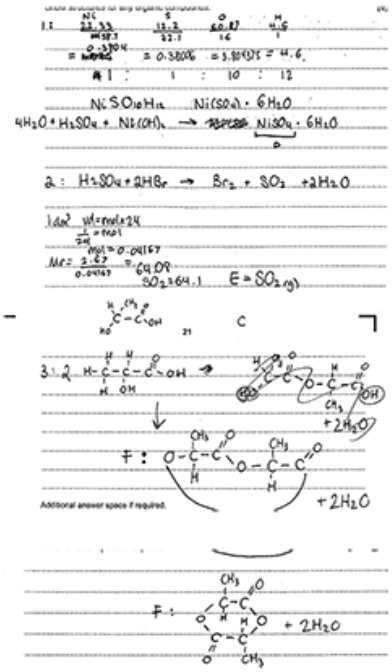
					catalyst. Some had the ester the wrong way round:  i.e. As seen with all parts of this question, some candidates struggled with the structural formula, resulting in some giving an additional carbon in their structure i.e.  A few candidates used an acyl chloride but it was rare to see an acid anhydride suggested.
			Total	**2**	
3	a		Diagram showing a hydrogen bond between a water molecule and a HCOOH *(dipoles and lone pairs not required)* **AND** Hydrogen bonding / H-bond stated **OR** labelled on diagram ✓  **OR**  H bond originates from lone pair on δ- O and goes to δ+ H (on another molecule) ✓	2	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **ALLOW** hydrogen bond to $HCOO^-$ (methanoate ion) **DO NOT ALLOW** H bond from **H**-C **DO NOT ALLOW** any marks for a diagram containing O_2H Hydrogen bond does **NOT** need to be labelled but it must be different from the covalent bond if it is not labelled. **IF** more than one hydrogen bond is shown they must **ALL** be correct to award each mark. **ALLOW** H bond between C=O and H_2O, i.e.  **DO NOT ALLOW** δ+ on H atom of C-H

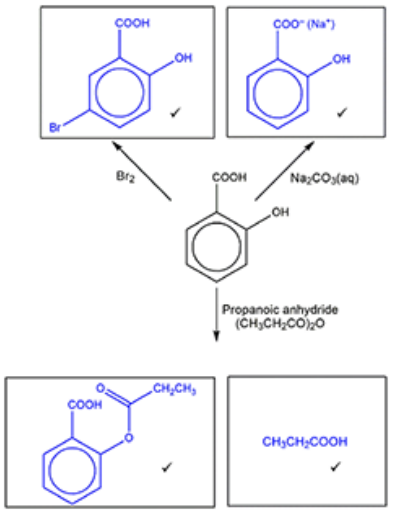
					All Hydrogen bonds must hit a lone pair **ALLOW** only one lone pair on O atom **DO NOT ALLOW** more than 2 lone pairs on O atom **Examiner's Comments** Most candidates were able to identify hydrogen bonding as being responsible for the solubility of methanoic acid. A minority of candidates did not gain any marks for this question. Some described the dissociation of methanoic acid into ions in water. Weaker candidates suggested this dissociation was sufficient to explain solubility. Some showed hydrogen bonds from H in the C-H bond in methanoic acid. Some drew hydrogen bonds from H to H or O to O. Most scored the first mark but lost the second mark usually for missing dipoles and/or lone pairs. Candidates often overcomplicated diagrams with multiple hydrogen bonds shown, increasing the likelihood of losing a mark for errors.
	b	i	ethyl 4-methylpentanoate ✓	1	**ALLOW** one word: ethyl4-methylpentanoate **OR** more words, e.g. ethyl 4-methyl pentanoate **DO NOT ALLOW** 1-ethyl-4-methylpentanoate **IGNORE** lack of hyphens, extra hyphens, full stops instead of commas, extra spaces **DO NOT ALLOW** the following for methyl:methy, meth, methly, methanyl **DO NOT ALLOW** the following for ethyl:ethy, eth, ethly, ethanyl **Examiner's Comments** Candidates found this difficult, with less than half gaining the mark. The most common error was incorrectly numbering the methyl group due to counting from the wrong end, giving ethyl-2-methylpentanoate.
		ii	**Step 1**  **Step 2**	4	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous e.g. $(CH_3)_2CHCH_2CH_2COOH + SOCl_2 \rightarrow (CH_3)_2CHCH_2CH_2COCl + SO_2 + HCl$ $(CH_3)_2CHCH_2CH_2COCl + C_2H_5OH \rightarrow (CH_3)_2CHCH_2CH_2COOC_2H_5 + HCl$ **DO NOT ALLOW** incorrect connectivity on OH **BUT ALLOW ECF** on subsequent structures

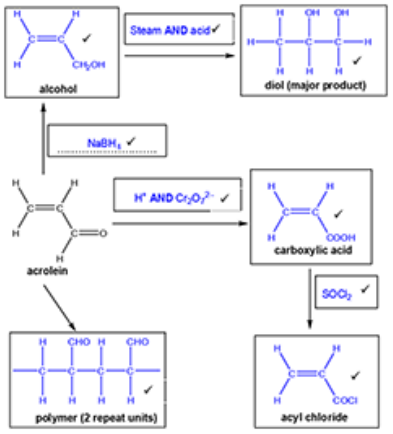
			 $SOCl_2$ used in **Step 1** ✓ Acyl chloride: $(CH_3)_2CHCH_2CH_2COCl$ correct ✓*Seen anywhere* **Step 1** correct equation ✓ **Step 2** correct equation ✓		**ALLOW** suitable non-specification alternatives for step 1 e.g. PCl_3, PCl_5, $COCl_2$ e.g. $3(CH_3)_2CHCH_2CH_2COOH + PCl_3 \rightarrow 3(CH_3)_2CHCH_2CH_2COCl + H_3PO_3$ $(CH_3)_2CHCH_2CH_2COOH + PCl_5 \rightarrow (CH_3)_2CHCH_2CH_2COCl + POCl_3 + HCl$ $(CH_3)_2CHCH_2CH_2COOH + COCl_2 \rightarrow (CH_3)_2CHCH_2CH_2COCl + HCl + CO_2$ **Examiner's Comments** This question differentiated between candidates well with the full range of marks seen. Some couldn't identify the correct reagent to use to form an acyl chloride i.e. $SOCl_2$, so lost 2 marks for the first step. Use of HC*l* as an alternative was common. A significant number used $SOCl_2$ but struggled to balance the equation. Many made errors with structures used, for example missing the CH_3 side chain, adding CH_3 to 3-position instead 4, inserting an additional CH_2 group or using a much easier structure, e.g. ethanoic acid. None of these structures were given marks as they would not form Ester F. Some used R- instead to simplify, for which credit was given, but only if it was clear what structure R represented. Another common error was to include an additional O in the acyl chloride group i.e. COOC*l* not COC*l*. The most common error made in Step 2 was to omit the formation of HC*l* or to use H_2O instead. A few lost the final mark for a connectivity error on ethanol i.e. $OHCH_2CH_3$.
	c		**Hydrolysis of ester:** Methanol / CH_3OH ✓ **Formation of carboxylate / carboxylic acid from hydrolysis of ester or amide:**  *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: ✓	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 **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

			 *Where R can be H or any other structure For X, ignore group attached to C=O* **Correct hydrolysis product:**  ✓		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	**11**	
4			**A**	1	**ALLOW** HC*l* **<u>Examiner's Comments</u>** 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			**Level 3 (5–6 marks)** • Reaches a comprehensive conclusion to determine all **three** correct formulae of **D**, **E AND F** • **AND** constructs most equations with few errors *There is a well-developed line of reasoning which is clear and logically structured.* *The information presented is relevant and substantiated.* **Level 2 (3–4 marks)** • Reaches a comprehensive conclusion to determine **two** correct formulae of **D**, **E AND F** • **AND** constructs some equations with some errors	6 (AO 3.1 ×3) (AO 3.2 ×3)	**Indicative scientific points may include:** **<u>Identify of D, E and F</u>** • **D**: $NiSO_4{\bullet}6H_2O$ **OR** $NiSO_4(H_2O)_6$ **OR** $NiSO_{10}H_{12}$ • **E**: SO_2 • **F: Cyclic diester**  **OR unsaturated ester/acid**  **OR unsaturated acid anhydride**

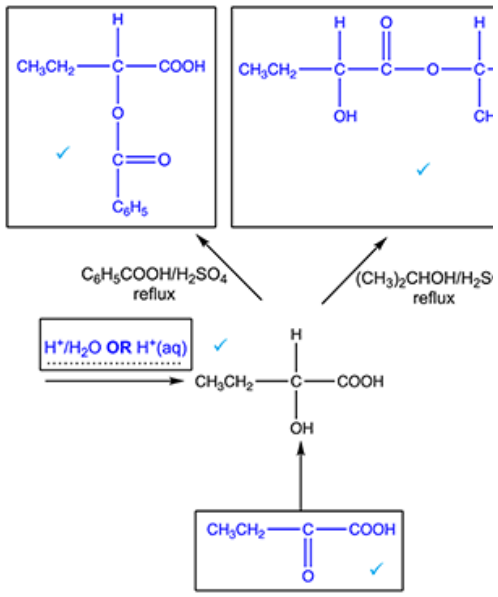
			There is a line of reasoning presented with some structure. *The information presented is relevant and supported by some evidence.* **Level 1 (1–2 marks)** • Determines a correct formula for **one** of **D, E AND F** • AND provides some evidence to support the formula *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.* **0 mark** *No response or no response worthy of credit.* **EQUATIONS SHOULD BE USED TO INFORM THE COMMUNICATION STRAND** *See next page for details* *CHECK TOP OF QUESTION FOR RESPONSES* *IGNORE CONNECTIVITY FOR F* **SUMMARY** **Setting the level** **For Level 3 (5–6 marks)**, • All 3 identified: **D**, **E** and **F** • Most equations **For Level 2 (3–4 marks)**, • 2 identified from **D**, **E** and **F** • 2 equations **For Level 1 (1–2 marks)**, • 1 identified from **D**, **E** and **F** • Evidence --- **Evidence to support a formula for Level 1** ***Molar ratios of D***		 **OR cyclic acid anhydride**  **Equations** $H_2SO_4 + Ni(OH)_2 \rightarrow NiSO_4 + 2H_2O$ **OR** $H_2SO_4 + Ni(OH)2 + 4H_2O \rightarrow NiSO_4 \bullet 6H_2O$ For equation **ALLOW** $NiSO_4 \bullet 6H_2O$ **OR** $NiSO_4(H_2O)_6$ --- $H_2SO_4 + 2HBr \rightarrow Br_2 + SO_2 + 2H_2O$  **OR**  **OR**  If structure of **F** is shown, **ALLOW** equation using molecular formulae, e.g. $2\ C_3H_6O_3 \rightarrow C_6H_8O_4 + 2H_2O$ **Examiner's Comments** This level of response question required candidates to interpret three pieces of information to identify 3 unknown chemicals, linked by three reactions of sulfuric acid. Levels were assigned based on identifying the three unknowns and writing equations for the reactions. The 3 reactions were tiered in difficulty with the cyclic structure for

			Ni : S : O : H 22.33/58.7 : 12.20/32.1 : 60.87/16.0 : 4.60/1.0 0.38 : 0.38 : 3.80 : 4.60 1 : 1 : 10 : 12 **OR** $NiSO_{10}H_{12}$ --- **Molar mass of E** Molar mass = 2.67 × 24 = 64(.08) g mol^{-1}		compound **F** being the most difficult. The question discriminated extremely well, with comparatively few candidates not scoring any marks. Exemplar 4  This exemplar shows an excellent response which was awarded Level 3 and 6 marks. The crossing out shows how the candidate progressively solved the problem. Despite the crossing out, working is shown throughout, and the presentation of the response is very clear. For reaction 1, the candidate initially made an error in the stock formula determination calculation. Notice that the candidate crossed out their initial values and wrote them afresh. This approach is recommended. as changing incorrect numbers can lead to ambiguous numbers. In reaction 2, the candidate comfortably identified compound **E** from its molar mass and wrote a balanced equation for this reaction. For reaction 3, you can see how the candidate's thought developed during the solve. They initially went for a straight chain structure and then worked out that there must be a cyclic structure. They finally show the cyclic diester as a conventional

					structural (based on glucose?), and with a balanced equation. This was an excellent response of a high-ability candidate and shows what a well-prepared candidate is capable of achieving.
			Total	**6**	
6				4 (AO2.5 ×4)	**IGNORE** connectivity of phenol OH group and COOH group throughout *(marks are for correct conversions)* **Br_2** **ALLOW** Br substitution at any position on ring **ALLOW** up to 4 Br atoms onto ring **Na_2CO_3** **ALLOW** COO^- **OR** COONa **$(CH_3CH_2CO)_2O$** **IGNORE** reaction of COOH to form an acid anhydride **ALLOW** structures in bottom 2 boxes in either order **<u>Examiner's Comments</u>** Overall, this question discriminated well with most candidates gaining some credit. Most candidates were able to suggest a correct product for the reaction of salicylic acid with bromine, with just a few candidates replacing the OH group with a Br atom. Most candidates recognised that the carboxylate salt would be produced from the reaction with Na_2CO_3 but not all were able to recall that the phenolic OH group is too weak acid to react. Some missed an O on carboxylate i.e. -CO-Na^+. Some added Na or CO_3 directly to the ring.

					The reaction with the anhydride proved much more challenging. All sorts of weird and wonderful structures of the main 'ester' product were given including joining the CH_3 group of propanoic anhydride to the O of the phenol group. Some used the bottom two boxes to form esters with the COOH and OH groups in turn. Many did not identify propanoic acid as a by-product even if they had correctly identified the ester product. Water was a common incorrect product. Marks were also occasionally lost for missing the benzene ring on structures or missing the -OH or -COOH groups that were left unreacted.
			Total	**4**	
7			 **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)

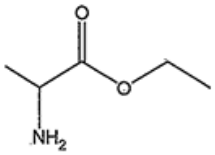
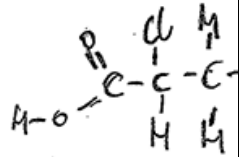
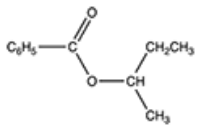
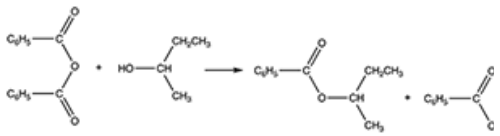
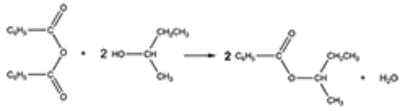
					IF NaCN/H^+ reacted with acrolein instead of $NaBH_4$ • No mark for NaCN/H+ **OR** HCN • Unsaturated alcohol award mark for product as shown • Final product must have CN hydrolysed as shown **Examiner's Comments** This question discriminated well. Many candidates were able to demonstrate an excellent 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**	
8			**D**	1 (AO1.2)	**Examiner's Comments** The most common incorrect response seen here was B. Candidates understood that nitriles can be hydrolysed but did not realise that it would give pentanoic acid not butanoic. Those who drew out the structures of the products for each were more likely to give the correct answer, D.

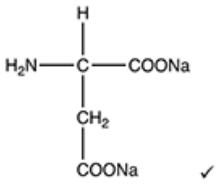
			Total	**1**	
9			**A**	1 (AO1.2)	**Examiner's Comments** Fewer than a third of candidates gave the correct response, A. Most identified that compounds 1 and 2 contain a bond angle of approximately 120° and consequentially selected option B. Only the most able candidates were able to apply their understanding of shapes to deduce that the carbocation would also exhibit trigonal planar geometry.
			Total	**1**	
10			**D**	1 (AO1.2)	**Examiner's Comments** Most candidates were able to correctly identify that amine D would be the one to react. However, some did not know what could react or were unable to spot the functional groups using skeletal formulae.
			Total	**1**	
11	a			4 (AO2.5× 4)	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **ALLOW** any vertical bond to the OH group e.g. **ALLOW** OH **OR** HO **IGNORE** connectivity of CH_3CH_2 group **IGNORE** inorganic by-products **ALLOW** HCl/H_2O, H_2SO_4/H_2O **IGNORE** dilute **Examiner's Comments** The majority of candidates were able to identify at least one of the structures. A significant number of candidates did not check the number of bonds of each atom in their structures and frequently had too many or too few hydrogen atoms attached. Most candidates identified that acidic conditions

					were required but some missed the aqueous condition that was also required for the mark.
	b		**Level 3 (5-6 marks)** Correct calculation of mass of $CH_3CHClCOOH$. **AND** Planned synthesis includes substitution of –Cl and formation of compound **I** (or its corresponding ammonium salt) with the correct reagents and some conditions identified and equations are mostly correct. *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3-4 marks)** Calculation of mass of $CH_3CHClCOOH$ is correct **AND** Planned synthesis includes one step of the synthesis with the correct reagent and some conditions identified and equation is mostly correct **OR** Calculation of mass of $CH_3CHClCOOH$ is partly correct **AND** Planned synthesis includes substitution of –Cl and formation of compound **I** (or its corresponding ammonium salt) with the correct reagents **OR** Attempts to calculate mass of $CH_3CHClCOOC_2H_5$ but makes little progress **AND** Planned synthesis includes substitution of –Cl and formation of compound **I** (or its corresponding ammonium salt) with the correct reagents and some conditions identified and equations are mostly correct	6 (AO3.3× 6)	**Indicative scientific points may include:** **<u>Calculation of mass of $CH_3CHClCOOCH_3$</u>** **Using moles** • $n(\mathbf{I}) = \frac{9.36}{117.0}$ = 0.08(00) (mol) • $n(CH_3CHClCOOC_2H_5) = 0.0800 \times \frac{100}{64}$ = 0.125 (mol) • Mass of $CH_3CHClCOOH$ = 108.5 × 0.125 = 13.5625 g **Using mass** • Theoretical mass of $\mathbf{I} = 9.36 \times \frac{100}{64}$ = 14.625 (g) • Theoretical $n(CH_3CHClCOOH) = \frac{14.625}{117.0}$ = 0.125 (mol) • Mass of $CH_3CHClCOOH$ = 108.5 × 0.125 = 13.5625 g **ALLOW** slip/rounding errors such as errors in M_r, e.g. use of 107.5 instead of 108.5 for $CH_3CHClCOOH$ → 13.4375

			There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence. **Level 1 (1-2 marks)** Calculation of mass of $CH_3CHClCOOH$ is partly correct **OR** Planned synthesis includes both steps with some of the reagents and conditions identified **OR** Attempts equations for both steps but these may contain errors **OR** Describes one step of the synthesis with reagents, conditions and equation mostly correct *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.* **0 marks** No response or no response worthy of credit.		**----------** ***Examples of partly correct calculations*** Mass = 5.5552 g from $0.0800 \times \frac{64}{100} \times 108.5$ (% *yield inverted*) Mass = 8.68 g from 0.0800 × 108.5 (% *yield omitted*) **<u>Synthesis: *Either order for 2 stages*</u>** **Substitution of –Cl → amine:** • Reagents: (excess) NH_3 • Condition: ethanol • Equation: $CH_3CHClCOOH + 2NH_3 \rightarrow CH_3CHNH_2COOH + NH_4Cl$ **OR** $CH_3CHClCOOH + NH_3 \rightarrow CH_3CHNH_2COOH + HCl$ **Esterification of amine → compound I** • Reagents: CH_3CH_2OH • Conditions: acid (catalyst), e.g. H_2SO_4 (reflux/heat) • Equation: $CH_3CHNH_2COOH + CH_3CH_2OH \rightarrow CH_3CHNH_2COOCH_2CH_3 + H_2O$ **OR ----------** **Esterification of carboxylic acid → ester** • Reagents: CH_3CH_2OH • Conditions: acid (catalyst), e.g. H_2SO_4 (reflux/heat)

					• Equation: $CH_3CHClCOOH + CH_3CH_2OH \rightarrow CH_3CHClCOOCH_2CH_3 + H_2O$ **Substitution of –Cl → amine:** • Reagents: (excess) NH_3 • Condition: ethanol • Equation: e.g $CH_3CHClCOOCH_2CH_3 + 2NH_3 \rightarrow CH_3CHNH_2COOCH_2CH_3 + NH_4Cl$ **OR** $CH_3CHClCOOCH_2CH_3 + NH_3 \rightarrow CH_3CHNH_2COOCH_2CH_3 + HCl$ **OR** $CH_3CHClCOOCH_2CH_3 + NH_3 \rightarrow CH_3CHNH_3ClCOOCH_2CH_3$ *(ammonium salt)* **Examiner's Comments** This question was marked using a level of response mark scheme. Most candidates gave an answer worth of at least Level 2 (3-4 marks) by providing the synthetic steps with reagents and equations for the synthesis of compound I. Exemplar 2, below, shows a frequent Level 2 response. The best performing candidates correctly determined the mass attempting to calculate the mass and showed the synthesis efficiently, using equations to communicate the preparation of compound I, with these responses being given Level 3 (5-6 marks). A number of responses omitted the mass calculation, such responses received Level 2 (1-2 marks). Exemplar 2

					 Compound I  Plan a synthesis to prepare 9.36 g of compound **I** starting from 2-chloropropanoic $CH_3CHClCOOH$. The overall percentage yield of compound **I** from 2-chloropropa is 64%. In your answer, include starting mass of 2-chloropropanoic acid, reagents, conditi equations where appropriate. $9.36 \times \frac{100}{64} = 14.625$ g to start $CH_3-CHCl-COOH + NH_3 \rightarrow CH_3-CH(NH_2)-COOH + HCl$ $H_3C-CH(NH_2)-COOH + HO-CH_2-CH_3 \rightarrow$ ester + H_2O Conditions H_2SO_4 catalyst + reflux Reagent: Ethanol In this response the candidate has attempted to calculate the starting mass but has made little progress. Two stages of the synthesis have been covered with the reagents and most of the conditions identified. Both equations are complete. This is a Level 2 response and 4 marks have been given as the repones is logical and well communicated
			Total	**10**	
12			Structure of ester product ✓  Correct balanced equation ✓ 	2 (AO3.1) (AO3.2)	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **ALLOW**  **Examiner's Comments** Most candidates did not secure a mark in this

					question. Many candidates used butan-1-ol in their equations or used benzoic acid rather than benzoic anhydride as the reactant. The most able candidates suggested that the benzoic acid product would then further react with butan-2-ol to produce a second ester molecule and water. This was an acceptable alternative response.
			Total	**2**	
13			$C_2H_5COOH + KOH \rightarrow C_2H_5COOK + H_2O$ ✓ $2HCOOH + Mg \rightarrow (HCOO)_2Mg + H_2$ ✓ H_2O **AND** CO_2 ✓  ✓ Correct formula of salt:	4 (AO2.6× 4)	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **IGNORE** state symbols and use of equilibrium sign **ALLOW** KC_2H_5COO **DO NOT ALLOW** a missing charge (e.g. $C_2H_5COO^-K$) the 1st time seen but **IGNORE** for next equations. For salts, **ALLOW** $C_2H_5COO^-K^+$ **OR** $C_2H_5COO^- + K^+$ **DO NOT ALLOW** –COO–K (covalent bond) the 1st time seen but **IGNORE** for next equations. **FOR** $CO_2 + H_2O$ **ALLOW** H_2CO_3 **Examiner's Comments** This question proved challenging for candidates. The first equation was often answered correctly, although some candidates used sodium hydroxide rather than potassium hydroxide in their response. The second equation was frequently incorrect. Candidates frequently missed a hydrogen from the structure for methanolic acid or did not recognise that hydrogen was a product. Many candidates did not account for magnesium having a 2+ charge when working out the product. For the third equation, the majority of candidates identified that carbon dioxide and water would be produced but were unable to give the correct formula of the salt as they did not interpret the information given regarding the R group.
			Total	**4**	

14	a		Number of optical isomers = 4 ✓	1 (AO2.1)	**Examiner's Comments** Most candidates added two asterisks to the diagram of vitamin C for the possible chiral centres. More successful responses usually realised that two chiral centres would give rise to $2^2 = 4$ optical isomers, with 2 optical isomers being the commonest error.
	b	i	Hydrogen bonding **AND** **Many** OH/hydroxyl / hydroxy / alcohol ✓	1 (AO2.1)	**ALLOW** 4 OH **DO NOT ALLOW** OH^- **Examiner's Comments** Most candidates realise that hydrogen bonds would be formed from the OH groups in vitamin C to water. Candidates are advised to read the question carefully as the word 'extremely' was a hint that 'many' OH groups would be needed in the explanation. The most successful responses quoted that hydrogen bonds would form between the 4 OH groups in vitamin C and water. Some candidates stated that O atoms in vitamin C would be involved. This was not given marks as not all O atoms in vitamin C are a part of OH groups and capable of hydrogen bonding.
		ii	x = 15 ✓ y = 31 ✓	1 (2 ×AO3.2)	**Examiner's Comments** More successful responses determined that $x = 15$ and $y = 31$. The key to success here was to subtract the formula of vitamin C from the formula of the ester and to add the formula of water: $C_{22}H_{38}O_7 - C_6H_8O_6 + H_2O \rightarrow C_{16}H_{32}O_2 \rightarrow C_{15}H_{31}COOH$. A significant number of candidates did obtain one of these values, with 15/16 and 29/30/32 being common incorrect answers. Omitting part(s) of sequence above would result in these incorrect numbers.
			Total	**4**	