PEARSON EDEXCEL IAL CHEMISTRY · YCH11

CHEMISTRY



EXAM QUESTION PACK

UNIT 4: CARBOXYLIC ACID DERIVATIVES

SCORE	PERCENTAGE
/93	%

STEMUP

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Q1.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Butanoic acid may be prepared by the acid hydrolysis of

☒ **A** butyl ethanoate

☒ **B** 1-chlorobutane

☒ **C** ethyl butanoate

☒ **D** propanenitrile

(Total for question = 1 mark)

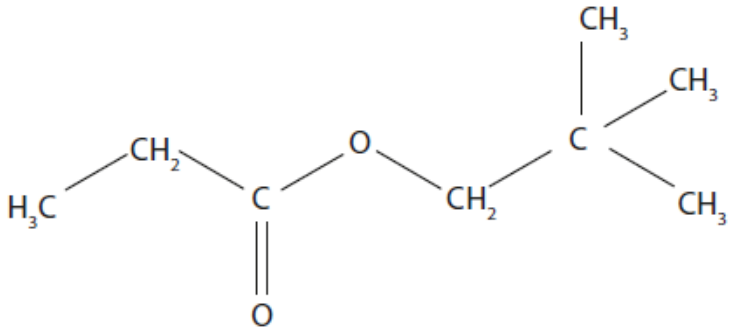
Q2.

This question is about an ester, **Y**, with the molecular formula $C_8H_{16}O_2$.

(a) **Y** contains 66.7 % carbon, 11.1 % hydrogen and 22.2 % oxygen by mass. Show that these data are consistent with its molecular formula.

(2)

(b) The structure of compound **Y** is



(i) Give the IUPAC name of **Y**.

(2)

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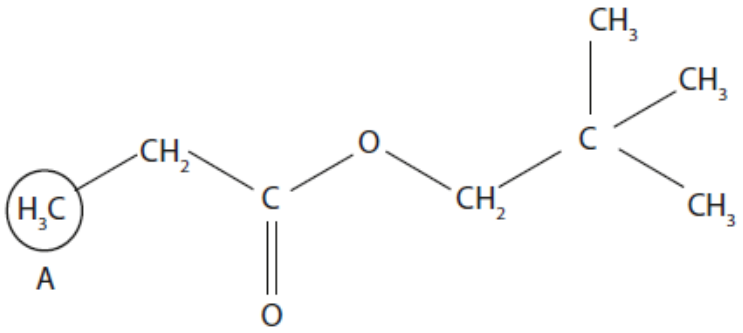
(ii) Draw the structures of two organic compounds that would react together to form **Y**.

(1)

(c) The high resolution proton NMR spectrum of compound **Y** was obtained.

(i) Label the three remaining hydrogen environments B, C and D on the structure.

(1)



(ii) Complete the table.

(3)

Hydrogen environment	Splitting pattern of peak	Relative peak area
A	triplet	3
B		
C		
D		

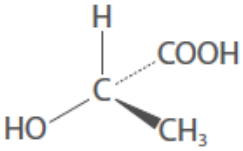
(Total for question = 9 marks)

Q3.

This question is about carboxylic acids and their derivatives.

(a) Lactic acid, $CH_3CH(OH)COOH$, is produced in muscles as a result of anaerobic respiration.

(i) The structure of lactic acid is



Give a reason why lactic acid shows optical isomerism.

(1)

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(ii) A laboratory sample of lactic acid does **not** rotate the plane of plane-polarised monochromatic light.

Give a reason for this observation.

(1)

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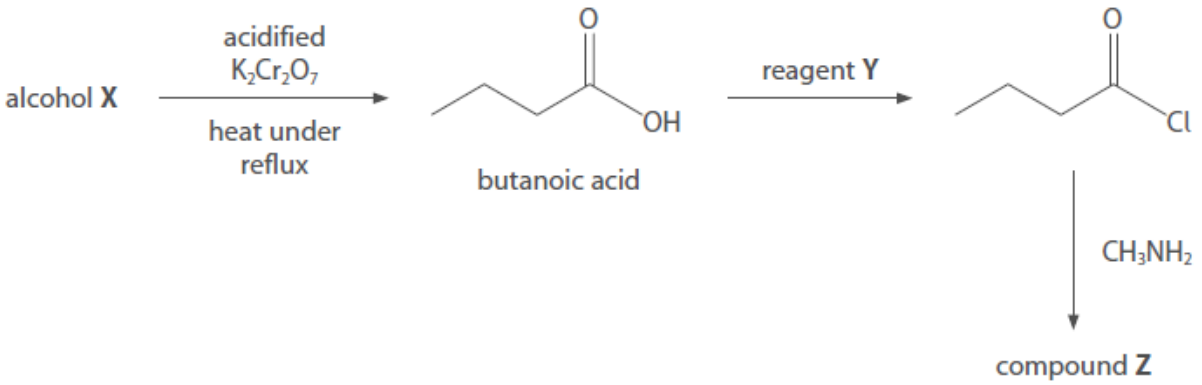
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(iii) Give the structure of the organic product formed when lactic acid reacts with concentrated phosphoric(V) acid, H_3PO_4 .

(1)

(b) A reaction scheme involving butanoic acid is shown.

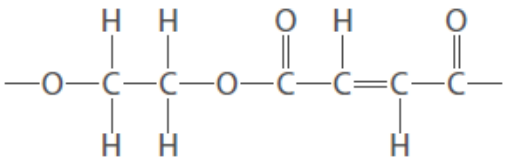


Identify **X**, **Y** and **Z** by name or formula.

(3)

Alcohol **X**
Reagent **Y**
Compound **Z**

(c) The repeat unit of a polyester is shown.



Give the structures of the two monomers that could form this polyester.

(2)

Monomer 1	Monomer 2

(d) An organic compound **E** contains carbon, hydrogen and oxygen only.

(i) The accurate relative atomic masses, A_r , of the three elements in **E** are shown in the table.

Element	A_r
hydrogen	1.0078
carbon	12.0000
oxygen	15.9949

E contains five carbon atoms and gives a molecular ion peak at $m / z = 102.0678$ in its mass spectrum.

Deduce the molecular formula of **E**.

(1)

(ii) Aqueous sodium hydrogencarbonate is added to a sample of **E**.
No effervescence occurs.

State what can be deduced by this observation.

(1)

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(iii) The infrared spectrum of **E** has an absorption in the range 1750 – 1735 cm^{-1}.

Name the functional group in **E**.

(1)

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(iv) Data from the high resolution proton NMR spectrum of **E** is shown.

Peak	Chemical shift, δ / ppm for TMS	Splitting pattern	Relative peak area
A	4.02	triplet	2
B	2.05	singlet	3
C	1.65	sextet	2
D	0.95	triplet	3

Deduce the structure of **E**.
Justify your answer by labelling the protons responsible for each peak.

(3)

(Total for question = 14 marks)

Q4.

Polyesters can be made by the reaction of:

(1)

☒ **A** diprotic carboxylic acids with a primary alcohol

☒ **B** diprotic carboxylic acids with diols

☒ **C** monoprotic carboxylic acids with triols

☒ **D** monoprotic carboxylic acids with a secondary alcohol

(Total for question = 1 mark)

Q5.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

In which of these esters is the percentage by mass of carbon 54.5%?

☒ **A** methyl methanoate, $HCOOCH_3$

☒ **B** methyl ethanoate, CH_3COOCH_3

☒ **C** ethyl ethanoate, $CH_3COOCH_2CH_3$

☒ **D** ethyl methanoate, $HCOOCH_2CH_3$

(Total for question = 1 mark)

Q6.

Esters are used in flavourings and perfumes.
They can be made by reactions involving alcohols.

(a) A flask containing a mixture of 0.200 mol of ethanoic acid and 0.150 mol of ethanol was left at 25 °C, in the presence of a catalyst, until equilibrium had been established.

$$CH_3COOH(l) + C_2H_5OH(l) \rightleftharpoons CH_3COOC_2H_5(l) + H_2O(l)$$

The ethanoic acid present in the equilibrium mixture required 34.8 cm^3 of a 2.50 mol dm^{-3} solution of sodium hydroxide for complete neutralisation.

(i) Calculate the value of the equilibrium constant, K_c, for this reaction at 25 °C.

(4)

(ii) The enthalpy change for this reaction is small.

Explain, by reference to the type and number of bonds being broken and made, how this might have been predicted.

(2)

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(b) An ester which smells of raspberries can be formed by either of two different reactions.

Reaction **1**

$$HCOOH + (CH_3)_2CHCH_2OH \overset{\text{catalyst}}{\rightleftharpoons} HCOOCH_2CH(CH_3)_2 + H_2O$$

Reaction **2**

$$HCOCl + (CH_3)_2CHCH_2OH \rightarrow HCOOCH_2CH(CH_3)_2 + HCl$$

(i) **Name** the carboxylic acid, alcohol and catalyst used in Reaction **1**.

(2)

$HCOOH$ ..... catalyst .....

$(CH_3)_2CHCH_2OH$ .....

(ii) Explain **one** advantage and **one** disadvantage of using Reaction **2** rather than Reaction **1**.

(4)

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(Total for question = 12 marks)

Q7.

This question is about ethanoic acid and some of its compounds.

(a) Three students, A, B and C, carried out an investigation to determine the amount of isoamyl acetate, an ester of ethanoic acid, in a banana food flavouring.

They hydrolysed the ester with excess sodium hydroxide solution.

$$CH_3COOCH_2CH_2CH(CH_3)_2 + NaOH \rightarrow CH_3COONa + (CH_3)_2CHCH_2CH_2OH$$

The amount of sodium hydroxide remaining was determined by titrating the reaction mixture with hydrochloric acid.

(i) Give the systematic name for isoamyl acetate.

(1)

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(ii) 6.06×10^{-3} mol of sodium hydroxide reacted with the ester present in 1.07 g of the flavouring.

Calculate the percentage by mass of the ester in the food flavouring.

(3)

(iii) The students used 25.0 cm^3 of sodium hydroxide solution with concentration 0.980 mol dm^{-3} for the hydrolysis.

Calculate the pH of the reaction mixture when the hydrolysis is complete. Assume the total volume is 25.0 cm^3.

[Ionic product of water, $K_w = 1.0 \times 10^{-14}\,mol^2\,dm^{-6}$]

(3)

(iv) Two indicators, methyl orange and phenolphthalein, were available for this titration.

Student A thought only methyl orange could be used.
Student B thought only phenolphthalein could be used.
Student C suggested either indicator could be used.

Explain which student is correct.

(2)

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(v) Describe how the sodium ethanoate in the final reaction mixture could be converted into ethanoic acid.

(1)

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(b) Ethanoic acid can be used to form buffer solutions.

(i) Calculate the pH of the buffer solution formed when 50.0 cm^3 of ethanoic acid with concentration of 0.150 mol dm^{-3} is mixed with 30.0 cm^3 of sodium hydroxide solution with

concentration of 0.142 mol dm^{-3}.

[K_a for ethanoic acid = 1.70×10^{-5} mol dm^{-3}]

(5)

(ii) Small amounts of sodium hydroxide and hydrochloric acid are added to separate samples of the buffer solution in (b)(i).

Explain why these samples resist change in pH.

Illustrate your answer with at least two equations.

(5)

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(Total for question = 20 marks)

Q8.

Carboxylic acids and acyl chlorides both react with alcohols to produce esters.
Acyl chlorides are often preferred to carboxylic acids for this reaction because the yield of the ester is usually higher.
Which of the following statements is the best explanation for the higher yield?

(1)

☒ **A** acyl chlorides react to remove any water produced

☒ **B** the reaction is not reversible

☒ **C** the reaction is less exothermic

☒ **D** the reaction has a higher atom economy

(Total for question = 1 mark)

Q9.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

The formation of esters and the hydrolysis of esters are reactions that are slow under normal laboratory conditions.

What speeds up these reactions?

	Esterification	Hydrolysis
☒ **A**	acids only	acids only
☒ **B**	acids only	acids and bases
☒ **C**	bases only	bases only
☒ **D**	bases only	acids and bases

(Total for question = 1 mark)

Q10.

For each question, select one answer from A to D and put a cross in the box ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Which of these compounds is a product of the hydrolysis of $CH_3COOC_3H_7$ by refluxing with aqueous sodium hydroxide?

☒ **A** CH_3OH

☒ **B** C_3H_7OH

☒ **C** C_3H_7COOH

☒ **D** $C_3H_7COO^-Na^+$

(Total for question = 1 mark)

Mark Scheme

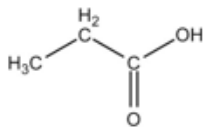
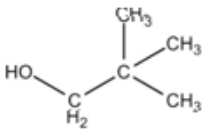
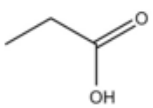
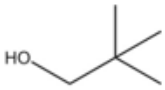
Q1.

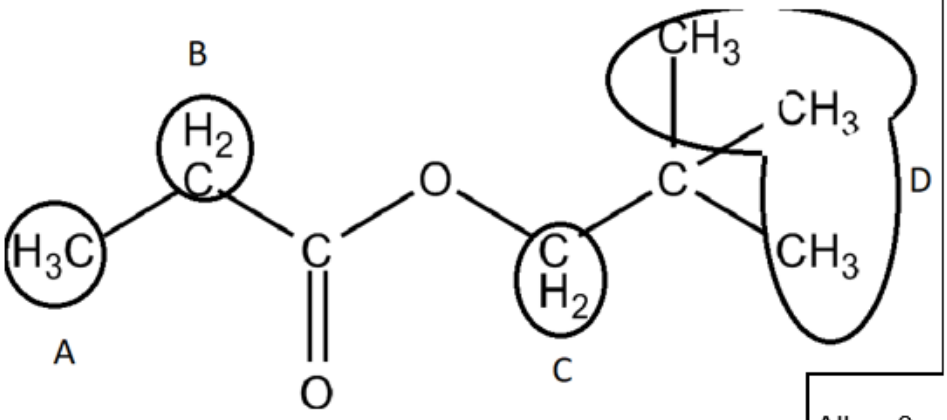
Question number	Answer	Mark
	The only correct answer is C (ethyl butanoate) *A is incorrect because hydrolysis would give ethanoic acid* *B is incorrect because hydrolysis would give butan-1-ol* *D is incorrect because hydrolysis would give propanoic acid*	**(1)**

Q2.

Q	Acceptable Answers	Additional Guidance	Mark
(a)	• calculation of moles of C, H and O **(1)** • calculation of ratio **and** identify that ratio matches molecular formula **(1)** OR • calculate molar mass of **Y** **(1)** • calculate % of each element **(1)**	element / moles / ratio C / 66.7○12 =5.56 / 5.56○1.3875 = 4 H / 11.1○1 = 11.1 / 11.1○1.3875 = 8 O / 22.2○16 =1.3875 / 1.3875○1.3875 = 1 Ratio C_4H_8O matches $C_8H_{16}O_2$ Molar mass = 144 (g mol^{-1}) C=96○144x100 = 66.7% H=16○144x100 = 11.1% O=32○144x100 = 22.2%	**2**

Q	Acceptable Answers	Additional Guidance	Mark
(b)(i)	2,2-dimethylpropyl propanoate **(2)**	Any name with '-propyl propanoate' scores 1 propyl-2,2-dimethyl propanoate scores 1 2,2-dimethylpropylethanoate scores 1	**2**

Q	Acceptable Answers	Additional Guidance	Mark
(b)(ii)	  **OR**  	Both structures required for mark Allow structures of propanoyl chloride / propanoic anhydride Allow any combination of correct skeletal, structural or displayed formulae. Ignore names even if incorrect Do not award connectivity to hydroxyl group via H atom	**1**

Q	Acceptable Answers	Additional Guidance	Mark
(c)(i)		Labels B C and D can be used interchangeably as long as the three proton environments are identified correctly. Allow 3 methyl groups to be circled individually but with a single label / labels pointing to all 3	1

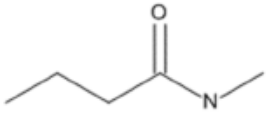
Q	Acceptable Answers	Additional Guidance	Mark
(c)(ii)	<table><tr><th>Hydrogen environment</th><th>Splitting pattern of peak</th><th>Relative peak area</th></tr><tr><td>(A)</td><td>(triplet)</td><td>(3)</td></tr><tr><td>B</td><td>quartet</td><td>2</td></tr><tr><td>C</td><td>singlet</td><td>2</td></tr><tr><td>D</td><td>singlet</td><td>9</td></tr></table> Note : allow 'quadruplet' as alternative for quartet / 'single' as alternative for singlet Do not award 'quadrat'	1 mark for each row. But If two or more rows are incorrect then award whichever of these alternatives is higher Allow 2 marks for 3 correct splitting patterns. OR Allow 1 mark for 3 correct peak areas. OR Allow 1 mark for correct row marked consequentially on the labelling in 17(c)(i)	3
	(Total for Question = 9 marks		

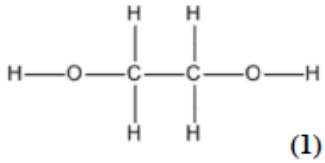
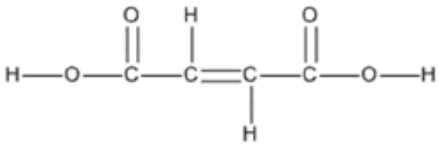
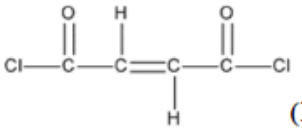
Q3.

Question Number	Answer	Additional Guidance	Mark
(a)(i)	An answer that makes reference to the following point: • it / lactic acid is non-superimposable on its mirror image	Allow there are four different atoms / groups attached to a carbon (atom) Allow it is chiral / has a chiral centre / has a chiral carbon (atom) / has an asymmetric carbon (atom) Ignore rotates the plane of plane-polarised light Do not award four different molecules attached to a carbon (atom)	(1)

Question Number	Answer	Additional Guidance	Mark
(a)(ii)	An answer that makes reference to the following point: • it is a racemic mixture or contains equal amounts of the two enantiomers / (optical) isomers	Allow rotations caused by both enantiomers / isomers cancel Ignore just contains two enantiomers / isomers Do not award plane-polarised light cannot pass through the solution	(1)

Question Number	Answer	Additional Guidance	Mark
(a)(iii)	• CH_2=CHCOOH	Allow any combination of structural or displayed formulae or skeletal formulae / $COOHCH=CH_2$	(1)

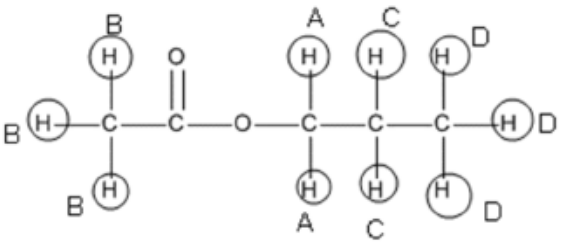
Question Number	Answer	Additional Guidance	Mark
(b)	• **X**: butan-1-ol or  or $CH_3CH_2CH_2CH_2OH$ / $CH_3(CH_2)_2CH_2OH$ **(1)** • **Y**: phosphorus(V) chloride / phosphorus pentachloride / PCl_5 **(1)** • **Z**: *N*-methylbutanamide or  or $CH_3CH_2CH_2CONHCH_3$ / $CH_3(CH_2)_2CONHCH_3$ **(1)**	Mark independently If names and formulae are given, both must be correct but penalise missing H from carbon chain displayed formulae once only Allow any combination of skeletal, structural or displayed formulae Ignore molecular formulae for **X**, **Y** and **Z** Ignore butanol / C_4H_9OH Do not award $CH_3CH_2CH_2CH_3O$ Do not award butanal Allow phosphorus(III) chloride / PCl_3 / thionyl chloride / $SOCl_2$ Do not award hydrochloric acid / HCl Ignore methylbutanamide / butanamide in addition to a correct structure Allow NH in skeletal formula Do not award $CH_3CH_2CH_2COHNCH_3$ / $CH_3CH_2CH_2COCH_3NH$	(3)

Question Number	Answer	Additional Guidance	Mark
(c)	• Monomer 1  (1) • Monomer 2  or  (1)	Allow monomers in either order Allow any combination of structural or displayed formulae / skeletal formulae Allow OH Ignore bond lengths and bond angles Penalise OH-C on left of molecules once only Penalise missing H from carbon chain displayed formulae once only Accept cis isomers	(2)

Question Number	Answer	Additional Guidance	Mark
(d)(i)	• $C_5H_{10}O_2$	Allow symbols in any order Ignore any working Ignore + charge	(1)

Question Number	Answer	Additional Guidance	Mark
(d)(ii)	• **E** is not a carboxylic acid or does not contain COOH (group)	If name and formula are given, both must be correct Allow **E** is not an acid Do not award additional functional groups	(1)

Question Number	Answer	Additional Guidance	Mark
(d)(iii)	• **E** is an ester	Ignore saturated / -COO- / C=O Do not award additional functional groups	(1)

Question Number	Answer	Additional Guidance	Mark
(d)(iv)	• structure of **E** (1) • 2 or 3 proton environments correct (1) • 4th proton environment correct (1)	Example of structure:  Protons can be circled and labelled or just labelled Allow labels using data from the table Only 1 proton from each group needs to be labelled Allow whole groups to be labelled, including the carbon atom	(3)

Q4.

Question number	Answer	Mark
	B diprotic carboxylic acids with diols	1

Q5.

Question Number	Answer	Mark
	The only correct answer is C (Ethyl ethanoate, $CH_3COOCH_2CH_3$) *A is incorrect because this has a percentage of 40%* *B is incorrect because this is isomeric to D so cannot be the answer* *D is incorrect because this is isomeric to B so cannot be the answer*	(1)

Q6.

Question Number	Answer	Additional Guidance	Mark
(a)(i)	• calculates moles of acid present in the mixture **(1)** • calculates moles of ester and water present in the mixture **(1)** • calculates moles of ethanol present in the mixture **(1)** • expression for K_c and final answer	Example calculation mol of acid = mol of NaOH = $\frac{34.8}{1000}$ x 2.50 = 0.087 (mol) mol of ester = mol of water = 0.2 – 0.087 = 0.113(mol) mol of ethanol = 0.150 – 0.113 = 0.037 If the expression for Kc is incorrect, e.g. no water, allow TE on M1-3 for example not calculating moles of water as well as ester $K_c = \frac{0.113/V \times 0.113/V}{0.087/V \times 0.037/V}$ = 3.9668 / 4.0 (no units) OR $K_c = \frac{[CH_3COOC_2H_5][H_2O]}{[CH_3COOH][C_2H_5OH]}$ = 3.9668 / 4.0 **and** statement that volumes cancel Do not penalise lack of square brackets in equilibrium expression Assumption that 0.087 is moles of acid used gives moles ethanol = 0.063 moles ester = water = 0.087 Kc = 1.0632 scores max (3) Calculation of acid moles at equilibrium larger than acid moles at the start can score M4 only If no other mark is scored Award (1) for calculation of 0.087(mol) however it is used, Ignore SF	**(4)**

Question Number	Answer	Additional Guidance	Mark
(a)(ii)	An answer that makes reference to the following points: • same type of / similar bonds being broken and made **(1)** • same number of each type of bond being broken and made **(1)**	Allow O-H and C-O bonds being broken and made Allow the same bond being broken and made Allow C-OH Ignore C-O-H and COH Ignore CO without the bond shown Award 2 marks for a complete list of the bonds being broken and made e.g. Bonds broken and made are 1 x C-O and 1 x O-H scores 2 Allow ester link as C-O If no other mark is scored award 1 mark for 1 O-H bond is broken and made Or 1 C-O bond is broken and made If no other mark is scored allow the energy required to break the bonds is similar to the energy released making the bonds for (1)	**(2)**

Question Number	Answer	Additional Guidance	Mark
(b)(i)	• methanoic acid • (concentrated) sulfuric acid • 2-methylpropan-1-ol	All three correct scores (2) Any two correct scores (1) Allow hydrochloric acid / H_2SO_4 / HCl Ignore H^+ Ignore (aq) after formulae Ignore hydrogen chloride in words Allow methylpropan-1-ol Allow 2-methyl-1-propanol Allow methyl-1-propanol Do not award 2-methylpropanol	**(2)**

Question Number	Answer	Additional Guidance	Mark
(b)(ii)	Any one advantage: • no heat required / works at room temperature **(1)** • so reduces energy cost **(1)** or • no catalyst required **(1)** • reducing product purification costs / making purification easier / no need to recover catalyst **(1)** or • reaction is not an equilibrium / reaction goes to completion **(1)** • so produces a higher yield **(1)** Any one disadvantage: • hydrogen chloride produced is acidic / corrosive **(1)** • corrosion resistant plant/equipment required (which is more expensive) **(1)** or • HCl is toxic • use a fume cupboard / clean exhaust gases / capture the gas (for sale)	• Accept the reaction is (much) faster • so no energy required Ignore just lower cost Ignore more product Allow reactants are not wasted Ignore reference to atom economy	**(4)**

Q7.

Question Number	Acceptable Answers	Additional Guidance	Mark
(a)(i)	3-methylbutyl ethanoate or 3-methyl-1-butyl ethanoate	Allow butanyl for butyl Do not award butanoyl Allow methly formethyl	1

Question Number	Acceptable Answers	Additional Guidance	Mark
(a)(ii)	• Calculation of M_r of ester (1) • Calculation of mass of ester (1) • Calculation of percentage of ester (1)	Example of calculation M_r of ester = 130 Mass of ester = $6.06 \times 10^{-3} \times 130$ = 0.7878 (g) TE on incorrect M_r of ester % of ester = (0.7878/1.07) x 100 =73.6 % Allow 73.8% as M2 rounded to 0.79 Correct answer with no working scores 3 marks. Allow TE from M2 Ignore SF except 1SF	3

Question Number	Acceptable Answers	Additional Guidance	Mark
(a)(iii)	• Calculation of mol of excess sodium hydroxide (1) • Calculation of concentration of excess sodium hydroxide (1) • Calculation of pH to at least 1 dp (1)	Example of calculation Excess amount of sodium hydroxide = $(0.025 \times 0.980) - 6.06 \times 10^{-3} = 0.01844$ (mol) Concentration of excess sodium hydroxide = 0.01844/0.025 = 0.7376 (mol dm^{-3}) allow TE from M1 if some attempt at subtraction pH = 14–(–log(0.7376)) = 13.8678 = 13.9 allow TE from M2 if pH is greater than7 and less than or equal to 14 Allow 1 mark for pH =13.99 (based on 0.98 mol dm^{-3} NaOH)	3

Question Number	Acceptable Answers	Additional Guidance	Mark
(a)(iv)	• student C is correct as the titration is between a strong acid and a strong base (1) • Both methyl orange and phenolphthalein change colour at equivalence / vertical section of the graph (1)	Allow A and B are incorrect Allow both pK_{IN} values / range of indicators are within vertical section (of the graph) If values are quoted they must be correct PP = 9.3 ; MO = 3.7	2

Question Number	Acceptable Answers	Additional Guidance	Mark
(a)(v)	Add (excess) HCl(aq) (1)	Allow 'add a strong acid' Allow name or formula of any strong acid but if both are given, both must be correct Ignore references to dilute / conc / heat / reflux	1

Question Number	Acceptable Answers	Additional Guidance	Mark
(b)(i)	**M1** Calculates moles of CH_3COONa/ NaOH (1) **M2** Calculates moles ofexcess CH_3COOH (1) **M3** Calculates / shows ratio of [CH_3COOH] to [CH_3COONa] OR ratio of moles CH_3COOH to CH_3COONa (1) **M4** re-arranges K_a or pK_a expression correctly and substitutes appropriate values to find [H^+] (1) **M5** Calculation of pH (1)	Example of calculation Moles of NaOH = moles of CH_3COONa = (30/1000) x 0.142 = 4.26 x 10^{-3} (mol) Moles of excess CH_3COOH = [(50/1000) x 0.15] - 4.26 x 10^{-3} = 3.24 x 10^{-3} (mol) [CH_3COOH] = 3.24 x 10^{-3} / (80/1000) = 0.0405 (mol dm^{-3}) [CH_3COONa] = 4.26 x 10^{-3} / (80/1000) = 0.05325 (mol dm^{-3}) ▫ 0.0405 / 05325 Allow ratio using moles as V cancels NOTE can be subsumed in M4 [H^+] = 1.70 x 10^{-5} x (0.0405/0.05325) = 1.29 x 10^{-5} (mol dm^{-3}) Or pH=pKa – log([acid]/[base]) / pH= 4.77-log (0.0405/0.05325) pH = 4.89 Correct answer with no working scores 5 marks Ignore SF except 1SF Allow TE throughout Comment 4.52 will score 4 (omission of subtraction)	5

Question Number	Acceptable Answers	Additional Guidance	Mark
(b) (ii)	**M1** (Large) 'reservoir' of CH_3COOH and CH_3COO^- (1) **M2** The OH^- ions react with CH_3COOH / H^+ ions (1) **M3** $H^+ + OH^- \rightarrow H_2O$ or $CH_3COOH + OH^- \rightarrow CH_3COO^- + H_2O$ (1) **M4** The H^+ ions react with CH_3COO^- or $H^+ + CH_3COO^- \rightleftharpoons CH_3COOH$ (1) **M5** The ratio of acid to base remains (almost) constant (1)	If both equations given both must be correct If equation given must be correct Allow base/salt remains (almost) constant Allow [H^+] remains(almost) constant	5

Q8.

Question number	Answer	Mark
	B the reaction is not reversible	1

Q9.

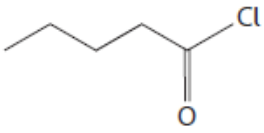
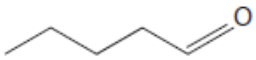
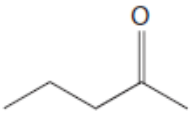
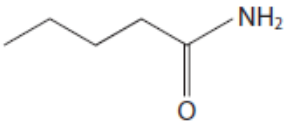
Question number	Answer	Mark
	The only correct answer is B (acids only ;acids and bases) ***A*** *is incorrect because bases also speed up hydrolysis* ***C*** *is incorrect because bases do not speed up esterification and acids also speed up hydrolysis* ***D*** *is incorrect because bases do not speed up esterification*	**(1)**

Q10.

Question Number	Correct Answer	Mark
	The only correct answer is B (C_3H_7OH) ***A*** *is incorrect because the alcohol formed would be* C_3H_7OH ***C*** *is incorrect because no carboxylic acid is formed under these reaction conditions* ***D*** *is incorrect because the sodium salt of ethanoic acid would be formed*	(1)

Q1.

This question is about four organic compounds each with five carbon atoms but different functional groups.

Compound	Skeletal formula
1	
2	
3	
4	

(a) Which of these, when mixed with water, produces the solution with the **lowest** pH?

(1)

☒ **A** compound **1**

☒ **B** compound **2**

☒ **C** compound **3**

☒ **D** compound **4**

(b) Which of these reacts with ethylamine, $CH_3CH_2NH_2$, to form an N-substituted amide?

(1)

☒ **A** compound **1**

☒ **B** compound **2**

☒ **C** compound **3**

☒ **D** compound **4**

(c) Which of these reacts with iodine and sodium hydroxide in solution to produce a pale yellow precipitate?

(1)

☒ **A** compound **1**

☒ **B** compound **2**

☒ **C** compound **3**

☒ **D** compound **4**

(Total for question = 3 marks)

Q2.

A polymer is prepared by the reaction between hexanedioyl dichloride and hexane-1-6-diamine.

What type of polymerisation occurs?

☒ **A** addition

☒ **B** condensation

☒ **C** hydrolysis

☒ **D** substitution

(Total for question = 1 mark)

Q3.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Which of the following could **not** be formed when methylamine is added to ethanoyl chloride?

☒ **A** HCl

☒ **B** $CH_3NH_3^+Cl^-$

☒ **C** CH_3CONH_2

☒ **D** $CH_3CONHCH_3$

(Total for question = 1 mark)

Q4.

Answer the question with a cross in the box you think is correct ☒ . If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒ .

Which reagent reacts at room temperature with methylamine, CH_3NH_2, to form the compound N-methylethanamide?

☒ **A** CH_3COCH_3

☒ **B** CH_3COOH

☒ **C** CH_3COOCH_3

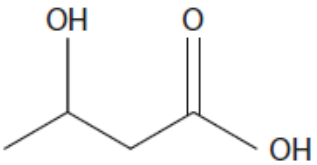
☒ **D** CH_3COCl

(Total for question = 1 mark)

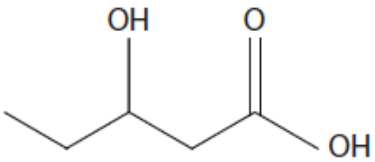
Q5.

Answer the question with a cross in the box you think is correct ☒ . If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒ .

The substance known as PHBV is a biodegradable polymer formed from 3-hydroxybutanoic acid and 3-hydroxypentanoic acid.



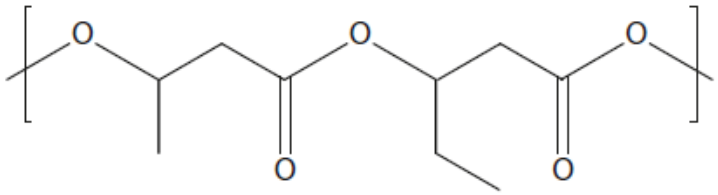
3-hydroxybutanoic acid

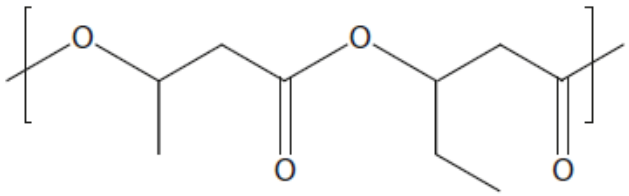


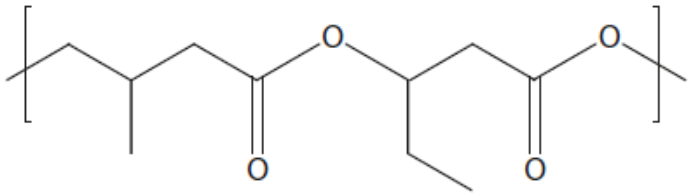
3-hydroxypentanoic acid

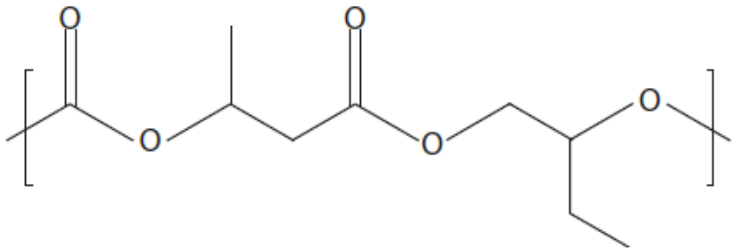
(a) Which of these is the repeat unit of the polymer?

(1)

☒ **A** 

☒ **B** 

☒ **C** 

☒ **D** 

(b) What reaction occurs when PHBV biodegrades to its monomers?

(1)

☒ **A** condensation

☒ **B** hydrolysis

☒ **C** hydration

☒ **D** hydrogenation

(Total for question = 2 marks)

Q6.

Which reaction does **not** produce a carboxylic acid?

(1)

☒ **A** hydrolysis of an acyl chloride with cold water

☒ **B** hydrolysis of an ester by refluxing with dilute hydrochloric acid

☒ **C** hydrolysis of a nitrile by refluxing with aqueous potassium hydroxide

☒ **D** oxidation of a primary alcohol by refluxing with excess acidified potassium dichromate

(Total for question = 1 mark)

Q7.

Answer the question with a cross in the box you think is correct ☒ . If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒ .

Propyl ethanoate, $CH_3COOCH_2CH_2CH_3$, is hydrolysed with aqueous sodium hydroxide.

Which products are formed?

☒ **A** CH_3COOH and $CH_3CH_2CH_2OH$

☒ **B** CH_3COOH and $CH_3CH_2CH_2ONa$

☒ **C** CH_3COONa and $CH_3CH_2CH_2OH$

☒ **D** CH_3COONa and $CH_3CH_2CH_2ONa$

(Total for question = 1 mark)

Q8.

The organic product of the reaction of ethanoyl chloride with ammonia gas is:

(1)

☒ **A** ammonium ethanoate

☒ **B** ethanamide

☒ **C** ethanenitrile

☒ **D** methanenitrile

(Total for question = 1 mark)

Q9.

* Compare and contrast the reactions of ethanoyl chloride with water, with ethanol and with ammonia.
Refer to the structural features of the molecules that determine the type of reaction. Identify the products of the reactions. You may include equations in your answers.

(6)

(Total for question = 6 marks)

Q10.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Which reaction cannot form a carboxylic acid?

☒ **A** oxidation of primary alcohol

☒ **B** acidic hydrolysis of a nitrile

☒ **C** alkaline hydrolysis of an ester

☒ **D** acyl chloride reacting with water

Use this space for any rough working. Anything you write in this space will gain no credit.

(Total for question = 1 mark)

Q11.

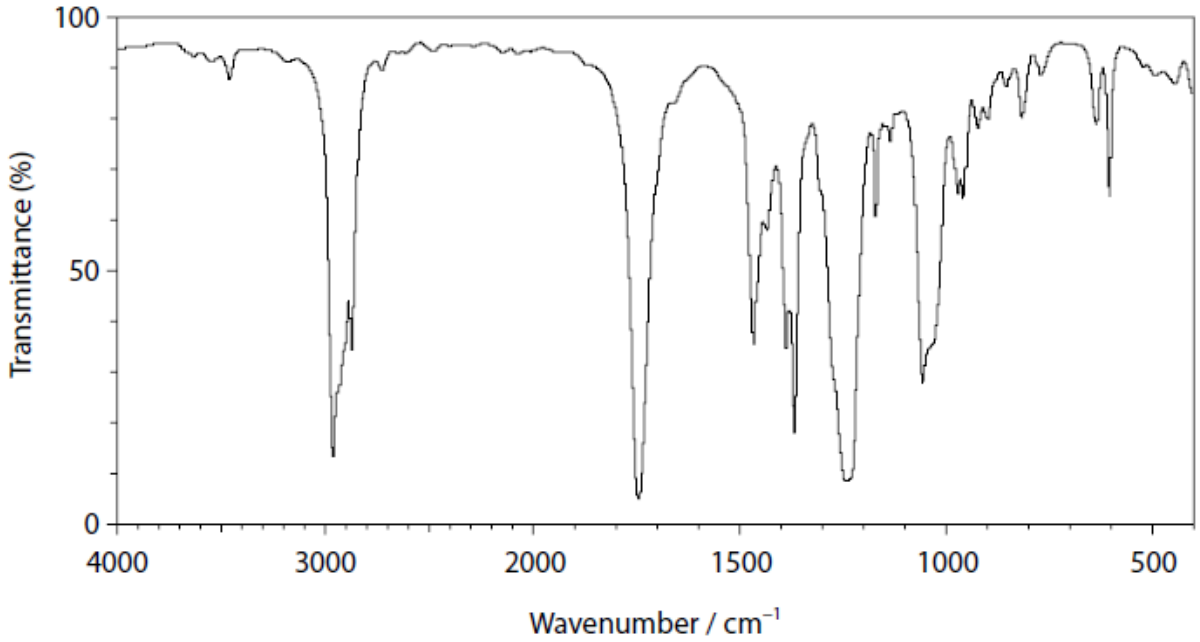
One of the compounds responsible for the characteristic smell of bananas is 3-methylbutyl ethanoate.
The structural formula of this compound is:

$$CH_3COOCH_2CH_2CH(CH_3)_2$$

(a) Draw the **skeletal** formula for 3-methylbutyl ethanoate.

(1)

(b) The infrared spectrum of a sample of 3-methylbutyl ethanoate is shown below.



(i) Use this spectrum to identify one peak resulting from a bond in the ester group of 3-methylbutyl ethanoate. Include the relevant bond and its wavenumber range.

(1)

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(ii) 3-methylbutyl ethanoate was synthesised by reacting a suitable carboxylic acid with an alcohol.

Show that its infrared spectrum confirms there is no alcohol remaining in the sample.

(1)

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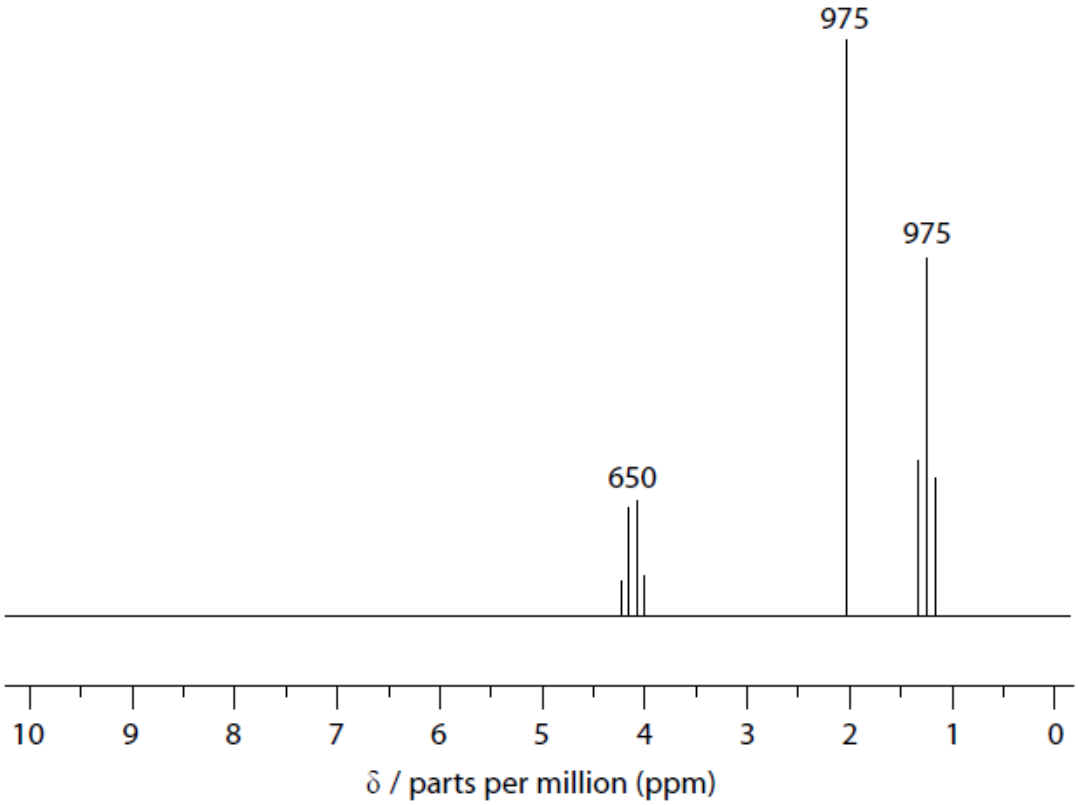
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*(c) The high resolution proton nuclear magnetic resonance (NMR) spectrum of a different ester, ethyl ethanoate, $CH_3COOCH_2CH_3$, is shown.

The numbers over each peak represent their approximate relative areas.



Show that the structure of ethyl ethanoate is consistent with this NMR spectrum, using all the data in the spectrum.

(6)

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(d) Ethyl ethanoate has three isomers which are also esters.

(i) Draw the structures of these three isomers.

(2)

(ii) Explain to what extent it is possible to distinguish between the three isomers using carbon-13 NMR spectroscopy.

(2)

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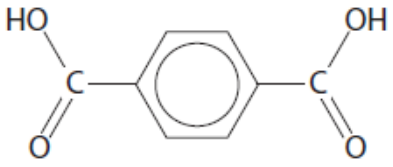
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(Total for question = 13 marks)

Q12.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

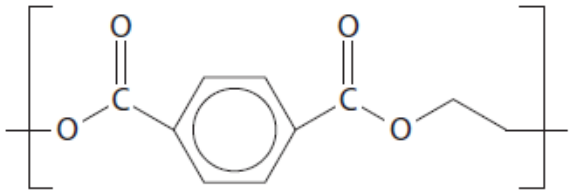
Terylene is a polyester derived from ethane-1,2-diol and terephthalic acid.



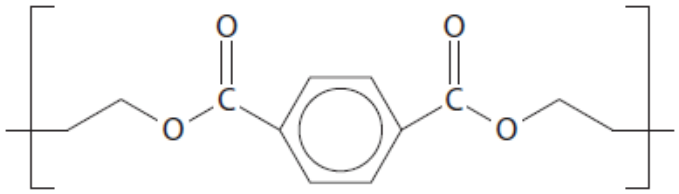
terephthalic acid

What is the structure of the repeat unit of terylene?

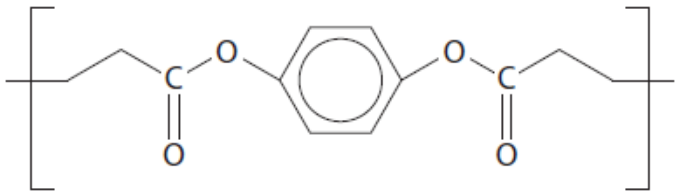
☒ **A**



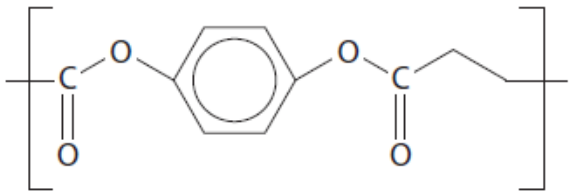
☒ **B**



☒ **C**



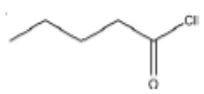
☒ **D**

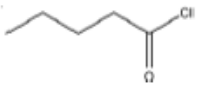


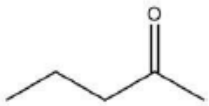
(Total for question = 1 mark)

Mark Scheme

Q1.

Question Number	Answer	Mark
(a)	The only correct answer is **A** (compound 1)  *B is incorrect as aldehydes do not change the pH of water C is incorrect as ketones do not change the pH of water D is incorrect as amides do not change the pH of water*	1

Question Number	Answer	Mark
(b)	The only correct answer is **A** (compound 1)  *B is incorrect as aldehydes do not react with amines to form an N-substituted amide C is incorrect as ketones do not react with amines* *D is incorrect as amides do not react with amines*	1

Question Number	Answer	Mark
(c)	The only correct answer is **C** (compound 3)  *A is incorrect as it does not form iodoform* *B is incorrect as it does not form iodoform D is incorrect as it does not form iodoform*	1

Q2.

Question Number	Answer	Mark
	The only correct answer is **B** (condensation) *A is incorrect as neither monomer has a carbon-carbon double bond C is incorrect as this is not a type of polymerisation* *D is incorrect as this is not a type of polymerization*	1

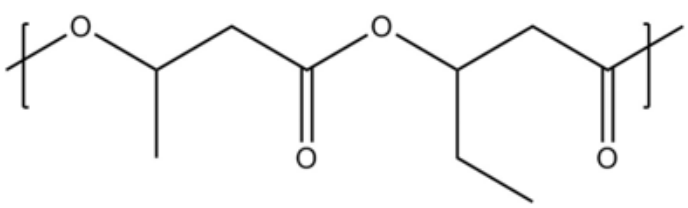
Q3.

Question Number	Answer	Mark
	The only correct answer is C (CH_3CONH_2) *A is incorrect because this is formed by the initial reaction between the two* *B is incorrect because this is formed by the reaction between HCl and methylamine* *D is incorrect because this is the organic product of the reaction between the two*	(1)

Q4.

Q	Correct Answer	Mark
	The only correct answer is D (CH_3COCl)	1
	A is incorrect as the reaction with ketone would NOT form an N-substituted amide	
	B is incorrect as any reaction with the carboxylic acid would be too slow at RT	
	C is incorrect as any reaction with the ester would be too slow at RT	

Q5.

Q	Correct Answer	Mark
(a)	**The only correct answer is B**	1
		
	A is incorrect as the repeat unit has an extra oxygen	
	C is incorrect as there is an extra carbon at the left-hand end of the repeat unit	
	D is incorrect as the repeat unit has an extra oxygen and the structure is incorrect	

Q	Correct Answer	Mark
(b)	**The only correct answer is B** (hydrolysis)	1
	A is incorrect as condensation is the reaction when the polymer forms	
	C is incorrect as hydration is the addition of water to a C=C bond	
	D is incorrect as hydrogen has not been added in a reduction reaction	

Q6.

Question number	Answer	Mark
	C hydrolysis of a nitrile by refluxing with aqueous potassium hydroxide	1

Q7.

Question Number	Answer	Mark
	The only correct answer is C (CH_3COONa and $CH_3CH_2CH_2OH$) *A is not correct because ethanoic acid reacts with NaOH to form the sodium salt* *B is not correct because ethanoic acid reacts with NaOH to form the sodium salt and propan-1-ol does not react with NaOH* *D is not correct because propan-1-ol does not react with NaOH*	(1)

Q8.

Question number	Answer	Mark
	B ethanamide	1

Q9.

<table>
<tr><th>Question Number</th><th>Answer</th><th>Additional Guidance</th></tr>
<tr>
<td>*</td>
<td>
This question assesses the student's ability to show a coherent and logically structured answer with linkages and fully sustained reasoning. Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.

The following table shows how the marks should be awarded for indicative content.

<table>
<tr><th>Number of indicative marking points seen in Answer</th><th>Number of marks awarded for indicative marking points</th></tr>
<tr><td>6</td><td>4</td></tr>
<tr><td>5-4</td><td>3</td></tr>
<tr><td>3-2</td><td>2</td></tr>
<tr><td>1</td><td>1</td></tr>
<tr><td>0</td><td>0</td></tr>
</table>

The following table shows how the marks should be awarded for structure and lines of reasoning.

<table>
<tr><th></th><th>Number of marks awarded for structure of Answer and sustained lines of reasoning</th></tr>
<tr><td>Answer shows a coherent logical structure with linkages and fully sustained lines of reasoning demonstrated throughout</td><td>2</td></tr>
<tr><td>Answer is partially structured with some linkages and lines of reasoning</td><td>1</td></tr>
<tr><td>Answer has no linkages between points and is unstructured</td><td>0</td></tr>
</table>
</td>
<td>
Guidance on how the mark scheme should be applied.
The mark for indicative content should be added to the mark for lines of reasoning. For example, a response with five indicative marking points that is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning).

If there were no linkages between the points, then the same indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages).

In general it would be expected that 5 or 6 indicative points would get 2 reasoning marks, and 3 or 4 indicative points would get 1 mark for reasoning, and 0, 1 or 2 indicative points would score zero marks for reasoning.

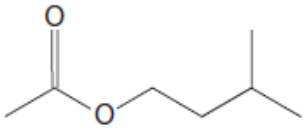
If there is any incorrect chemistry, deduct mark(s) from the reasoning. If no reasoning mark(s) awarded do not deduct mark(s).
Comment: Look for the indicative marking points first, then consider the mark for the structure of the Answer and sustained line of reasoning.
</td>
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	Indicative content Similarities IP1 the Cl is lost in all reactions IP2 water, ethanol and ammonia all contain a lone pair that attacks the delta+ carbon atom in ethanoyl chloride IP3 all reactions are very vigorous/violent Differences IP4 water: forms ethanoic acid/ CH_3COOH $(CH_3COCl + H_2O) \longrightarrow CH_3COOH (+ HCl)$ IP5 ethanol: forms ethyl ethanoate/ $CH_3COOCH_2CH_3$ $(CH_3COCl + CH_3CH_2OH) \longrightarrow CH_3COOCH_2CH_3 (+ HCl)$ IP6 Ammonia: forms ethanamide/ CH_3CONH_2 $(CH_3COCl + 2NH_3) \longrightarrow CH_3CONH_2 (+ NH_4Cl)$	Allow all produce HCl IP1 can be scored by the equations in IP4, IP5 and IP6 Allow water, ethanol and ammonia are all nucleophiles/ they are all nucleophiles/all reactions are nucleophilic Allow all reactions take place at room temperature/ are very fast/spontaneous/ do not require catalysts If name or formula are given, they must both be correct but only penalise once in IP4, IP5 and IP6. Penalise minor slips e.g. missing H, pentavalent C once only in IP4, IP5 and IP6. Note the mark is for the organic product not the equation. Allow $CH_3COCl + NH_3 \longrightarrow CH_3CONH_2 + HCl$ Ignore nature of the reactions e.g. esterification/ hydrolysis/elimination/addition/substitution/condensation. Polymerisation is incorrect chemistry so will penalise a reasoning mark.

Q10.

Question Number	Answer	Mark
	The only correct answer is C (alkaline hydrolysis of an ester) ***A** is not correct because this reaction will produce a carboxylic acid* ***B** is not correct because this reaction will produce a carboxylic acid* ***D** is not correct because this reaction will produce a carboxylic acid*	(1)

Q11.

Question number	Answer	Additional guidance	Mark
(a)	• 	Must be skeletal formula	1

Question number	Answer	Additional guidance	Mark
(b)(i)	• C=O peak identified **and** range 1750 - 1735 cm^{-1}	Allow C-O peak identified **and** range 1250 - 1230 cm^{-1}	1

Question number	Answer	Additional guidance	Mark
(b)(ii)	• Absence of a peak in the range 3750 - 3200 cm^{-1}	Absence of alcoholic O-H peak	1

Question number	Answer	Additional guidance	Mark
(c)	This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning. Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning. The following table shows how the marks should be awarded for indicative content. Number of indicative marking points seen in answer / Number of marks awarded for indicative marking points 6 / 4 5-4 / 3 3-2 / 2 1 / 1 0 / 0 The following table shows how the marks should be awarded for structure and lines of reasoning. Number of marks awarded for structure and sustained lines of reasoning	Guidance on how the mark scheme should be applied. The mark for indicative content should be added to the mark for lines of reasoning. For example, an answer with five indicative marking points that is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning). If there are no linkages between points, the same five indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages). If there is any incorrect chemistry, deduct mark(s) from the reasoning. If no reasoning mark(s) awarded, do not deduct mark(s). Comment: Look for the indicative marking points first, then consider the mark for the structure of the answer and sustained line of	6

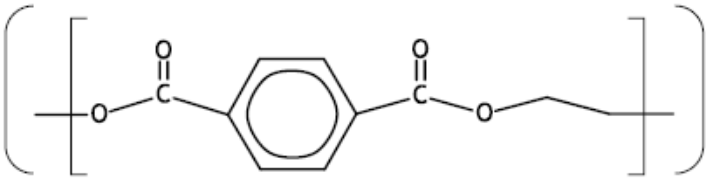
	Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout.	2	reasoning. Some or all the information may be shown on a diagram of the molecule.	
	Answer is partially structured with some linkages and lines of reasoning.	1		
	Answer has no linkages between points and is unstructured.	0		
	Indicative points: • three groups of peaks indicates three hydrogen environments • one or two shifts identified (by number) **and** linked to alkanes • three shifts correctly identified **and** linked to alkanes • two (or more) splitting patterns correctly identified		2.1 (±0.2) = CH_3 next to C=O 4.1 (±0.2) = CH_2 next to C-O- 1.2 (±0.2) = CH_3 next to CH_2 singlet, triplet, quartet	

	• use of n + 1 rule to explain splitting for one (or more) group(s) of protons • areas under peaks/integration numbers linked to numbers of protons in each group.	ratio of areas = 3:2:3	

Question number	Answer	Additional guidance	Mark
(d)(i)	An answer that makes reference to the following points: • $HCOOCH_2CH_2CH_3$ • $HCOOCH(CH_3)_2$ • $CH_3CH_2COOCH_3$ All three correct scores two marks, any two correct scores one mark	Allow displayed/skeletal formulae	2

Question number	Answer	Additional guidance	Mark
(d)(ii)	An explanation that makes reference to the following points: • $HCOOCH(CH_3)_2$ has three carbon enviornments (1) whereas • $HCOOCH_2CH_2CH_3$ **and** $CH_3CH_2COOCH_3$ both have four carbon environments. (1)		2

Q12.

Question number	Answer	Mark
	The only correct answer is A  *B* *is incorrect because this structure has —C_2H_4— groups at both ends* *C* *is incorrect because this structure has —C_2H_4— groups at both ends and the ester groups are reversed* *D* *is incorrect because this structure has the ester groups reversed*	(1)