PEARSON EDEXCEL A-LEVEL CHEMISTRY · 9CH0

CHEMISTRY



MARK SCHEME

TOPIC 17: ORGANIC CHEMISTRY II

SCORE	PERCENTAGE
/486	%

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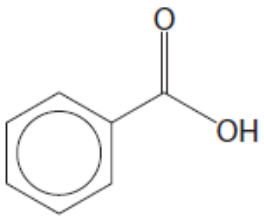
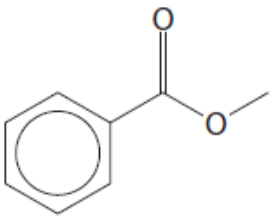
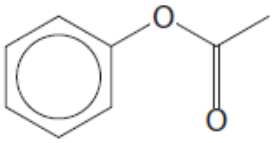
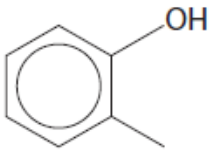
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Compound **P**	Compound **Q**
	
Compound R	**Compound S**
	

(i) Which of these compounds can be hydrolysed to form methanol as one of the products?

(1)

☒ **A** Compound P

☒ **B** Compound Q

☒ **C** Compound R

☒ **D** Compound S

(ii) Which of these compounds produces carbon dioxide when it reacts with aqueous sodium hydrogencarbonate?

(1)

☒ **A** Compound P

☒ **B** Compound Q

☒ **C** Compound R

☒ **D** Compound S

(Total for question = 2 marks)

Mark Scheme

Q1.

Question Number	Correct Answer	Reject	Mark
(a)	A		**1**

Question Number	Correct Answer	Reject	Mark
(b)	D		**1**

Question Number	Correct Answer	Reject	Mark
(c)	A		**1**

Question Number	Correct Answer	Reject	Mark
(d)	D		**1**

Q2.

Question Number	Acceptable Answers	Additional Guidance	Mark
(a)	Any one from: Catalyst / speeds up reaction / increases rate / increases rate of attainment of equilibrium / lowers activation energy	Ignore any mention of protonation or mechanism for catalysis Do not award additional incorrect types of reaction	**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(b)(i)	• calculation of moles of H^+ in 25.0 cm^3 **(1)** • calculation of moles of H^+ in 250 cm^3 flask **(1)**	Ignore SF throughout 8(b)(i) to 8(c)(ii) except 1 SF, which should be penalised once only Example of calculation: (moles NaOH = 0.200 x $\frac{23.60}{1000}$) = 0.00472 (mol) (= mol H^+ in 25.0 cm^3) (= 10 x 0.00472) = 0.0472 (mol) (in 250 cm^3) Allow TE for M2 on moles of NaOH Correct answer with or without working scores 2 marks	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(b)(ii)	• subtracts moles of H^+ in HCl from answer to (b)(i)	Example of calculation: 0.0472 – 0.00400 = 0.0432 (mol) Allow TE on answer to part (b)(i)	**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(c)(i)	• calculation of moles of CH_3COOH that have reacted	Example of calculation: (0.105 — 0.0432) = 0.0618 Allow TE on part (b)(ii) unless negative value	(1)

Question Number	Acceptable Answers	Additional Guidance	Mark
(c)(ii)	• calculation of equilibrium moles of $CH_3CH_2CH_2OH$ **(1)** • calculation of equilibrium moles of $CH_3COOCH_2CH_2CH_3$ **(1)** • calculation of equilibrium moles of H_2O **(1)**	Example of calculation: 0.0800 — 0.0618 = 0.0182 0.0618 0.111 + 0.0618 = 0.1728 Allow TE on answer to part (c)(i) unless negative value	(3)

Question Number	Acceptable Answers	Additional Guidance	Mark
(d)(i)	$(K_c =) \frac{[CH_3COOCH_2CH_2CH_3][H_2O]}{[CH_3COOH][CH_3CH_2CH_2OH]}$	IGNORE state symbols even if incorrect Do not award round brackets	(1)

Question Number	Acceptable Answers	Additional Guidance	Mark
(d)(ii)	An explanation that makes reference to the following points: • Same number of moles/molecules on both sides of the equation **(1)** • (so) volume / V cancels in K_c expression **(1)**	2 marks could be scored by a correct mathematical expression showing V or dm^3 cancel Allow same number of terms on top and bottom of K_c expression Allow units cancel out Allow "**all** divided by the same volume"	(2)

Question Number	Acceptable Answers	Additional Guidance	Mark
(d)(iii)	• calculates value of K_c **(1)** • final value of K_c quoted to 2 or 3 SF **(1)**	Example of calculation $K_c = \frac{(0.0618) \times (0.1728)}{(0.0432) \times (0.0182)} = 13.58241758$ = 14 / 13.6 (no units) Correct answer with no working gains full marks Ignore units No TE on wrong K_c expression	2

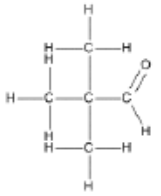
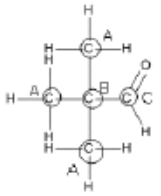
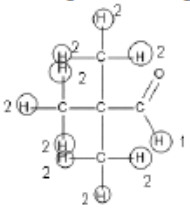
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Question Number	Acceptable Answers	Additional Guidance	Mark
(e)	An explanation that makes reference to the following points: • the equilibrium shifts to the left **or** the mixture absorbs carbon dioxide from the atmosphere **(1)** • so the mixture is (becoming more) acidic / the acid reforms **(1)**	Mark independently Allow no longer alkaline Do not award just "pH decreases"	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(f)	An explanation that makes reference to the following points: • carry out / repeat experiment **and** leave for longer than a week **(1)** • the titre value / K_c value will remain unchanged (if equilibrium has been established) **(1)**	Ignore pH probes / checking pH Allow repeat experiment **and** check titres within first week Allow moles / concentration are unchanged Ignore just "results unchanged"	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(g)	An answer that makes reference to the following points: • K_c value will be greater than that calculated in (d)(iii) **(1)** • because the (forward) reaction is endothermic **or** backward / reverse reaction is exothermic **(1)**	M2 depends on M1 Ignore References to the equilibrium position shifting to the right (with increasing temperature)	**(2)**

Q3.

Question Number	Answer	Additional Guidance	Mark
	An answer that makes reference to the following points: • displayed formula of aldehyde (1) • three different carbon environments indicated (1) • two different proton environments indicated (1) • no splitting as there are no hydrogens on the adjacent carbon atom(s)	Example of displayed formula:  Allow CH_3 groups but aldehyde group must be displayed Example of three carbon environments:  Example of two proton environments:  Stand alone mark	(4)

Q4.

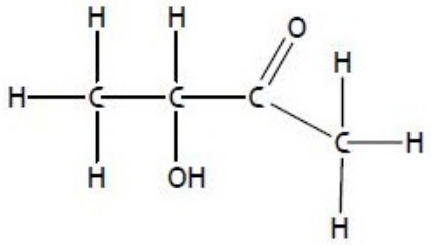
Question Number	Acceptable Answers	Reject	Mark
(a)(i)	C : H : O Mole ratio / mol $\frac{54.5}{12}$: $\frac{9.1}{1}$: $\frac{36.4}{16}$ **(1)** = 4.5417 : 9.1 : 2.275 = 1.996 : 4 : 1 = 2 : 4 : 1 C_2H_4O **(1)** Correct empirical formula of C_2H_4O, with or without working, scores **(2)**		**2**

Question Number	Acceptable Answers	Reject	Mark
(a)(ii)	**First mark:** Any mention of **44** or of doubling C_2H_4O **(1)** **Second mark:** Any mention of **88 in the context of the mass spectrum** eg mentions 'molecular ion' / M^+ / heaviest peak / peak furthest to the right / annotation at 88 on the mass spectrum itself / highest $\frac{m}{z}$ value **(1)**	**88** obtained **just** by adding up the relative atomic masses in $C_4H_8O_2$ scores **(0)** for 2nd scoring point	**2**

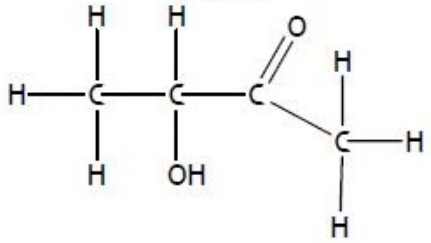
Question Number	Acceptable Answers	Reject	Mark
(b)	(Peak at 3500 cm^{-1}) **O—H** **(1)** Allow OH (Peak at 1700 cm^{-1}) **C=O** **(1)** **Penalise extra extension bond on an otherwise correct answer once only** (eg —O—H **and** —C=O scores (1)) **IGNORE** any names for the bonds suggested even if incorrect	—O—H / —OH C—O / —C=O / CO	**2**

Question Number	Acceptable Answers	Reject	Mark
(c)(i)	**First mark:** (**X** is neutral) so not a (carboxylic) acid **(1)** **IGNORE** "**X** doesn't have a charge as it is neutral" / "**X** is not an alkali" / "**X** is not a base" **Second mark:** (**X** does not react with Tollens') so is **not** an aldehyde / is a ketone **(1)** **Third mark:** (**X** reacts with H^+ / $Cr_2O_7^{2-}$ so) is an alcohol /contains an OH (group) / contains R—OH / contains hydroxyl (group) **(1)** **IGNORE** 'not an acid' if this is deduced **solely** from the H^+ / $Cr_2O_7^{2-}$ information **Fourth mark:** a primary or a secondary (alcohol) **both needed** **OR** (**X** is) not tertiary (alcohol) **(1)** **Mark each point separately** **NOTE:** '**X** is a primary or a secondary alcohol' scores both the third and fourth marks **ALLOW** Correct formulae for the functional groups, instead of their names	**X** is an aldehyde scores **(0)** for this scoring point / **X** is not a ketone scores **(0)** for this scoring point	**4**

Question Number	Acceptable Answers	Reject	Mark
(c)(ii)	(primary or secondary) alcohol **and** ketone **NOTE** **BOTH names** are required here	Just 'hydroxyl for 'alcohol' and/or 'C=O /carbonyl' for ketone/	**1**

Question Number	Acceptable Answers	Reject	Mark
(d)	**MARKING ADVICE** Check answer for the suggested structure of X. If the correct structure is shown  Mark answer according to the following. However if no structure for **X** is shown or an incorrect structure for **X** is proposed, mark answer according to "COMMENTS" scheme below **MARKS CAN BE AWARDED FROM SUITABLY ANNOTATED FORMULAE FOR X.** **<u>First mark:</u>** Four different H / hydrogen / proton environments **(1)** **<u>Any five from following seven points</u>:** **Either** Application of the (n+1) rule to peak **J** (which is a quartet / splits into **four**) **or** application of the (n+1) rule peak **M** (which is a doublet / splits into **two**) **(1)** Any mention to explain **no** splitting for peak **L** as there is no H is attached to the adjacent carbon **(1)**	**Just** 'four different **chemical** environments'	**7**

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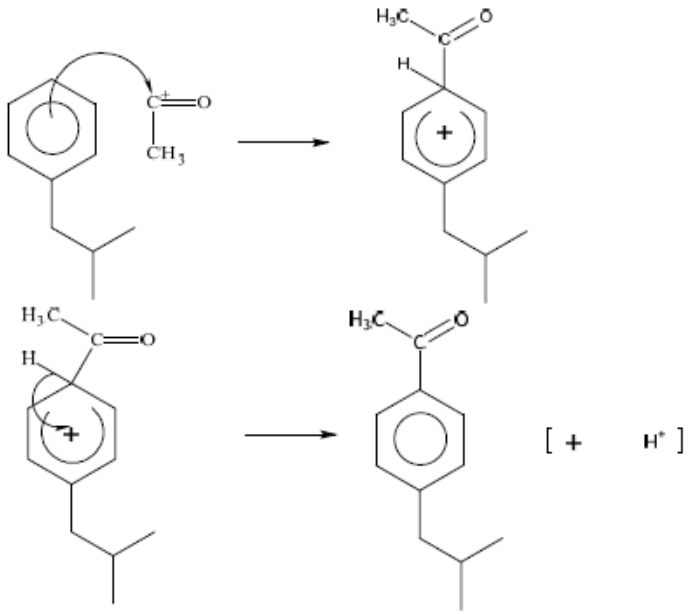
	Peak **L** (CH_3) next to C=O **(1)** Peak **M** (CH_3) next to CH **(1)** Peak **K** O**H** **(1)** Peak **J** (C**H**) next to CH_3 **(1)** Any **one** correct δ value quoted within ± 0.2 of the following chemical shifts: 1.4(**M**) or 2.2 (**L**) or 3.7(**K**) or 4.2 (**J**) (ppm) **(1)** **Final mark** (Compound **X** is) $CH_3CH(OH)COCH_3$ **NO** other compound allowed. **ACCEPT** any unambiguous formula, e.g. displayed formula **Peak J**  **Peak M** **Peak K** **Peak L** **ACCEPT** 3-hydroxybutan-2-one **(1)**	If any incorrect chemical shift **OR A RANGE** of chemical shifts is quoted, this scoring point is not available	

Q5.

Question Number	Acceptable Answers	Reject	Mark
(a)(i)	Overall **yield** higher OR Reduces use of solvents (ALLOW chemicals / reactants) OR Less loss of chemicals OR Less waste products IGNORE References to Energy / fuel / CO_2 References to atom economy More efficient conversion Fewer side products		**1**

Question Number	Acceptable Answers	Reject	Mark
(a)(ii)	Lowers (operating) temperature / energy (requirements) OR Less fuel needed IGNORE References to catalyst properties such as 'lowers E_a', 'can be re-used' Atom economy		**1**

Question Number	Acceptable Answers	Reject	Mark
(b)(i)	$CH_3COCl + AlCl_3 \rightarrow CH_3CO^+ + AlCl_4^-$ Structural formulae not required Positive charge may be anywhere on the electrophile. IGNORE Curly arrows even if incorrect		**1**

Question Number	Acceptable Answers	Reject	Mark
(b)(ii)	 TE on incorrect electrophile in (b)(i) If benzene used instead of substituted benzene OR If final product is not 1,4 only MP 1 and 2 can be scored Curly arrow from on or within the circle to positively charged carbon		**3**
	ALLOW Curly arrow from anywhere within the hexagon Arrow to **any** part of the electrophile including to the + charge (which can be anywhere on the electrophile) **(1)** Intermediate structure including charge with horseshoe covering at least 3 carbon atoms, **and** facing the tetrahedral carbon **and** with some part of the positive charge within the horseshoe ALLOW dotted horseshoe **(1)** Curly arrow from C—H bond to anywhere in the benzene ring reforming delocalized structure of a stable molecule **(1)** Correct Kekulé structures score full marks Ignore any involvement of $AlCl_4^-$ in the final step	Curly arrow on or outside the hexagon Partial bonds to H and CH_3 unless part of a 3D with a wedge bond	

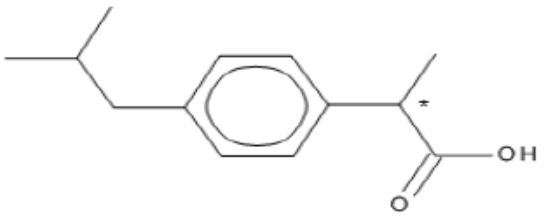
Question Number	Acceptable Answers	Reject	Mark
(b)(iii)	No HCl formed (as a by-product) OR Ethanoic acid easier to recover ALLOW Reverse arguments IGNORE Chlorine containing product References to ozone layer, acid rain, global warming Atom economy	Chlorine	**1**

Question Number	Acceptable Answers	Reject	Mark
(c)(i)	Catalyst (more) easily recovered / separated OR can be filtered OR Facilitates the use of flow (rather than batch) systems IGNORE references to properties of catalysts		**1**

Question Number	Acceptable Answers	Reject	Mark
(c)(ii)	**Reaction 1** (red) phosphorus / P / P_4 and iodine / I_2 ALLOW PI_3 / HI **(1)** **Reaction 3** Hydrochloric acid / HCl(aq) or sulfuric acid / H_2SO_4 (aq) **(1)** **and** reflux / heat **(1)** Award second mark for Acid / H^+ / H_3O^+ **and** reflux OR NaOH(aq) / KOH(aq) **(1)** (reflux) **then** acidify with HCl(aq) or H_2SO_4 (aq) **(1)** IGNORE Omission of states throughout	NaI + H_2SO_4 PI_5 Just H^+ / H_3O^+ reflux / heat without acid or with warm or <50°C	

Question Number	Acceptable Answers	Reject	Mark
(c)(iii)	C=O / carbonyl group (only) in carboxylic acid / ibuprofen **(1)** Absorption / peak at 1725 - 1700 (cm^{-1}) **(1)** If no other mark has been awarded, then ALLOW (for 1 mark) OH in both but in alcohol 3750 - 3200 (cm^{-1}) but in carboxylic acids 3300 to 2500 (cm^{-1})	ketone 1700 - 1680 (cm^{-1}) Single values rather than ranges	**2**

Question Number	Acceptable Answers	Reject	Mark
(d)(i)	(A chiral molecule is) non-superimposable on its mirror image. ALLOW Asymmetric (tetrahedral) carbon atom / has a carbon atom bonded to **four** different groups / atoms IGNORE Has two enantiomers Functional (as in functional groups) Reference to rotation of plane polarized light	molecules / species (for groups)	**1**

Question Number	Acceptable Answers	Reject	Mark
(d)(ii)	 ALLOW any clear indication of chiral carbon		**1**

Question Number	Acceptable Answers	Reject	Mark
(d)(iii)	(A racemic mixture is) an equimolar mixture of the two enantiomers / (optical) isomers ALLOW (for equimolar mixture) equal amounts / concentrations / volumes / proportions OR 50:50 mixture	Just 'no effect on plane polarised light'	**1**

Q6.

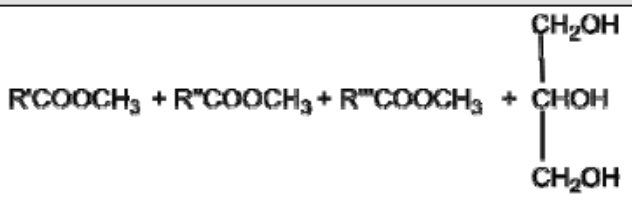
Question Number	Correct Answer	Reject	Mark
(a)	**EITHER** (consideration of kinetics) Rate of reaction increases **(1)** As collisions are **more frequent** / **increases frequency** of collisions / more collisions **per second** IGNORE **Just** 'more collisions' or **just** 'more successful collisions' **(1)** **OR** (if assumes an equilibrium reaction) Yield increases / eq'm shifts to RHS **(1)** Since fewer moles **of gas** / no moles **of gas** / fewer molecules **of gas** (on RHS) **(1)** **MUST AWARD MARKS BY ONLY CONSIDERING ONE OF THE ROUTES – CANNOT score full marks via one mark from each route if 'MIX UP' KINETICS AND EQUILIBRIUM ARGUMENTS** Eg Rate increases, so yield of product increases scores **(1)**		**2**

Question Number	Correct Answer	Reject	Mark
(b)	**[FIRST, CHECK THE FINAL ANSWER IF ANSWER = 3.1 (tonnes), award 3 marks]** **EITHER** 1 tonne C_6H_5ONa : 180/116 tonnes $C_6H_4(OH)(CO_2H)$ **(1)** 2.5 tonnes C_6H_5ONa : (180/116) x 2.5 (tonnes) $C_6H_4(OH)(CO_2H)$ at 100% yield **(1)** (= 3.879 tonnes) So actual yield = (180/116) x 2.5 x 79/100 (3.06) = 3.1 (tonnes) **(1)** **OR** Moles C_6H_5ONa (= 2.5 x 10^6 ÷ 116) = 21 551.7 (mol) **(1)** Moles C_6H_5ONa (79% yield) (= 21 551.7 x 0.79) = 17025.8 (mol) **(1)** Mass C_6H_5ONa (= 17025.8 x 180 = 3064644 g = 3.06 tonnes) = 3.1 (tonnes) **to 2SF** **(1)** Correct answer **TO 2 SF**, no working **(3)** Can work in g (instead of tonnes) until final answer So final answer of 3.06 (tonnes) scores M1 and M2 only Award only **(1)** mark for 3.07 (tonnes) without working	**g**	**3**

Question Number	Correct Answer	Reject	Mark
(c)	Esterification / acylation / ethanoylation ALLOW 'acetylation' **OR** '(nucleophilic) addition-elimination' BOTH words (addition and elimination) are needed for this option IGNORE 'Condensation' **(1)** CH_3COCl / ethanoyl chloride **OR** $(CH_3CO)_2O$ / ethanoic anhydride **(1)** ALLOW CH_3COOH / ethanoic acid (in presence of H_2SO_4) Correct displayed / skeletal formulae **IGNORE** JUST 'acid anhydride' / 'acid chloride'		**2**

Q7.

Question Number	Correct Answer	Reject	Mark
(a)(i)	**1st mark:** Filter (off solid) / centrifuge **(1)** **2nd mark:** (Fractionally) distil / evaporate ALLOW Just 'heat' / steam distillation for 2nd mark **(1)** **IGNORE** Any other practical steps (e.g. separating funnel) Mark the two scoring points independently, but award **(1)** if 'filter' is first mentioned **after** 'distil' / 'evaporate' / 'heat' / 'steam distillation'	'recrystallise' for 2nd mark	**2**

Question Number	Correct Answer	Reject	Mark
(a)(ii)	 First mark for all three esters **(1)** Second mark for structure of propane–1,2,3-triol IGNORE Formulae written such as $C_3H_5(OH)_3$ or $C_3H_8O_3$ **(1)** ALLOW CO_2 or OCO for COO for ester linkage H_3COOCR' / CH_3OOCR' Mark independently		**2**

Question Number	Correct Answer	Reject	Mark
(iii)	Sodium hydroxide / potassium hydroxide / NaOH / KOH / OH^- **ALLOW** sulfuric acid / H_2SO_4 or any other named strong acids or strong alkalis / HCl / just 'acid' / just 'base' / just 'alkali' / just H^+	Ni / nickel 'weak'	**1**

Question Number	Correct Answer	Reject	Mark
	Advantage of coffee grounds: **1st mark: For any mention of re-use of a resource or other listed advantages** EXAMPLES TO LOOK FOR: Reuse of a waste material / less waste / no need to set up (new) coffee plantations / recycling Prevents using up landfill Coffee (plants / beans are) renewable (resource) / can be re-grown NOTE 'renewable' can score M3 as well if palm oil also described as renewable Coffee is widely-used (so grounds available) IGNORE Just coffee easier to grow / JUST 'doesn't require tropical conditions' / doesn't require (extra) land **(1)**		**4**

Disadvantage of coffee grounds:

2nd mark: For any mention that coffee grounds made on a small-scale (so uneconomical) or other features listed below

EXAMPLES TO LOOK FOR:

Uses solvents / uses methanol / not carbon-neutral
(from non-renewable resources such as crude oil)

Only 10 – 15% by mass of oil / has a low(er) yield of oil (than palm oil)) **if not awarded for M3**

(Only made on a) small-scale so will not meet demand for biodiesel

Coffee grounds distributed in small amounts (so will need collecting and transporting)

ALLOW
Costs of the use of solvents
or
energy required for extraction / energy required for distillation / energy required for purification
or
transport costs **if not awarded for M4**

(1)

Advantage of palm oil:
3rd mark: For any mention of palm oil being a plant-based / renewable / sustainable (resource)

EXAMPLES TO LOOK FOR:

Palm oil (made from plants that) can be re-grown / palm oil made from natural resources

Palm oil (made from plants that are) renewable resources / palm oil made from 'sustainable' resource
NOTE 'renewable' can score M1 as well if coffee also described as renewable

Palm oil (made from plants that are) carbon-neutral / better carbon foot print / absorb CO_2

IGNORE
Just 'greener' (already mentioned in question)

ALLOW economic argument such as:

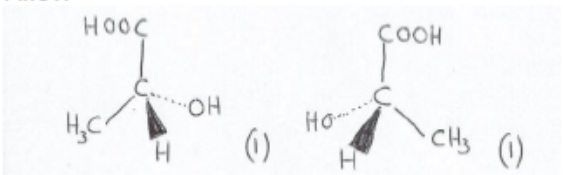
Higher yield of oil (than in coffee grounds) **if not already awarded for M2**

Large scale production so economies of scale / more able to meet demand

Fewer stages in its production (so more economical)

	(1) **Disadvantage of palm oil:** **4th mark: For any mention of a disadvantage of a plant-based resource** EXAMPLES TO LOOK FOR: Large scale plantations could lead to habitat loss Deforestation Loss of land (which should be used for food production) Only grows in hot/tropical climates High cost of transporting palm oil (from the tropical countries) **if not already awarded for M2** Palm plants take a long time to grow **(1)**		

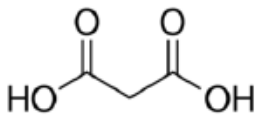
Q8.

Question Number	Answer	Additional Guidance	Mark
(i)	Allow  	Diagram must be 3-dimensional with either wedges or dashes to score 2 marks Ignore orientation of group at the top Ignore vertical bond to H of OH group	**(2)**

Question Number	Answer	Additional Guidance	Mark
(ii)	• They **rotate** the plane of plane-polarised light (equally) and in opposite/different directions OR Determine in which direction they **rotate** the plane of plane-polarised light	Allow one plane	**(1)**

Question Number	Answer	Additional Guidance	Mark
(iii)	• Does not accumulate in the environment/does not occupy landfill	Accept answers that outline the benefit of avoiding other means of disposal such as incineration, use of toxic chemicals Ignore just less harm to environment/less harm to animal life/less pollution/less of an "eyesore"/less energy to break it down	(1)

Q9.

Question Number	Answer	Additional Guidance	Mark
	• calculation of amount of sodium hydroxide (1) • calculation of amount of **Y** in 25.0 cm^3 (1) • calculation of amount of **Y** in 250 cm^3 (1) • calculation of molar mass of **Y** (1) • deduction of structure of **Y** (1)	Example of calculation $26.10/1000 \times 0.320 = 8.352 \times 10^{-3}$ (mol) $8.352 \times 10^{-3} / 2 = 4.176 \times 10^{-3}$ (mol) $4.176 \times 10^{-3} \times (250/25) = 4.176 \times 10^{-2}$ (mol) $4.34 / 4.176 \times 10^{-2} = 103.9 / 104$ (g mol^{-1})  Allow structural / displayed / skeletal or any combination Allow TE throughout M1-M4 Penalise 1 SF in M1	(5)

Q10.

Question Number	Correct Answer	Reject	Mark
	B		**1**

Q11.

Question Number	Correct Answer	Reject	Mark
	B		**1**

Q12.

Question Number	Correct Answer	Reject	Mark
(a)	B		**1**

Question Number	Correct Answer	Reject	Mark
(b)	C		**1**

Question Number	Correct Answer	Reject	Mark
(c)	C		**1**

Question Number	Correct Answer	Reject	Mark
(d)	B		**1**

Q13.

Question Number	Correct Answer	Reject	Mark
(a)	D		**1**

Question Number	Correct Answer	Reject	Mark
(b)	C		**1**

Question Number	Correct Answer	Reject	Mark
(c)	C		**1**

Question Number	Correct Answer	Reject	Mark
(d)	C		**1**

Question Number	Correct Answer	Reject	Mark
(e)	D		**1**

Q14.

Question Number	Correct Answer	Reject	Mark
	D		**1**

Q15.

Question Number	Correct Answer	Reject	Mark
	A		**1**

Q16.

Question Number	Correct Answer	Reject	Mark
	C		**1**

Q17.

Question Number	Correct Answer	Reject	Mark
	C		**1**

Q18.

Question Number	Acceptable Answers	Reject	Mark
(a)(i)	Aldehydes often contain (carboxylic) **acid** formed by oxidation (by the oxygen in air)		**1**

Question Number	Acceptable Answers	Reject	Mark
(a)(ii)	A larger volume of sodium carbonate solution is neutralized / a larger volume of carbon dioxide forms / faster reaction / more effervescence / more vigorous ALLOW reverse argument for impure aldehyde	(The old stock of) aldehyde does not react	**1**

Question Number	Acceptable Answers	Reject	Mark
(a)(iii)	$Na_2CO_3(aq) + 2C_3H_7COOH(aq) \rightarrow$ $2C_3H_7COO^{(-)}Na^{(+)}(aq) + CO_2(g) + H_2O(l)$ Correct balanced equation **(1)** Correct state symbols on correct species **(1)** ALLOW $H_2O(aq)$ $C_3H_7COO^{(-)}Na^{(+)}(s)$ $C_3H_7COOH(l)$	$NaCO_3$	**2**

Question Number	Acceptable Answers	Reject	Mark
(a)*(iv)	3300 -2500 (cm^{-1}) AND O-H (stretching) **(1)** 1725 – 1700 (cm^{-1}) AND C=O (stretching) **(1)** ALLOW single numbers or ranges within these ranges ALLOW 1300-1250 (cm^{-1}) AND C-O in COOH Very broad (O-H) due to hydrogen bonding **(1)**	COOH (group) COOH (group) Hydrogen Bonding in C=O	**3**

Question Number	Acceptable Answers	Reject	Mark
(a)(v)	**First mark** (stand alone) 4 peaks OR 4 hydrogen environments ALLOW 4 chemical shifts **(1)** **Second and Third Marks** Splitting pattern: ($CH_3CH_2CH_2COO\underline{\mathbf{H}}$) singlet /1 line ($CH_3CH_2C\underline{\mathbf{H_2}}COOH$) triplet / three lines ($CH_3C\underline{\mathbf{H_2}}CH_2COOH$) sextuplet / sextet / six lines ($C\underline{\mathbf{H_3}}CH_2CH_2COOH$) triplet / three lines All four correct **(2)** any three **(1)** ALLOW No splits, 2 splits, five splits, 2 splits scores 2 1,3,6,3 'splits' scores 1 mark	 1 split 3 splits 6 splits 3 splits	**3**

Question Number	Acceptable Answers	Reject	Mark
(b)	Start pH at 2.9 ALLOW 2—4 **(1)** Initial sharp rise to buffer region then vertical section at 25 cm^3 ALLOW Gradual rise to vertical section at 25 cm^3 **(1)** Vertical within pH range 6-11 **and** 2.5-4 units long **(1)** End pH value in range 12-13 **(1)**	 Horizontal from start deviation from vertical maximum before final pH Graph ending before 50cm^3	**4**

Question Number	Acceptable Answers	Reject	Mark
(c)(i)	White / steamy / misty fumes ALLOW 'gas' for fumes IGNORE correct indicator test on product	White smoke Effervescence Just 'fumes' Just 'gas'	**1**

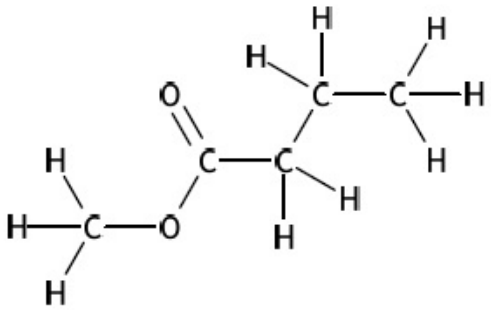
Question Number	Acceptable Answers	Reject	Mark
(c)(ii)	$CH_3CH_2CH_2COCl$ **(1)** ALLOW displayed formula butanoyl chloride **(1)** ALLOW Butanyl chloride No TE on incorrect structure	C_3H_7COCL Butyl Chloride Buthyl Chloride	**2**

Question Number	Acceptable Answers	Reject	Mark
(d)(i)	Butan-1-ol OR $CH_3CH_2CH_2CH_2OH$ If 2 answers are given both must be correct	Butanol Butanal C_4H_9OH	**1**

Question Number	Acceptable Answers	Reject	Mark
(d)(ii)	(Dry) Ethoxyethane / diethylether / Ether OR $C_2H_5OC_2H_5$ / $CH_3CH_2OCH_2CH_3$ If 2 answers are given they must both be correct		**1**

Question Number	Acceptable Answers	Reject	Mark
(d)(iii)	The responses are in pairs: a type (1) and an **associated** justification (1) Reduction (of butanoic acid) **(1)** By addition of hydrogen / loss of oxygen **(1)** **OR** Oxidation of lithium tetrahydroidaluminate / aluminium hydride / $LiAlH_4$ **(1)** By addition of oxygen **(1)** **OR** (Nucleophilic) addition **(1)** of hydride / H^- **(1)** **OR** Redox **(1)** Because butanoic acid has been reduced AND $LiAlH_4$ has been oxidised **(1)**	Any substitution Electrophilic addition	**2**

Question Number	Acceptable Answers	Reject	Mark
(e)(i)	(Concentrated / dilute) sulfuric / hydrochloric acid ALLOW any **strong** acid ALLOW 'acid (catalyst)' **(1)** (heat or boil under) reflux ALLOW Heat / warm **(1)** Elevated temp$\leq 65^0$C	Just 'catalyst' Just H^+ Just 'boil' Just 'distil' High temperature Increased concentration	**2**

Question Number	Acceptable Answers	Reject	Mark
(e)(ii)	 All bonds must be shown except ALLOW CH_3 at either end of molecule.	Omitted Hydrogen / sticks	**1**

Question Number	Acceptable Answers	Reject	Mark
(e)(iii)	Butanoyl chloride / $CH_3CH_2CH_2COCl$ ALLOW Butanyl chloride OR Butanoic anhydride / $(CH_3CH_2CH_2CO)_2O$ OR Specified alkyl butanoate (not methyl butanoate) If name and structure are both given they must both be correct	Butyl Chloride Buthyl Chloride	**1**

Question Number	Acceptable Answers	Reject	Mark
(e)(iv)	**Advantage** marks are dependent on correct reagent (or near miss e.g. propanoyl chloride) in (iii). No TE on random answer to (iii) eg H_2SO_4 Advantages – any **two** from: Higher yield / goes to completion/ not an equilibrium reaction / not reversible No heat / no refluxing / less energy needed No catalyst needed / faster By-product is a gas (so easier to separate) **(2)** Disadvantage (marked independently of (e)(iii)) any **one** of: (Acyl chloride is) more expensive / corrosive IGNORE Acyl chloride is toxic / hazardous / harmful / difficult to store OR toxic /corrosive **and** HCl /gas / fumes evolved IGNORE harmful/ hazardous/ dangerous OR has lower atom economy **(1)**	Good yield	**3**

Q19.

Question Number	Correct Answer	Reject	Mark
	D		**1**

Q20.

<table>
<tr><th>Question Number</th><th>Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td></td><td>A description that makes reference to two of the following points:

• reagent (1)

• corresponding observation (1)</td><td>Examples of reagents and observations

<table>
<tr><th>Reagent</th><th>Observation</th></tr>
<tr><td>bromine water
Allow bromine (in an organic solvent)</td><td>orange / yellow / brown solution goes colourless
Allow bromine water is decolourised</td></tr>
<tr><td>carboxylic acid and (concentrated) H_2SO_4 / HCl / H^+</td><td>characteristic smell (of an ester)</td></tr>
<tr><td>acidified potassium manganate(VII) / permanganate</td><td>purple to colourless / decolourised</td></tr>
<tr><td>alkaline potassium manganate(VII)</td><td>purple to green</td></tr>
<tr><td>(neutral) potassium manganate(VII)</td><td>purple to brown ppt</td></tr>
<tr><td>acidified (potassium) dichromate((VI)) (ions)</td><td>orange to green</td></tr>
</table>

Allow names or formulae for reagents but if both are given, both must be correct

Ignore conditions e.g. heat

Do not award PCl_5 / Na

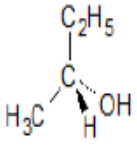
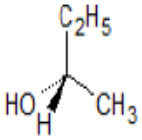
If more than one test is given, penalise any incorrect tests</td><td>(2)</td></tr>
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Q21.

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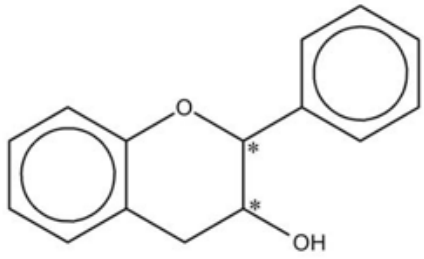
Question Number	Answer	Additional Guidance	Mark
	A description that makes reference to the following points: • reagent (1) • observation (1)	Examples of reagents and observations Reagent / Observation any carbonate / $NaHCO_3$ / $KHCO_3$ (added to aqueous acid) / effervescence / fizzing / bubbles / gas evolved that turns limewater milky magnesium (added to aqueous acid) / effervescence / fizzing / bubbles / gas evolved that gives a pop with a lighted splint alcohol **and** (concentrated) H_2SO_4 / HCl / H^+ / characteristic smell (of an ester) Allow names or formulae for reagents but if both are given, both must be correct Ignore conditions e.g. heat Do not award PCl_5 / Na If more than one test is given, penalise any incorrect tests	(2)

Q22.

Question Number	Acceptable Answer	Additional guidance	Mark
	 (1)  (1) Forms (two) isomers which are non-superimposable **(1)**	Diagram must be 3-dimensional, i.e. include 'wedges'. Allow Br instead of OH Ignore attachment of –OH, CH_3 and C_2H_5 groups Standalone mark Allow a chiral carbon has **four** different groups attached (so they are non-superimposable) Do not award has four different 'molecules' attached	**(3)**

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Q23.

Question Number	Answer	Additional Guidance	Mark
			(1)

Q24.

Question Number	Correct Answer	Reject	Mark
	D		**1**

Q25.

Question Number	Acceptable Answers	Reject	Mark
(a)	(It has) three (moles of) COOH groups / three (moles of) carboxylic acid groups / three (moles of) protons /three (moles of) H^+ /it is tribasic / three acid groups/ three (moles of) replaceable hydrogens/triprotic ALLOW Three acid groups	'carbonyl'/'carboxylate'	**1**

Question Number	Acceptable Answers	Reject	Mark
(b)(i)	**FIRST, CHECK THE FINAL ANSWER** **IF** answer = **+**546 (J mol^{-1} K^{-1}) award **2** marks "546" (J mol^{-1} K^{-1}) scores **(1)** as sign omitted) ($\Delta S^{\ominus}_{system}$ =)[200.5 + (3 x 213.6) + (3 x 69.9)] – [199.9 + (3 x 101.7)] **(1)** = [+1051] – [+ 505] = **+**546 (J mol^{-1} K^{-1}) **(1)** Allow **+** 0.546 **kJ mol^{-1} K^{-1}** 2nd mark is CQ on entropy values used for example EITHER Omission of factor of x3 for some or all substances in the equation OR The use of one incorrect entropy value(s) from the data book OR One missing value Note If two or more of the above three errors are made together, (0) awarded. **IGNORE** sf except 1 sf	**Incorrect** units (no 2nd mark)	**2**

Question Number	Acceptable Answers	Reject	Mark
(b)(ii)	**First mark** Gas formed (from solid) OR Liquid formed (from solid) OR Gas and liquid formed (from solid) **(1)** **Second mark** EITHER More moles of product than reactants / more moles formed OR 4 mol (of reactants) to 7 mol (of products) OR 4 'molecules' to 7 'molecules' NOTE: If specific numbers are stated, these must be correct (ie 4→7) OR Increase in disorder / increase in ways of arranging particles **(1)** IGNORE 'entropy increases' **NOTE:** Both points may be made in the same sentence	**Just** 'more product' / 'more particles formed' 2 substances going to 3 substances	**2**

Question Number	Acceptable Answers	Reject	Mark
(b)(iii)	$(\Delta S^{\ominus}_{surroundings} =) \frac{-\Delta H}{T}$ OR $\frac{-70000}{298}$ **(1)** $= -234.8993289$ $= \mathbf{-235\ J\ mol^{-1}\ K^{-1}}$ **(1)** OR $(\Delta S^{\ominus}_{surroundings} =) \frac{-\Delta H}{T}$ OR $\frac{-70}{298}$ **(1)** $= \mathbf{-0.235\ kJ\ mol^{-1}\ K^{-1}}$ **(1)** **IGNORE** sf except 1 sf **NOTE:** Correct units are required for the award of the second mark **+**235 with units scores **(1)**	Incorrect rounding (e.g. −234 / −234.89) no 2nd mark **+**235 with no units **(0)** overall	**2**

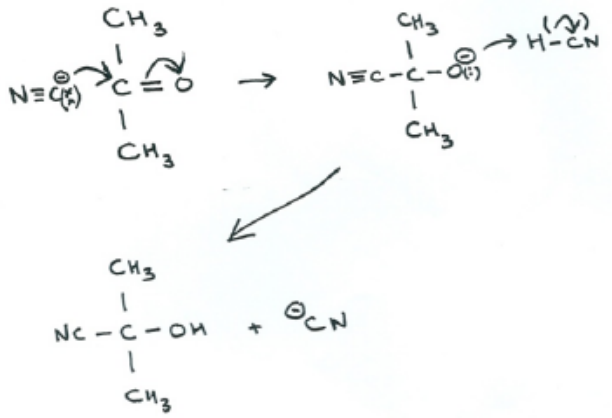
Question Number	Acceptable Answers	Reject	Mark
(b)(iv)	$(\Delta S^{\ominus}_{total} = \Delta S^{\ominus}_{system} + \Delta S^{\ominus}_{surroundings})$ $= (+546) + (-235)$ $= (+)311\ (J\ mol^{-1}\ K^{-1})$ OR $= (+)0.311\ \mathbf{kJ\ mol^{-1}\ K^{-1}}$ CQ on (i) and (iii) **IGNORE** sf except 1 sf	Incorrect units	**1**

Question Number	Acceptable Answers	Reject	Mark
(b)(v)	Positive so feasible / spontaneous / will occur / reaction goes / reacts (at 298 K) **NOTE:** **LOOK BACK** at answer to (b)(iv) **IF** answer to (b)(iv) has a positive sign (the + sign can be **stated** or **implied**) **THEN ALLOW JUST** feasible / spontaneous / will occur / reaction goes / reacts (at 298 K) **Mark CQ on sign of answer to (iv)**		**1**

Q26.

Question Number	Correct Answer	Reject	Mark
(a)(i)	Sodium/potassium dichromate ((VI)) **and** (Dilute/concentrated) sulfuric acid OR correct formulae / H^+ **and** $Cr_2O_7^{2-}$ ALLOW H^+ **and** $Cr_2O_7^{2-}$/acidified dichromate((VI)) **(1)** Reflux/distil Ignore 'heat', 'warm', and 'boil' alone. ALLOW Just 'under reflux' Just 'under distillation' **(1)** Second mark depends on mention of dichromate/$Cr_2O_7^{2-}$ in first part OR $KMnO_4$ and acid with heat **(1)**	Hydrochloric acid	2

Question Number	Correct Answer	Reject	Mark
(a)(ii)	Carbonyl group – addition of 2,4-dinitrophenylhydrazine / 2,4-DNP(H) / Brady's reagent **(1)** to give yellow/orange/red precipitate/ppt/ppte/solid/crystals ALLOW recognisable spelling e.g., percepitate **(1)** $CH_3C{=}O$ reaction with iodine in alkali/NaOH/KOH/OH^- ALLOW Iodoform/tri-iodomethane/haloform AND reaction/test **(1)** to form (pale) yellow / cloudy precipitate/solid/crystals **(1)** Ignore references to smell Ignore heat in either part	2-DNP/4DNP Just DNP Brick red ppt	4
	Note • In both cases result mark depends on test being recognisably correct even if it did not score a mark Examples: DNP gives yellow ppt Iodine test gives yellow ppt Tests for aldehydes with correct results, no marks		

Question Number	Correct Answer	Reject	Mark
(b)(i)			3
	Arrow (from carbon) of CN^- to carbon of C=O	CN without negative charge	
	AND		
	Arrow from part of C=O double bond to oxygen		
	ALLOW		
	Two steps via a charged canonical form **(1)**		
	Intermediate anion with C-CN bond. **(1)**		
	Arrow from resulting O^- to hydrogen of $HCN/H^+/H_2O$ **(1)**		
	Note	…C-NC bond	
	Arrow directions must be correct to score each mark		
	Penalise half-headed arrows each time in both parts		
	ALLOW skeletal formulae.		

Question Number	Correct Answer	Reject	Mark
(c)(i)	(Acid) hydrolysis OR Alkaline hydrolysis followed by acidification	Hydration	1

Question Number	Correct Answer	Reject	Mark
(b)(ii)	At low pH very few CN^- ions ALLOW No CN^- ions OR No KCN/ only HCN present **(1)** At high pH very few H^+ / HCN ALLOW No H^+ / HCN OR Hydroxide reacts with H^+ / HCN/ acid **(1)**		1

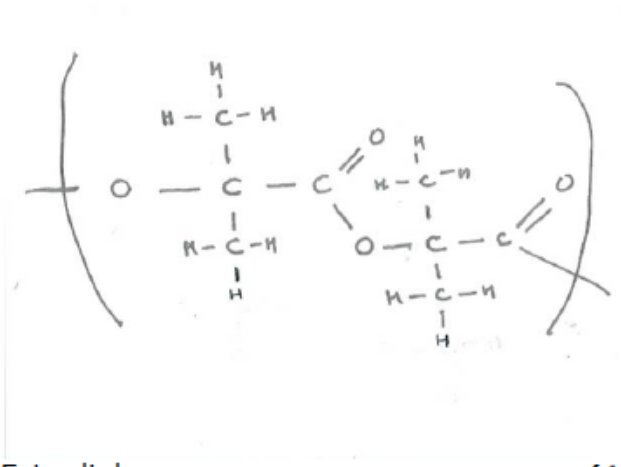
Question Number	Correct Answer	Reject	Mark
(c)(ii)	The O-H absorptions for alcohol and carboxylic acid overlap. OR OH absorption for an acid is very broad OR Quote data booklet values which must show some overlap, to include 3300 to 3200. ALLOW OH absorptions similar/the same.	Just 'both have OH groups' Just 'two OH groups present'	1

Question Number	Correct Answer	Reject	Mark
(c)(iii)	(Chemical shift □) 2.0 - 4.0 (ppm) / any value within this range e.g 3.1/ 3.12/3 ALLOW Correct number followed by□□, eg 3δ		1

Question Number	Correct Answer	Reject	Mark
(c)(iv)	3 (peaks) / three		1

Question Number	Correct Answer	Reject	Mark
(c)(v)	There is no hydrogen atom/proton on the adjacent/neighbouring carbon atom ALLOW No adjacent/neighbouring hydrogens/protons		1

Question Number	Correct Answer	Reject	Mark
(c)(vi)	(No) 2-hydroxy-2-methylpropanoic acid does not have a chiral centre OR It is not chiral OR It does not have a mirror image which is non-superimposable OR Does not have a carbon atom attached to four different groups	Yes...	1

Question Number	Correct Answer	Reject	Mark
(d)(i)	 Ester linkage **(1)** Rest of molecule **(1)** ALLOW Attached chains as structural formulae Ignore n or other numbers outside bracket **COMMENT** Check formulae carefully – different carbon frameworks appear.		1

Question Number	Correct Answer	Reject	Mark
(d)(ii)	Ester		1

Q27.

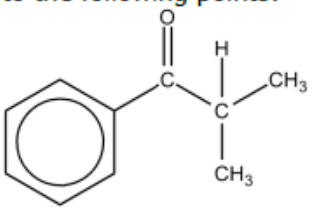
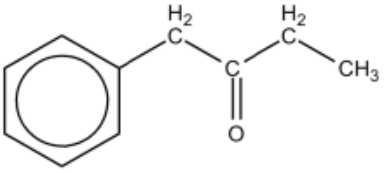
<table>
<tr><th>Question Number</th><th>Acceptable Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td>(a)</td><td>• mass of C (1)
• mass of H (1)
• mass of oxygen <u>and</u> mols of C, H and O (1)
• ratio (1)
• empirical and use of molar mass to determine molecular formula (1)</td><td><u>Example of calculation</u>
mass of C = 2.83 x 12/44 = 0.772 g
mass of H = 0.693 x 2/18 = 0.077 g
mass of oxygen = 0.952 – (0.772 + 0.077) = 0.103 g
<table><tr><td></td><td>C</td><td>H</td><td>O</td></tr><tr><td>Moles</td><td>0.772/12=0.0643</td><td>0.077/1=0.077</td><td>0.103/16=0.0064</td></tr><tr><td>ratio</td><td>0.0643/0.0063=10</td><td>0.077/0.00643=12</td><td>0.0064/0.0064=1</td></tr></table>Empirical formula = $C_{10}H_{12}O$, this has mass =148
so molecular formula = $C_{10}H_{12}O$</td><td>5</td></tr>
</table>

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	An answer that makes reference to the following point: • contains benzene ring / arene	Ignore comments about alkenes / unsaturated	**1**

Question Number	Acceptable Answer	Additional Guidance	Mark
(ii)	• is an aldehyde or ketone / is a carbonyl compound	Both aldehyde and ketone required for first alternative	**1**

Question Number	Acceptable Answer	Additional Guidance	Mark
(iii)	• (**Q** is a) ketone	Allow 'not an aldehyde' if first alternative given in (b)(ii)	**1**

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Question Number	Acceptable Answer	Additional Guidance	Mark
(c)	An answer that makes reference to the following points:  (2) • **Chemical shift** (1) peak at 7.5 ppm indicates a benzene ring <u>and</u> peak at 2.55 ppm indicates H on carbon adjacent to C=O <u>and</u> peak at 1.25 ppm indicates alkyl hydrogens • **Splitting pattern** (2) Any 2 from 3: – complex multiplet indicates a benzene ring – septuplet indicates 6 equivalent protons on adjacent carbons – doublet indicates one hydrogen on adjacent carbon • **Area under peak** (2) Any 2 from 3: – five H's indicate C_6H_5 / monosubstituted benzene ring – one H indicates one H on C next to carbonyl group – six H's indicates six H's on two methyl groups	Award 1 mark for any structure of $C_{10}H_{12}O$ which includes a benzene ring and a ketone e.g. 	**7**

Q28.

Question Number	Correct Answer	Reject	Mark
(a)(i)	Mass of ethanoic acid = 0.04 x 60.1 = (2.404 g) **(1)** Volume of ethanoic acid = 2.404 ÷ 1.049 = 2.2917 = 2.3 (cm^3) **(1)** Correct answer with no working **(2)** Ignore SF except only one ALLOW 60.0 for molar mass which gives mass 2.4 and volume 2.288 = 2.3 cm^3 **(2)** OR First step 1.049 ÷ 60/60.1 to find number of moles in 1 cm^3 = 0.017 **(1)** Then volume = 0.04 ÷ 0.017 = 2.3529 (cm^3) But note, if whole calculation done on calculator, 60 gives 2.2879 and 61 gives 2.2917. **(1)** If units given, they must be correct, but penalise wrong units only once here.		**2**

Question Number	Correct Answer	Reject	Mark
(a)(ii)	Syringe ALLOW Burette Graduated/adjustable pipette	Gas syringe Biuret Just 'pipette'	**1**

Question Number	Correct Answer	Reject	Mark
(a)(iii)	To prevent... evaporation/vapour escaping water vapour entering OR To maintain a closed system OR To maintain a closed environment ALLOW To prevent: air oxidizing the alcohol reaction with air OR Due to volatility (of chemicals) IGNORE ...gas escaping ...HCl escaping		**1**

Question Number	Correct Answer	Reject	Mark
(a)(iv)	**First and second mark** Phenolphthalein **(1)** From colourless to (pale) pink/red **(1)** ALLOW Other indicators with pK_{in} in range 7.5 – 10 Some examples are: Thymol blue ((base)) (yellow to blue) Phen**ol** red (yellow to red) Thymolphthalein (colourless to blue) Second mark depends on correct indicator except bromothymol blue, which is incorrect but very close to range so allow colour yellow to blue. **Third mark** Sodium ethanoate is (slightly) alkaline OR Ethanoic acid is a weak acid OR Phenolphthalein pH range coincides with vertical section of the pH/titration curve	Litmus/universal indicator Pink to colourless Thymol blue **(acid)** Phenyl red Methyl red	**3**
	OR Titration of weak acid with strong base OR Neutralisation/equivalence point is at 8-10/ any number between 8 and 10. OR pK_{in} +/-1 lies within vertical region **(1)** Third mark is independent		

Question Number	Correct Answer	Reject	Mark
(b)(i)	$CH_3COOH+CH_3CH_2OH \rightleftharpoons CH_3COOCH_2CH_3+H_2O$ ALLOW Single arrow $-CO_2H$ $-C_2H_5$ Displayed formulae IGNORE state symbols even if incorrect		**1**

Question Number	Correct Answer	Reject	Mark
(b)(ii)	Volume of alkali reacting with ethanoic acid = 77.1-11.7 = 65.4 cm^3 **(1)** Moles of ethanoic acid = $\frac{65.4 \times 0.200}{1000}$ = $0.01308/1.308\times10^{-2}$ (mol) **(1)** Correct answer no working (2) Ignore SF except 1 Allow internal TE for use of Moles of ethanoic acid = $\frac{77.1 \times 0.200}{1000}$ = $0.01542/1.542\times10^{-2}$ (mol) max**(1)**		**2**

Question Number	Correct Answer	Reject	Mark
(b)(iii)	Number of moles of ethanol = $0.01308/1.308\times10^{-2}$ (mol) TE same as (ii)		**1**

Question Number	Correct Answer	Reject	Mark
(b)(iv)	Number of moles of ethyl ethanoate =0.0400−0.01308 = 0.02692 (mol) Allow TE from (ii)/(iii) for example 0.01542 gives 0.02458		**1**

Question Number	Correct Answer	Reject	Mark
(b)(v)	$K_c = \frac{[CH_3CO_2CH_2CH_3][H_2O]}{[CH_3CO_2H][\ CH_3CH_2OH]}$ **(1)** $= \frac{0.02692 \times 0.02692}{0.01308 \times 0.01308}$ = 4.23579 = 4.24 **(1)** Ignore SF except one Allow TE from (ii), (iii) and (iv) for example 0.01542 etc gives 2.54 No TE for incorrect expression of K_c		**2**

Question Number	Correct Answer	Reject	Mark
(b)(vi)	The units cancel OR There are the same numbers of moles of reactants and products		**1**

Question Number	Correct Answer	Reject	Mark
(b)(vii)	(Concentrated) hydrochloric acid contains water		**1**

Question Number	Correct Answer	Reject	Mark
(c)(i)	First test tube esterification OR addition/elimination ALLOW Condensation **(1)** Second test tube (acid) hydrolysis **(1)** Two fully correct answers in wrong order **(1) max**	Alkaline hydrolysis followed by acidification	**2**

Question Number	Correct Answer	Reject	Mark
(c)(ii)	The values are the same within experimental error OR The values are concordant ALLOW The values are similar **(1)** The equilibrium can be approached from either direction OR The reaction is reversible OR Any comment relating equilibrium to reversibility IGNORE Dynamic equilibrium OR Rate of reverse reaction = rate of forward reaction **(1)**	Just...the same	**2**

Question Number	Correct Answer	Reject	Mark
(c)(iii)	(Acid) catalyst (makes it faster) OR Provides H^+ (as a catalyst) OR Protonates... OR Protonating agent... OR Donates protons OR Increases H^+ concentration	Initiates Reacts with... Protates	**1**

Q29.

Question Number	Answer	Mark
(i)	**The only correct answer is B** (alkaline iodine solution) ***A*** *is not correct because this oxidising agent would react with phenylethanal and not with phenylethanone which is the wrong way round* ***C*** *is not correct because test is for aldehydes and so would react with phenylethanal and not with phenylethanone which is the wrong way round* ***D*** *is not correct because test is for aldehydes and so would react with phenylethanal and not with phenylethanone which is the wrong way round*	**(1)**

Question Number	Answer	Additional Guidance	Mark
(ii)	An answer that makes reference to the following points: • formation of yellow/orange/red (crystalline) precipitate **(1)** • (Filter then) recrystallisation of products **(1)** • determination of melting temperature **(1)** • comparison (and hence identification) from use of database/known values **(1)**	Colour and state are both required Allow solid for ppt Ignore any conditions given with the use of 2,4-DNPH Penalise M3 if any reference to boiling temperature Award only in the context of melting temperature of the hydrazones or as a TE of boiling temperature Max 3 out of 4 if test is only carried out with one of the carbonyls	**(4)**

<table>
<tr><th>Question Number</th><th>Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr>
<td>* (iii)</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 four 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 and overall score of 3 marks (3 marks for indicative content and zero 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).

If there is no mention of protons/hydrogens in the response then deduct one structure and reasoning mark
</td>
<td>(6)</td>
</tr>
</table>

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	Indicative content **Similarities**	Ignore references to C^{13} nmr Accept annotations on a structure towards crediting the following IPs Allow either a single chemical shift value or a range within the stated values Penalise incorrect chemical shifts	
	• **IP1**: aromatic hydrogens will give similar/same peaks	Both have peaks in the range 6.5-8.4 (ppm) Ignore any splitting description	
	• **IP2**: both have a peak in the range 1.7-3.0 (ppm) (due to the hydrogen of the H–C–C=O type)	Ignore any splitting pattern given for this peak to award this mark	
	Differences • **IP3** (Hydrogen environments): Phenylethanone has one less peak/hydrogen environment than phenylethanal	Allow any difference of one in the number of peaks stated	
	• **IP4** (Splitting patterns): a singlet for phenylethanone but a doublet and a triplet in phenylethanal	All these splitting patterns required for this IP	
	• **IP5** (Peak area ratios): relative peak (area) ratio in phenylethanone is 3 but in phenylethanal the peak (area) ratio is 2 to 1	Ignore the splitting pattern for this IP and ignore any peak areas given for the aryl hydrogens	
	• **IP6** (Chemical shifts): (Only) phenylethanal has an aldehyde (hydrogen) peak in the range 9 – 10.1 (ppm)	Ignore the splitting pattern for this IP	

Q30.

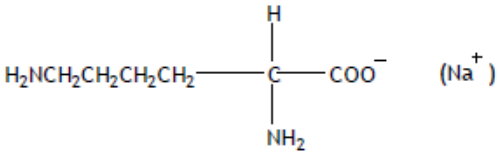
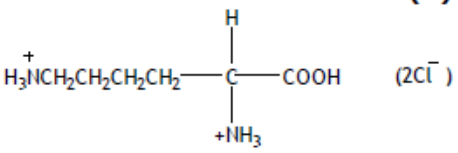
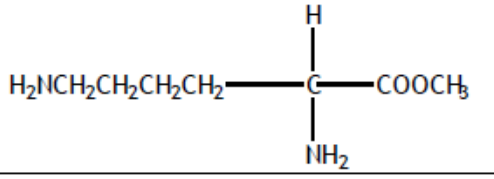
Question Number	Acceptable Answer	Additional Guidance	Mark
(a)	An explanation that makes reference to the following points: • **A** no because the two substances have the same molecular formula/ relative molecular mass (1) • **B** yes because only 2-aminopropanal is chiral (1) • **C** no because both substances react with Fehling's solution (to produce a red precipitate) (1)	Allow no because 3-aminopropanal is not chiral and 2-aminopropanal could be a racemic mixture	**3**

Question Number	Acceptable Answer	Additional Guidance	Mark
***(b)**	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.	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).	

	Number of marks awarded for structure of answer and sustained line of reasoning
Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout.	2
Answer is partially structured with some linkages and lines of reasoning.	1
Answer has no linkages between points and is unstructured.	0

	Indicative content • both have 4 different proton environments/ peaks will be at same chemical shift • peak areas are 1:1:2:3 in 2-aminopropanal • peak areas are 1:2:2:2 in 3-aminopropanal • explanation or use of the (n+1) rule for any splitting pattern • 2-aminopropanal has 1 singlet (NH_2), 2 doublets (C**H**O), and (CH_3), 1 pentuplet (C**H**) • 3-aminopropanal has 1 singlet (NH_2), 2 triplets (C**H**O), and (CH_2-NH_2), 1 quartet (CH_2)	Allow ratios in any order for the second and third marking points Only penalise use of peak heights instead of peak areas once	**6**

Q31.

Question Number	Acceptable Answers	Additional Guidance	Mark
	• Deprotonated structure **(1)**  (Na^+)	Allow displayed /structural /condensed formulae Allow NH_2- Allow $-CO_2^-$ Allow –COONa but penalise if O–Na covalent bond is shown	**(3)**
	• Protonated structure **(1)**  ($2Cl^-$)	**Both** NH_2 groups must be protonated Allow NH_3^+- / $^+H_3N-$ Allow $-CO_2H$	
	• Ester structure **(1)** 	Allow CO_2CH_3 Allow NH_3^+- or NH_2- for each amine group Penalise wrong side chain only once If alanine used throughout then only MP3 can be awarded	

Q32.

Question Number	Acceptable Answers	Reject	Mark
(a)(i)	$(K_C =) \frac{[CH_3COOCH_2CH_3]\ [H_2O]}{[CH_3COOH]\ [CH_3CH_2OH]}$ ALLOW C_2H_5 for CH_3CH_2 State symbols are not required IGNORE any incorrect state symbols		**1**

Question Number	Acceptable Answers	Reject	Mark
(a)(ii)			**2**

Component	$CH_3COOH(l)$	$CH_3CH_2OH(l)$	$CH_3COOCH_2CH_3(l)$	$H_2O(l)$
Equilibrium amount / mol	(0.20)	**0.10**	**0.20**	**0.35**

BOTH 0.10 AND 0.20 (1) **0.35 (1)**

0.10 **and** 0.20 scores first mark
Allow 0.1 and 0.2
0.35 scores second mark

Question Number	Acceptable Answers	Reject	Mark
(a)(iii)	Units cancel **OR** same number of **moles**/same number of **molecules** on each side **OR** volume / V cancels Ignore statements such as 'concentrations cancel' 'products and reactants cancel' 'same number of products as reactants'	Concentrations are the same	**1**

Question Number	Acceptable Answers	Reject	Mark
(a)(iv)	$K_C = \frac{(0.20) / V \times (0.35) / V}{(0.20) / V \times (0.10) / V}$ $= 3.5 / 3.50$ Correct answer with or without working scores 1 Ignore omission of V TE from values in (ii) table	$K_C = 4$	**1**

Question Number	Acceptable Answers	Reject	Mark
(b)	• No effect on (position of) equilibrium **(1)** • Rate (of attainment of equilibrium) is faster / equilibrium reached sooner **(1)**		**2**

Question Number	Acceptable Answers	Reject	Mark
(c)(i)	**Bonds Broken** C—O **and** O—H **(1)** Ignore where these bonds are broken in the acid and alcohol molecules. **ALLOW** C—OH for C—O CO—H for O—H **Bonds Made** C—O **and** O—H **(1)** Ignore where these bonds are made in the ester and water molecules. **ALLOW** C—OC for C—O H—OH for O—H Marks can be awarded by annotating displayed or structural formulae. Comment: Max **1** if any other bonds mentioned	**Two** O—H bonds formed in H_2O molecule **ONLY** C—O bond broken and made scores **(0)** overall	**2**

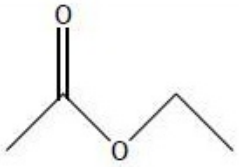
Question Number	Acceptable Answers	Reject	Mark
(c)(ii)	(C–O and O–H) bond enthalpies differ in: different environments /different molecules /different compounds OR Bond enthalpies/bond energies are average values **ALLOW** Bonds being broken and made are attached to different atoms	'Heat loss'	**1**

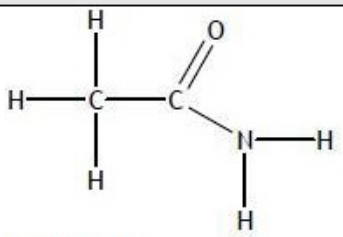
Question Number	Acceptable Answers	Reject	Mark
(d)(i)	$\Delta S_{total} = R \ln K$ Allow ΔS_{total} is proportional to **<u>ln</u>***K* ALLOW K_c or K_p instead of K	log instead of ln ΔS_{total} is proportional to K / ΔS_{total} increases as K increases	**1**

Question Number	Acceptable Answers	Reject	Mark
* **(d)(ii)**	**First mark:** (ΔH = 0 so) $\Delta S_{surroundings} = 0$ OR $-\frac{\Delta H}{T} = 0$ **(1)** IGNORE "$\Delta S_{surroundings}$ stays the same". **Second mark:** (so) ΔS_{total} does not change OR (so) $\Delta S_{total} = \Delta S_{system}$ **(1)** **Third mark:** (As $\Delta S_{total} = R \ln K$) ***K*** does not alter **(1)** **ALLOW** "it does not alter" to assume K does not alter. ALLOW use of K_c or K_p instead of K **Each point is stand alone** **IGNORE** justifications in terms of Le Chatelier's Principle **NOTE:** **Can award max (1) (i.e. the third scoring point) if the effect on *K* stated follows on CQ from a change to ΔS_{total}**	If only mentions 'no effect on position of equilibrium' rather than the equilibrium constant	**3**

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Question Number	Acceptable Answers	Reject	Mark
(e)(i)	$CH_3COCl + CH_3CH_2OH \rightarrow CH_3COOCH_2CH_3 + HCl$ Allow C_2H_5 for CH_3CH_2 Allow $CH_3CO_2CH_2CH_3$ for $CH_3COOCH_2CH_3$ IGNORE missing or incorrect state symbols	CH_3CClO/ CH_2CH_3OH	**1**

Question Number	Acceptable Answers	Reject	Mark
(e)(ii)	 **IGNORE** Bond angles and length of the lines.		**1**

Question Number	Acceptable Answers	Reject	Mark
(e)(iii)	 **IGNORE** Other products of the reaction if the above structure has been correctly drawn.	NH_2 or CH_3	**1**

Question Number	Acceptable Answers	Reject	Mark
(f)(i)	$(CH_3COOCH_2CH_3 + NaOH \rightarrow)$ $CH_3COONa + CH_3CH_2OH$ /C_2H_5OH Allow ionic representations of the sodium salt $CH_3COO^-Na^+$ IGNORE missing or incorrect state symbols	CH_2CH_3OH for ethanol	**1**

Question Number	Acceptable Answers	Reject	Mark
(f)(ii)	(Reaction with sodium hydroxide is) **not** an equilibrium / **not** reversible / goes to completion OR Reverse argument for acid hydrolysis		**1**

Q33.

Question Number	Answer	Additional Guidance	Mark
	A comparison that makes reference to: (with ethanoyl chloride) • the reaction is irreversible compared to reversible **(1)** • hydrogen chloride is the by-product rather than water **(1)** • the reaction is very fast/occurs at room temperature so an acid catalyst is not needed **(1)**	Accept reverse arguments Allow steamy fumes for 'HCl'	**(3)**

Q34.

Question Number	Answer	Additional Guidance	Mark
(a)	**B** (hydrolysis of butanenitrile with dilute hydrochloric acid)		**1**

Question Number	Answer	Additional Guidance	Mark
(b)	**D** (CH_3COCl and $CH_3CH_2CH_2OH$)		**1**

Question Number	Acceptable Answer	Additional Guidance	Mark
(c)(i)	An answer that makes reference to the following points: • to separate (the esters)		**1**

Question Number	Acceptable Answer	Additional Guidance	Mark
(c)(ii)	An answer that makes reference to the following points: • to identify (the esters) (by determining the M_r / measuring the molecular ion's *m/z* to 4 dp / by fragmentation)		**1**

Q35.

Question Number	Acceptable Answers	Additional Guidance	Mark
	A synthetic pathway that includes:	Allow names or formulae for reagents but if both are given, both must be correct Allow correct species in unbalanced equations Allow any combination of structural, displayed or skeletal formulae for the intermediates Penalise missing H once only Ignore conditions e.g. heat / reflux	**(5)**
	Conversion to alcohol • (aqueous ethanolic) potassium / sodium hydroxide **(1)**	Allow hydroxide ions / OH^- Ignore concentration Do not award just ethanol / ethanolic	
	• name or structure of propan-1-ol **(1)**	Stand alone mark e.g. $CH_3CH_2CH_2OH$ Allow propanol if correct structure shown somewhere	
	EITHER ROUTE 1 **Conversion to carboxylic acid** • (oxidise some of the propan-1-ol using) potassium dichromate((VI)) **and** (dilute) sulfuric acid **(1)**	Allow acidified potassium dichromate((VI)) / $Cr_2O_7^{2-}$ **and** H^+ Allow acidified manganate((VII)) Ignore concentration of acid / formation of aldehyde Do not award hydrochloric acid / HCl	
	• name or structure of propanoic acid **(1)**	Stand alone mark e.g. CH_3CH_2COOH	
	Formation of ester • react propan-1-ol and propanoic acid together **and** using (concentrated) sulfuric acid (catalyst) **(1)**	Stand alone mark for C_3 compounds Allow (concentrated hydrochloric) acid / H^+ / H_3O^+ instead of sulfuric acid Ignore concentration of acid	
	PTO for ROUTE 2	Ignore incorrect structure of ester e.g. with H or O missing	

	OR ROUTE 2 **Conversion to acyl chloride** • (oxidise some of the propan-1-ol using) potassium dichromate((VI)) **and** (dilute) sulfuric acid **and** add phosphorus(V) chloride to propanoic acid **(1)** • name or structure of propanoyl chloride **(1)** **Formation of ester** • react propan-1-ol and propanoyl chloride together **(1)**	Allow acidified potassium dichromate((VI)) / $Cr_2O_7^{2-}$ **and** H^+ Allow acidified manganate((VII)) Ignore concentration of acid / formation of aldehyde Do not award hydrochloric acid / HCl Stand alone mark e.g. CH_3CH_2COCl Stand alone mark for C_3 compounds Ignore incorrect structure of ester e.g. with H or O missing	

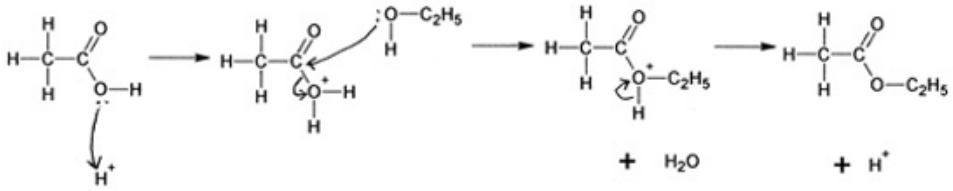
Q36.

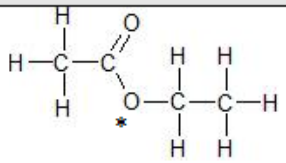
Question Number	Correct Answer	Mark
	D	**1**

Q37.

Question Number	Correct Answer	Mark
	A	**1**

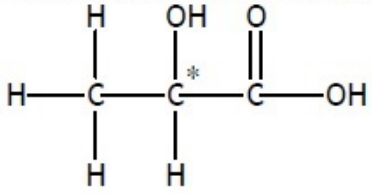
Q38.

	Answer	Additional Guidance	Mark
(i)	• oxygen lone pair and curly arrow to the H^+ **(1)** • curly arrow from oxygen lone pair on the ethanol to the carbon of the C = O **(1)** • curly arrow from C-O bond to oxygen of water molecule **(1)** • curly arrow from O–H bond back to the O^+ oxygen **(1)** Example of reaction mechanism  Penalise additional curly arrows for each marking point Penalise missing lone pair on oxygen once only in M1 and M2		**(4)**

Question Number	Answer	Additional Guidance	Mark
(ii)	• correct oxygen identified **(1)** • the single bond C–O in the carboxylic acid breaks rather than the one in ethanol **or** the oxygen in ethanol acts as the nucleophile (to attack the carbon of the carboxylic acid group and so ends up in the ester) **(1)**	 Allow 'loss of OH from the carboxylic acid'	**(2)**

Question Number	Answer	Additional Guidance	Mark
(iii)	• (M1) calculation of ΔG **(1)** • (M2) correct equation **(1)** • (M3) rearrangement of equation **(1)** • (M4) calculation of ΔS_{system} **(1)** • (M5) rearrangement of equation so $S_{(ethyl\ ethanoate)}$ = **(1)** • (M6) calculation of $S_{(ethyl\ ethanoate)}$ with sign and units **(1)**	Example of calculation $\Delta G = -RT \ln K = -8.31 \times 298 \times \ln 4.0 = -3433$ (J mol^{-1}) $\Delta G = \Delta H - T\Delta S_{system}$ $\Delta S_{system} = (\Delta H - \Delta G) \div T$ $\Delta S_{system} = (-6.0 \times 10^3 - (-3433)) \div 298 = -8.614....$ (J mol^{-1} K^{-1}) ($\Delta S_{system} = \sum S_{(products)} - \sum S_{(reactants)}$) $S_{(ethyl\ ethanoate)} = \Delta S + \sum S_{(reactants)} - S(water)$ $S_{(ethyl\ ethanoate)} = (-8.614 + (159.8+160.7) - 69.9) = +242/240$ J mol^{-1} K^{-1} Ignore SF except 1SF Correct final answer without working scores (6) TE throughout	**(6)**

Q39.

Question Number	Acceptable Answers	Reject	Mark
(a)(i)	A chiral molecule is non-superimposable on its mirror image / 3D molecule with no plane of symmetry **(1)** 2-hydroxypropanoic acid has a carbon atom which is asymmetric / has **four** different groups attached **(1)** **Middle** carbon labelled in any clear way **(1)** e.g.  ALLOW asymmetric C described but not labelled IGNORE references to rotation of plane polarized light	just 'non-superimposable' just 'no plane of symmetry' Molecules for groups	**3**

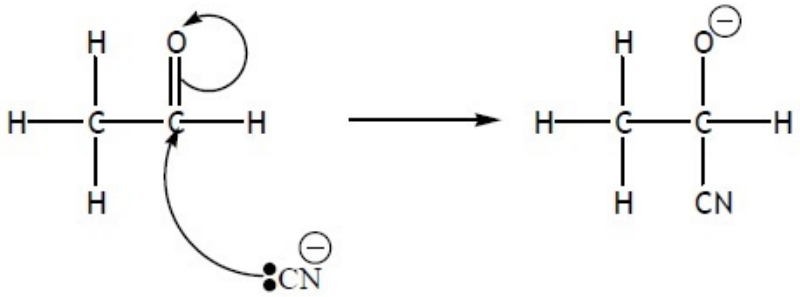
Question Number	Acceptable Answers	Reject	Mark
(a)(ii)	2-hydroxypropanoic acid formed in muscles is a single (allow pure) enantiomer /(optical) isomer ALLOW Unequal mixture of enantiomers /(optical) isomers **(1)** 2-hydroxypropanoic acid formed in milk is a racemic mixture / equimolar mixture of the two enantiomers / racemate **(1)** If milk and muscles are reversed but the rest is correct, one mark is awarded	Just "not a racemic mixture" Just 'a mixture of enantiomers'	**2**

Question Number	Acceptable Answers	Reject	Mark
(b)(i)	**First step** NaOH(aq) / KOH(aq) or names **(1)** Second mark dependent on first being correct **Second step** HCl(aq) / hydrochloric acid / H_2SO_4(aq) / sulfuric acid ALLOW HNO_3 / nitric acid /dil HCl /(dil) H_2SO4 /(dil) HNO_3 or any strong acid (name or formula) including HBr((aq)) and HI((aq)) **(1)** IGNORE Omission of (aq) and references to temperature Ethanolic /alcoholic solutions ALLOW One mark for correct two reagents in the wrong order One mark for 'alkali / OH^- followed by acid / H^+ /H_3O^+'	OH^- / alkali H^+ / H_3O^+ /acid	**2**

Question Number	Acceptable Answers	Reject	Mark
(b)(ii)	**First mark** (Stand alone) A racemic mixture is not formed OR More of one enantiomer /(optical) isomer is formed OR Only one enantiomer /(optical) isomer is formed **(1)** **Second mark** (Stand alone) (Some of the) reaction is S_N2 **(1)** **Third mark** (Stand alone) Nucleophile / OH^- only attacks from one side of the molecule / from the opposite side to leaving group **(1)** ALLOW Use of 'intermediate' for 'transition state' in description of S_N2 Reverse argument based on S_N1 forming a racemic mixture	Carbocation (for molecule)	**3**

Question Number	Acceptable Answers	Reject	Mark
(c)(i)	Nucleophilic **(1)** Addition **(1)**	 S_N1/S_N2	**2**

Question Number	Acceptable Answers	Reject	Mark
(c)(ii)	Cyanide (ion) / CN^- /$C\equiv N^-$/ $:C\equiv N^-$/ ^-CN	HCN/ $C\equiv N$	**1**

Question Number	Acceptable Answers	Reject	Mark
(c) (iii)	 Both curly arrows **(1)** Intermediate **(1)** ALLOW Omission of lone pair Curly arrow from anywhere on nucleophile including from charge or nitrogen Formation of charged canonical form followed by attack of cyanide ion IGNORE δ+/δ- even if unbalanced	Omission of charges (penalise once only) Full charges on ethanal —C—NC in intermediate	**2**

Question Number	Acceptable Answers	Reject	Mark
(c) (iv)	Racemic mixture / equal amounts of the two enantiomers / racemate formed **(1)** Stand alone mark CHO / aldehyde group is (trigonal) planar **(1)** ALLOW ethanal / molecule is (trigonal) planar Cyanide (ion) / CN^- /nucleophile attacks (equally) from above or below / either side (of the molecule) **(1)** Penalise use of intermediate / ion for aldehyde group **once** only Third mark cannot be awarded if the reaction is described as a nucleophilic substitution	Intermediate / carbonyl group /C_O is planar two positions Intermediate	**3**

Question Number	Acceptable Answers	Reject	Mark
(d)(i)	Any value /range within the range 3750—2500 cm^{-1} due to O—H / OH / —OH IGNORE COOH / CO_2H / carboxylic acid	Wavenumbers alone OH in alcohol	**1**

Question Number	Acceptable Answers	Reject	Mark
(d)(ii)	These three marks are stand alone Q is due to C═O **(1)** The (C═O) aldehyde range is 1740—1720 cm^{-1} **and** (C═O) carboxylic acid range is 1725—1700 cm^{-1} **(1)** So the peaks / absorptions cannot be used to distinguish these two compounds because they overlap. OR The (broad) absorption Q covers both the aldehyde and the carboxylic acid ranges **(1)** ALLOW 'too close'/'quite similar' for 'overlap'	Carboxylic acid / COOH group Just 'cannot be used to distinguish the compounds'	**3**

<table>
<tr><th>Question Number</th><th>Acceptable Answers</th><th>Reject</th><th>Mark</th></tr>
<tr><td>(e)</td><td>If reagent incorrect, observation mark can only be awarded for a near miss

Test positive for ethanal
<table>
<tr><th>Reagent (1)</th><th>Observation (1)</th></tr>
<tr><td>Tollens'</td><td>Silver mirror / black / grey ppt</td></tr>
<tr><td>Fehling's / Benedict's</td><td>Red-brown ppt</td></tr>
<tr><td>2,4-DNP(H) / Brady's reagent</td><td>Orange / red / yellow ppt
ALLOW brick-red ppt</td></tr>
</table>
Test positive for 2-hydroxypropanoic acid
<table>
<tr><th>Reagent (1)</th><th>Observation (1)</th></tr>
<tr><td>PCl_5 / Phosphorus (V)chloride / phosphorus pentachloride</td><td>Steamy fumes*
ALLOW gas evolved turns (blue) litmus / UI red</td></tr>
<tr><td>Named metal carbonate (solution)</td><td>Effervescence
ALLOW gas / CO_2 evolved turns lime water cloudy</td></tr>
<tr><td>Sodium hydrogencarbonate (solution)</td><td>Effervescence
ALLOW gas / CO_2 evolved turns lime water cloudy</td></tr>
<tr><td>Magnesium (& water)</td><td>Effervescence</td></tr>
<tr><td>Ethanol & H_2SO_4/named strong acid</td><td>Sweet / fruity / pear drops / glue smell</td></tr>
<tr><td>Ethanoic acid & H_2SO_4/named strong acid</td><td>Sweet / fruity / pear drops / glue smell</td></tr>
</table>
ALLOW
Na and effervescence / gas evolved pops with a lighted splint for2-hydroxypropanoic acid
(2)

ALLOW
fizzing / bubbling for effervescence

IGNORE
names of product

IF two tests given for one substance both must be correct for full marks

*misty fumes / white fumes / gas for fumes</td><td>Iodine in alkali / iodoform test
Acidified potassium dichromate

Smoke
Just 'fumes'

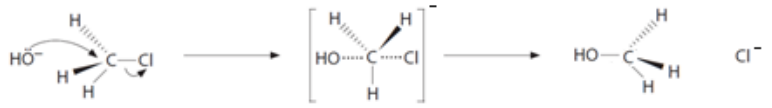
Any indicator as sole test

incorrect formulae of reagents</td><td>4</td></tr>
</table>

Q40.

Question Number	Answer	Additional Guidance	Mark
	• Reagent: lithium tetrahydridoaluminate((III)) /$LiAlH_4$ **(1)**	Allow lithium aluminium hydride Accept sodium tetrahydridoborate /sodium borohydride/ $NaBH_4$ In water/alcohol for 2 marks Ignore reference to addition of acid after use of $LiAlH_4$ in dry ether Do not award with additional reagents	**(2)**
	• Conditions: (dry) ether/ethoxyethane **(1)**	Ignore heat The mark for conditions is dependent on correct reagent or near miss such as incorrect formula $LiAlH_3$/LiAlH/LiAl	

Q41.

<table>
<tr><th>Question Number</th><th>Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td>(a)</td><td>
• attack by hydroxide ion on positive carbon (1)
• breaking of C-Cl bond (1)
• formula of transition state with correct charge (1)
• ‘partial’ bonds to OH and Cl shown in transition state (1)</td><td>Arrow must start from O and go to C; lone pair not required

Arrow from bond to Cl

Ignore brackets</td><td>4</td></tr>
<tr><td>(b)(i)</td><td>3-bromo-3-methylhexane</td><td>3-methyl-3-bromohexane</td><td>1</td></tr>
<tr><td>*(b)(ii)</td><td>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.

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</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, an answer with five indicative marking points which 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).</td><td>6</td></tr>
</table>

***(b)(ii) cont.**

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

	Number of marks awarded for structure of answer and sustained line of reasoning
Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout.	2
Answer is partially structured with some linkages and lines of reasoning.	1
Answer has no linkages between points and is unstructured.	0

Indicative content

- Reaction 2 forms optically active product as only one enantiomer formed (S_N2)
- as hydroxide ion can only attack on opposite side to leaving group
- which causes inversion (of configuration) of the chiral centre
- Reaction 3 product mixture shows no significant optical activity as a racemic mixture forms (S_N1)
- as intermediate is a planar carbocation,
- so can be attacked (by hydroxide ion) from either side

Could use labelled diagrams to illustrate attack of hydroxide ions in either mechanism

***(b)(ii) cont.**

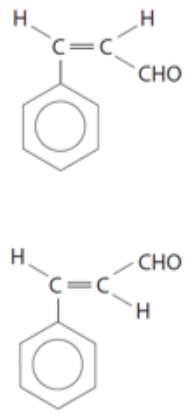
Or

- mechanism of reaction 2 is S_N2
- because single enantiomer is formed as product and is optically active
- as hydroxide ion can only attack on opposite side to leaving group
- reaction 3 produces a racemic mixture as product is not significantly optically active
- so reaction 3 is S_N1
- as the two products rotate the plane of plane-polarised light in opposite directions

Q42.

Question Number	Answer	Additional Guidance	Mark
	An answer that makes reference to the following point • the ester (functional group) will react (with the water) in a hydrolysis reaction	Ignore reference to H-bonds between water and OH groups Allow 'hydrolysis reaction' if equation showing break up of ester group also shown	(1)

Q43.

Question Number	Answer	Additional guidance	Mark
(b)(i)	• contains C=C/alkene		1
(b)(ii)	• contains carbonyl group/ aldehyde or ketone	C=O alone	1
(b)(iii)	• aldehyde/ -CHO		1
(c)(i)	• 77 $C_6H_5^+$ (1) • 103 $C_8H_7^+$ (1)	Must show a charge but only penalise omission once Allow structural, displayed or skeletal formulae	2
(c)(ii)	 	Allow non-displayed benzene C-Hs	2
(c)(iii)	• The peak is due to the presence of an atom of a (^{13}C) isotope	Allow reference to other named isotope of H or O	1

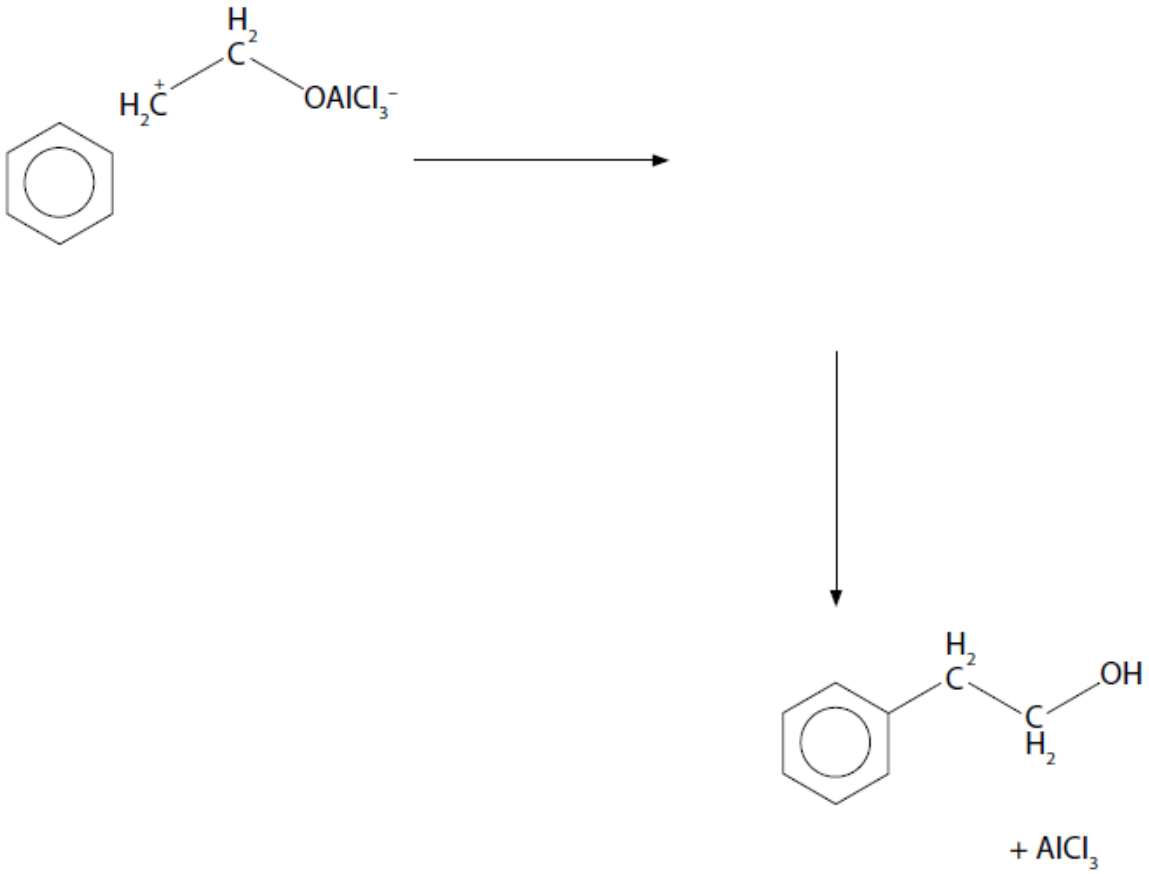
Q44.

Question Number	Correct Answer	Mark
	A	**1**

Q45.

Question number	Answer	Mark
(i)	**The only correct answer is B** (Compound **Q**) ***A*** *is incorrect because this is not hydrolysed* ***C*** *is incorrect because this is hydrolysed to form phenol and ethanoic acid* ***D*** *is incorrect because this is not hydrolysed*	**(1)**

Question number	Answer	Mark
(ii)	**The only correct answer is A** (Compound **P**) ***B*** *is incorrect because it is an ester and does not react with sodium hydrogencarbonate* ***C*** *is incorrect because it is an ester and does not react with sodium hydrogencarbonate* ***D*** *is incorrect because it is not acidic enough to react with sodium hydrogencarbonate*	**(1)**



(iii) In the synthetic route, what type of reaction is Step 2?

(1)

- ☒ **A** hydrolysis
- ☒ **B** esterification
- ☒ **C** neutralisation
- ☒ **D** hydrogenation

(iv) Name a suitable catalyst for Step 2.

(1)

.....

.....

.....

Mark Scheme

Q1.

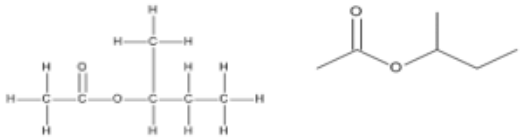
Question Number	Correct Answer	Mark
	A	**1**

Q2.

Question number	Answer	Mark
(i)	**The only correct answer is B** (Compound **Q**) ***A*** *is incorrect because this is not hydrolysed* ***C*** *is incorrect because this is hydrolysed to form phenol and ethanoic acid* ***D*** *is incorrect because this is not hydrolysed*	**(1)**

Question number	Answer	Mark
(ii)	**The only correct answer is A** (Compound **P**) ***B*** *is incorrect because it is an ester and does not react with sodium hydrogencarbonate* ***C*** *is incorrect because it is an ester and does not react with sodium hydrogencarbonate* ***D*** *is incorrect because it is not acidic enough to react with sodium hydrogencarbonate*	**(1)**

Q3.

Question Number	Answer	Additional Guidance	Mark
	Structures: • **T**: structure of butan-2-ol **(1)** • **U**: structure of butanone **(1)** • V: structure of 1-methylpropyl ethanoate **(1)** **Justification:** • **U** is a ketone because it gives an orange precipitate with 2,4-dinitrophenylhydrazine **and** does not give a precipitate with Fehling's solution **(1)** • **T** is a secondary alcohol because it was oxidised to / formed a ketone **(1)** • V is an ester as alcohols react with acyl chlorides / ethanoyl chloride to form esters **(1)**	Examples of structures Ignore names, even if incorrect **T**: $CH_3CH_2CHOHCH_3$ Ignore connectivity of OH group in displayed formula **U**: $CH_3CH_2COCH_3$ V:  Allow skeletal formulae or any combination of displayed and structural formulae Do not award C_4H_9 from alcohol Allow butyl ethanoate if **T** is butan-1-ol Allow **U** is a carbonyl compound because it gives an orange precipitate with 2,4-dinitrophenylhydrazine **and** is not an aldehyde as it does not give a precipitate with Fehling's solution	**(6)**

Q4.

Question Number	Correct Answer	Reject	Mark
	B		1

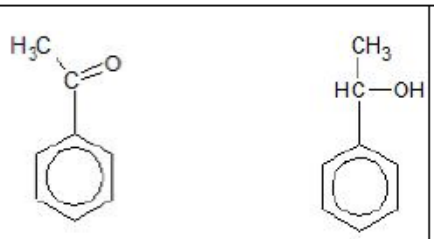
Q5.

Question Number	Correct Answer	Reject	Mark
(a)	D		1

Question Number	Correct Answer	Reject	Mark
(b)	A		1

Question Number	Correct Answer	Reject	Mark
(c)	C		1

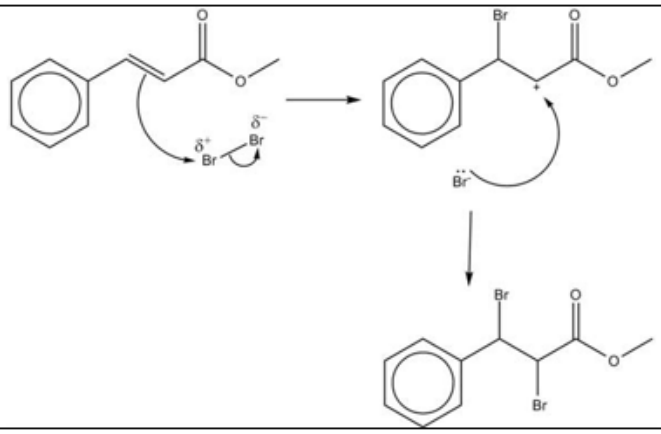
Q6.

Question Number	Acceptable Answer	Additional Guidance	Mark
	An answer that makes reference to the following: synthetic pathway that consists of: (Step 1) • (acylation of benzene) using ethanoyl chloride **(1)** • use of aluminium chloride (and heat) **(1)** (Step 2) • (reduction of) **A** with $LiAlH_4$ in ether (dry) **(1)** (Step 3) • (dehydration of) **B** with (conc.) phosphoric acid/H_3PO_4 **(1)** (Intermediates) • identification of **A** as phenylethanone and **B** as (1-)phenylethanol	The compounds used can be stated or given within equations. Only award if part of a Friedel-Crafts reaction Only award if given to reduce an aromatic carbonyl or carboxylic acid Allow (conc.) sulfuric acid/ H_2SO_4 Only award if given to dehydrate an aromatic alcohol Accept formulae for names, but if both given, then both must be correct This also applies to reagents	**(5)**
	 **(1)**	Do not award use of other reagents not in the table.	

Q7.

Question Number	Answer	Additional Guidance	Mark
(i)	• **M1** arrow from double bond to (δ+)Br in Br_2 (1) • **M2** arrow from bond in Br_2 to $Br^{\delta-}$ (1) • **M3** structure of carbocation (1) • **M4** arrow from **lone pair** on Br^- to C^+ in carbocation **and** final product (1)	Example of mechanism **See below** Penalise lack of dipole only once in M1 and M2 Award C^+ in intermediate on either C from the double bond Do not award M3 if four bonds are shown on carbocation Br atoms can be shown either upwards or downwards in final product Award (0) if just electrophilic substitution mechanism given. If **both** electrophilic substitution and addition shown allow 2 max Penalise errors in structure of methyl cinnamate once only in either M3 or M4	(4)

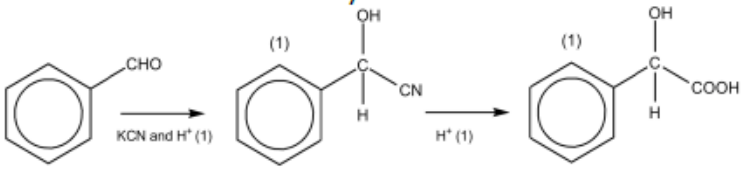
Example of mechanism

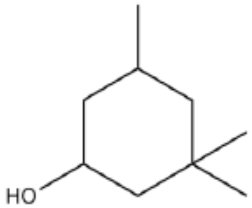


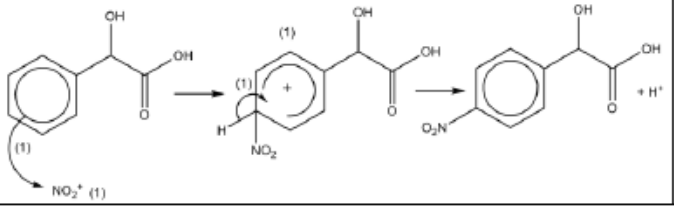
Question Number	Answer	Mark
(ii)	**The only correct answer is C (4)** **A** *is not correct because 2 chiral centres form in reaction, so 4 possible combinations of +/- forms* **B** *is not correct because 2 chiral centres form in reaction, so 4 possible combinations of +/- forms* **D** *is not correct because 2 chiral centres form in reaction, so 4 possible combinations of +/- forms*	**(1)**

Question Number	Answer	Mark
(iii)	**The only correct answer is D** (rotated) **A** *is not correct because diffracted is the wrong term* **B** *is not correct because reflected is the wrong term* **C** *is not correct because refracted is the wrong term*	**(1)**

Q8.

Question Number	Acceptable Answer	Additional Guidance	Mark
(a)	• reagent for step 1 (1) • product of step 1 (1) • reagent for step 2 (1)	KCN and HCN **or** KCN and H^+ **or** HCN Allow structural or displayed formulae Allow name or formula of any mineral acid 	**3**

Question Number	Acceptable Answer	Additional Guidance	Mark
(b)	 (1) • esterification (1)		**2**

Question Number	Acceptable Answer	Additional Guidance	Mark
(c)	• NO_2^+ ion (1) • curly arrow from ring to electrophile (1) • formula of intermediate (1) • curly arrow from CH bond to ring and formation of H^+ (1)	Ignore equation to produce electrophile To any part of the electrophile including the plus sign The horseshoe must cover at least three carbon atoms, opening towards the carbon atom approached by the electrophile and at least part of the plus charge within the horseshoe 	4

Q9.

Question Number	Answer	Additional Guidance	Mark
	• Name of the three functional groups (2)	Alcohol / diol, ester and alkene Allow hydroxy / hydroxyl (group) for alcohol Ignore primary Do not award incorrect structures of functional groups in conjunction with correct name Do not award secondary or tertiary alcohol Three correct functional groups scores (2) Two correct functional groups scores (1) One or zero correct functional groups (0) Four groups named with three correct scores (1)	(2)

Q10.

Question Number	Acceptable Answers	Additional Guidance	Mark
(i)	An explanation that makes reference to the following points: • glycinate ions / they do not contain a carbon atom with four different atoms / groups attached **or** the glycinate ion is superimposable on its mirror image **(1)** • so there will be no effect (on plane-polarised monochromatic light) **(1)**	An answer that states there will be an effect scores (0) Allow not chiral / achiral / has no enantiomers / has no asymmetric carbon atom Allow the carbon atom attached to NH_2 is only attached to 3 different atoms / groups / is not attached to 4 different atoms / groups Ignore glycinate ions are not optically active / do not exhibit optical isomerism Do not award it is a racemic mixture / there are equal amounts of the two isomers / four different molecules attached M2 is conditional on M1 Do not award the (monochromatic) light will not be polarised	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(ii)	• correct formula of one of the copper species **(1)** • rest of equation correct **(1)**	Example of equation $(CH_3COO)_2Cu + 2\ NH_2CH_2COOH \rightarrow (NH_2CH_2COO)_2Cu + 2CH_3COOH$ Allow $Cu(CH_3COO)_2$ / $Cu(NH_2CH_2COO)_2$ Allow both charges shown e.g. $(CH_3COO^-)_2Cu^{2+}$ Allow displayed / skeletal formulae for organic substances but not molecular formulae Ignore state symbols, even if incorrect Do not award M1 if covalent bond between Cu and O in any species but M2 can still score	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(iii)	An answer that makes reference to any **four** of the following points: Student **1** / higher yield • the crystals were not dry / still damp when they were weighed **(1)** • there are impurities in the crystals **(1)** Student **2** / lower yield • reaction was incomplete **(1)** • not all of the copper(II) glycinate had crystallised / some is left in solution **(1)** • description of a specific handling loss **(1)**	Ignore reference to weighing errors for both students Allow the student did not subtract the mass of filter paper / product container Do not award the crystals contain water of crystallisation / are (partially) hydrated Allow a specific impurity e.g. glycine Allow the reaction reached equilibrium / side reactions occur / by-products form Ignore just 'the solution has not cooled enough' Allow any specific example e.g. some crystals left on the walls of the container / beaker / flask / lost during filtration / lost during transfer Ignore just 'transfer error' / lost when handling	**(4)**

Q11.

<table>
<tr><th>Question Number</th><th>Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr>
<td>*</td>
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Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.

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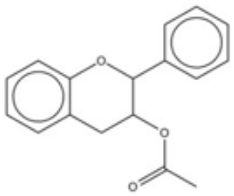
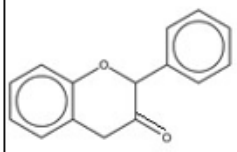
Typically

Number of IPs Reasoning mark

6 or 5 scores 2

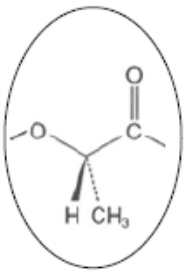
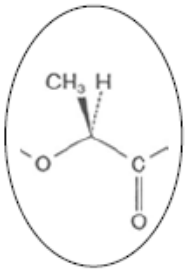
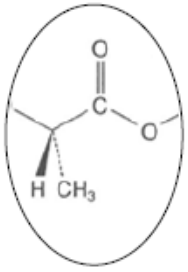
4 or 3 scores 1

2 or 1 or 0 scores 0</td>
<td>(6)</td>
</tr>
</table>

	Indicative content • **IP1** any mention of **oxidation** of ethanol **or oxidation** of flavan-3-ol (by oxygen in the air) • **IP2** for formation of **either** ethanoic acid **or** ethanal (from ethanol) • **IP3** for formation of ethyl ethanoate (from the reaction between ethanol and ethanoic acid) • **IP4** for structure / name of flavan-3-one • **IP5** for (-OH group on) flavan-3-ol forms an ester with ethanoic acid • **IP6** correct structure of the ester formed between flavan-3-ol and ethanoic acid  **This is the structure of the ester formed between flavan-3-ol and ethanoic acid**	Allow names or formulae **but** if both are given **both** must be correct  **Comment** For correct structure of the ester formed between flavan-3-ol and ethanoic acid award both **IP5** and **IP6** Do not award IP4 if the product is described as an aldehyde	

Q12.

Question Number	Acceptable Answers	Additional Guidance	Mark
(i)	• Condensation (polymerisation)	Ignore esterification or addition-elimination Do not award addition	**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(ii)	• Repeat unit circled on diagram as follows:  **or** 	Allow any repeat unit e.g  Do not award circle containing more than one repeat unit	**(1)**

Q13.

<table>
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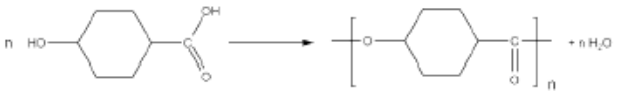
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<tr><td></td><td>Indicative content
• IP1 in both cases many monomers join (by covalent bonds to form polymers)

• IP2 cyclohexene forms an addition polymer / the polymer is formed by an addition reaction

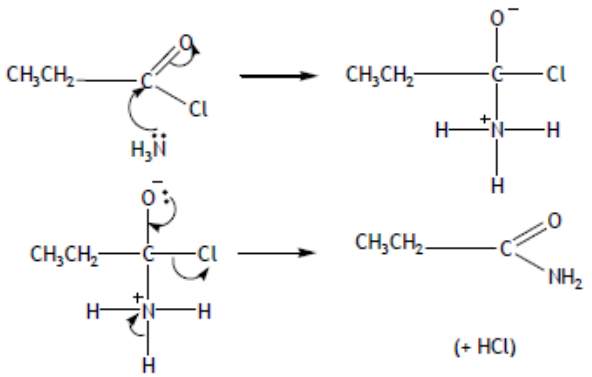
• IP3 4-hydroxycyclohexanecarboxylic acid forms a condensation polymer / the polymer is formed by a condensation reaction

• IP4 no additional products from when cyclohexene polymerises, but water is also</td><td>Allow both polymerisations require a catalyst
Allow both polymers are formed from a single type of monomer

Allow unsaturated monomer forms saturated polymer</td><td></td></tr>
</table>

	formed when 4-hydroxycyclohexanecarboxylic acid polymerises • **IP5** • **IP6**  	Allow 'only 1 product in addition but two products in condensation' Allow only one functional group is needed for addition polymerisation but two different functional groups are needed for condensation polymerisation Allow cyclohexene polymerisation has 100% atom economy, 4-hydroxycyclohexanecarboxylic polymerisation has less than 100% atom economy Ignore omitted or misplaced n in **IP5** and **IP6** Allow 1 IP for IP5 and IP6 if both correct repeat units shown Allow 2 oxygen atoms on RHS and none on LHS for IP6 repeat unit	

Q14.

Question Number	Acceptable Answers	Additional Guidance	Mark
	• first two curly arrows and lone pair shown on the nitrogen **(1)** • structure of intermediate including both charges **(1)** • three curly arrows and structure of final organic product **(1)**		**(3)**

Q15.

Question Number	Correct Answer	Reject	Mark
(a)	B		**1**

Question Number	Correct Answer	Reject	Mark
(b)	C		**1**

Question Number	Correct Answer	Reject	Mark
(c)	A		**1**

Question Number	Correct Answer	Reject	Mark
(d)	D		**1**

Q16.

Question Number	Answer	Additional Guidance	Mark
(i)	**B** (alcohol **Q**)		**1**

Question Number	Answer	Additional Guidance	Mark
(ii)	**C** (alcohols **P, R** and **S** only)		**1**

Question Number	Answer	Additional Guidance	Mark
(iii)	**C** (alcohol **R**)		**1**

Q17.

Question Number	Correct Answer	Reject	Mark
(a)	D		1

Question Number	Correct Answer	Reject	Mark
(b)	C		1

Question Number	Correct Answer	Reject	Mark
(c)	A		1

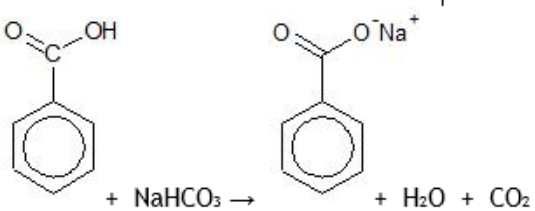
Question Number	Correct Answer	Reject	Mark
(d)	C		1

Question Number	Correct Answer	Reject	Mark
(e)	B		1

Q18.

Question Number	Correct Answer	Reject	Mark
	A		**1**

Q19.

Question Number	Answer	Additional Guidance	Mark
		Example of equation 	**(2)**
	• formula of sodium benzoate **(1)**	Accept C_6H_5COONa and/or $C_6H_5COO^{(-)}Na^{(+)}$ Allow omission of charges Allow Kekulé structures Do not award O–Na	
	• remainder of equation **(1)**	Ignore state symbols even if incorrect Standalone mark	

Q20.

Question Number	Correct Answer	Mark
(a)	B	**1**

Question Number	Correct Answer	Mark
(b)	A	**1**

Question Number	Correct Answer	Mark
(c)	C	**1**

Question Number	Correct Answer	Mark
(d)	A	**1**

Q21.

Question Number	Answer	Mark
(i)	**The only correct answer is B** (2-methylpentan-2-ol) **A** *is not correct because it is a secondary alcohol* **C** *is not correct because it is a secondary alcohol* **D** *is not correct because it is a secondary alcohol*	**(1)**

Question Number	Answer	Mark
(ii)	**The only correct answer is A** (hexan-2-ol) **B** *is not correct because it is a tertiary alcohol* **C** *is not correct because it does not contain a CH_3CHOH group* **D** *is not correct because it does not contain a CH_3CHOH group*	**(1)**

Q22.

Question Number	Answer	Additional Guidance	Mark
	• correct name (1) • correct formula (1)	Propanoyl chloride Allow propanoic anhydride CH_3CH_2COCl Allow $(CH_3CH_2CO)_2O$ Allow displayed or skeletal formula Allow 1 mark for correct name **and** formula for propanoic acid Allow 1 mark for name and formulae of acyl chloride / acid anhydride with incorrect number of carbon atoms	(2)

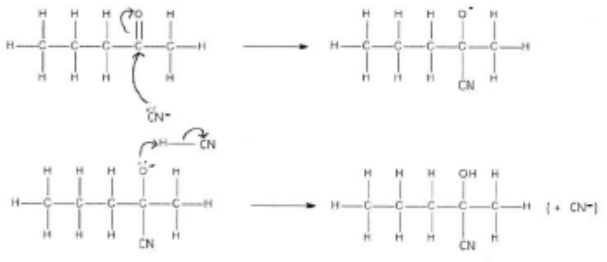
Q23.

Question Number	Answer	Additional Guidance	Mark
(b)	C		1
(c)	D		1

Q24.

Question Number	Answer	Additional Guidance	Mark
	A description that makes reference to the following points: • (add a solution of) iodine and alkali / sodium hydroxide / potassium hydroxide / hydroxide ions (and warm) (1) **or** (add a solution of) potassium iodide in sodium chlorate(I) (and warm) (1) • (only) pentan-2-one give a (pale) yellow precipitate / ppt(e) / solid	Allow names or formulae but if both are given, both must be correct Stand alone mark Allow antiseptic smell Ignore observation for pentan-3-one unless also stated that it gives a yellow precipitate	(2)

Q25.

Question Number	Answer	Additional Guidance	Mark
(i)	An answer that makes reference to the following points: • curly arrow from lone pair on C of CN^- to C of ketone group (1) • curly arrow from C=O to, or just beyond, O (1) • intermediate (1) • curly arrow from lone pair on O^- to H and curly arrow from H-CN bond to anywhere on CN (1)	Example of mechanism:  Allow C_3H_7 and CH_3 for propyl and methyl groups Allow CN bond displayed Ignore correct dipoles, penalise an incorrect dipole once only Do not award M3 if C^+ is shown on intermediate For M4, allow curly arrow from lone pair on O^- to H^+ ion / H_2O molecule Penalise incorrect ketone once only in M3 intermediate Penalise curly arrow from -ve charge instead of lone pair once only	(4)

Question Number	Answer	Additional Guidance	Mark
(ii)	An explanation that makes reference to the following points: • pentan-2-one / ketone is planar about the carbonyl carbon (1) • so the CN^-/ nucleophile attacks (equally) from above and below / either side (of the plane) (1)	Allow bonds about C=O are (trigonal) planar or the carbonyl carbon is (trigonal) planar Do not award planar molecule / reference to planar intermediate / ion Do not award multiple directions	(2)

Q26.

<table>
<tr><th>Question Number</th><th>Acceptable Answers</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td>*</td><td>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.

<table>
<tr><td>Number of indicative marking points seen in answer</td><td>Number of marks awarded for indicative marking points</td></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><td></td><td>Number of marks awarded for structure of answer and sustained line of reasoning</td></tr>
<tr><td>Answer shows a coherent and 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, 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).</td><td>(6)</td></tr>
</table>

	Comment: Look for the indicative marking points first, then consider the mark for structure of answer and sustained line of reasoning	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	

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	Indicative content • **IP1 Reagents and conditions for oxidation –** acidified potassium dichromate((VI)) / $K_2Cr_2O_7$ **and** H^+/H_2SO_4 **or** acidified sodium dichromate((VI)) / $Na_2Cr_2O_7$ **and** H^+/H_2SO_4 **or** Fehling's solution / Benedict's solution **or** Tollens' reagent / ammoniacal silver nitrate / $Ag(NH_3)^{2+}$	or 2 indicative points would score zero marks for reasoning.	

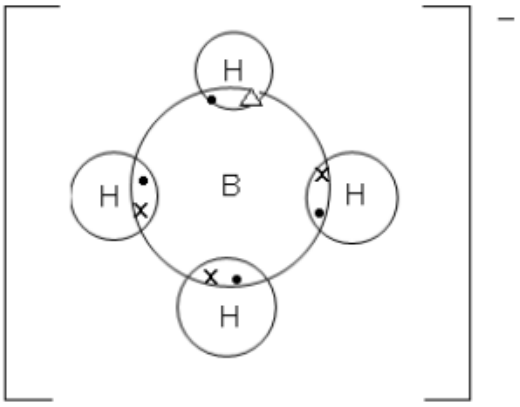
	• **IP2 Oxidation of aldehyde** – structure of pentanoic acid • **IP3 Oxidation of ketone**–pentan-3-one / ketone is not (easily) oxidised • **IP4 Reagents and conditions for reduction –** lithium tetrahydridoaluminate((III)) / lithium aluminium hydride **and** dry ether /ethoxyethane (followed by a dilute acid) **or** sodium tetrahydridoborate((III)) / sodium borohydride **and** aqueous / methanol solution (followed by a dilute acid) • **IP5 Reduction of aldehyde** – structure of pentan-1-ol • **IP6 Reduction of ketone** – structure of pentan-3-ol	Reagents - Allow names or formulae but if both are given, both must be correct Products - Allow any combination of displayed and structural formulae / skeletal formulae Allow C_4H_9 / C_3H_7 for the alkyl groups Allow acidified dichromate((VI)) ions / $Cr_2O_7^{2-}$ **and** H^+/H_2SO_4 Allow acidified manganate((VII)) ions / MnO_4^- **and** H^+/H_2SO_4 Ignore reference to heat Do not award just Cu^{2+} for Fehling's / Benedict's $CH_3CH_2CH_2CH_2COOH$	

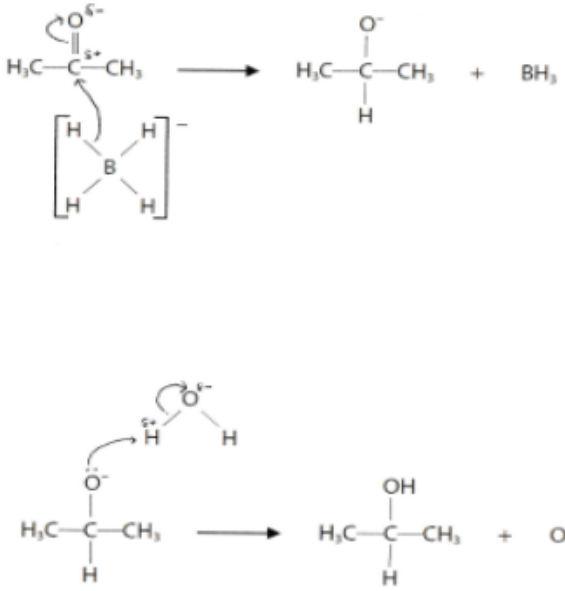
		Allow lithal Ignore hydrogen and platinum (catalyst) Ignore reference to heat $CH_3CH_2CH_2CH_2CH_2OH$ CH_3CH_2 $CH(OH)CH_2CH_3$	

Q27.

Question Number	Answer	Mark
	The only correct answer is A ($LiAlH_4$ and ether) ***B*** *is incorrect as acidified* $KMnO_4$ *is an oxidising agent* ***C*** *is incorrect as Sn/HCl is too mild a reducing agent* ***D*** *is incorrect as acidified* $Na_2Cr_2O_7$ *is an oxidising agent*	**(1)**

Q28.

Question Number	Acceptable Answers	Additional Guidance	Mark
(i)	• dot-and-cross diagram	Example of diagram  Electrons must have the correct symbols i.e. 3 bonds with • and x and 1 bond with • and Δ Circles do not need to be shown Allow missing brackets but charge needs to be shown Allow charge anywhere on or close to diagram Ignore lines representing covalent bonds e.g. x • Ignore missing atom labels / inner shell of 2 electrons on B	(1)

Question Number	Acceptable Answers	Additional Guidance	Mark
(ii)	• curly arrow from B-H bond to C of C=O **(1)** Allow curly arrow from B-H bond to H **and** curly arrow from H to C • dipole on C=O **(1)** **and** curly arrow from C=O bond to or just beyond O • lone pair on O^- **(1)** **and** curly arrow from lone pair to H of H_2O • curly arrow from O-H bond to O **(1)** **and** dipole on H-O bond	Example of mechanism  Allow curly arrow from any B-H bond Ignore lone pair on O in H_2O Penalise half-headed curly arrow once only	**(4)**

Q29.

Question Number	Correct Answer	Reject	Mark
(a)	D		1

Question Number	Correct Answer	Reject	Mark
(b)	B		1

Question Number	Correct Answer	Reject	Mark
(c)	C		1

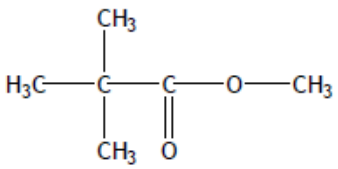
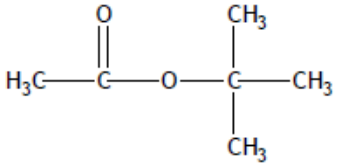
Q30.

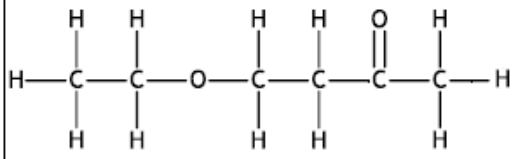
Question Number	Answer	Additional Guidance	Mark
	An explanation that makes reference to the following points: • a racemic mixture / racemate is formed **or** equal amounts / an equimolar mixture of both optical isomers forms **(1)** • intermediate / carbocation is (trigonal) planar around the reaction site / C^+ / central carbon **(1)** • (equal probability of) attack (by nucleophile / hydroxide ions) from either side / above and below / both sides / opposite sides (of the plane) **(1)**	Allow enantiomers / D-L isomers / (+) and (-) isomers Allow the two isomers rotate the plane of plane-polarised light in opposite directions and cancel out Ignore just 'mixture is not optically active' / 'mixture does not rotate the plane of plane-polarised light' Allow the intermediate / carbocation is planar (around the reaction site) Do not award 'the molecule is planar'	**(3)**

Q31.

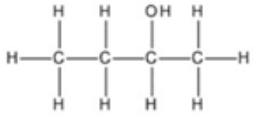
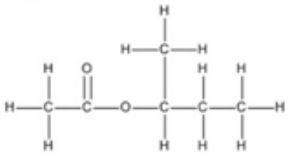
Question Number	Answer	Additional Guidance	Mark
	Method 1 • **(M1)** mass of benzoic acid in 50 cm^3 **(1)** • **(M2)** no. of moles of benzoic acid in 50 cm^3 **(1)** OR Method 2 • **(M1)** moles of benzoic acid in 1000 cm^3 **(1)** • **(M2)** no. of moles of benzoic acid in 50 cm^3 **(1)** then • **(M3)** evaluation of the number of molecules of benzoic acid in 50 cm^3 **(1)**	<u>Example of calculation</u> m=(1.70 x 0.05=)0.0850 (g) n=(0.0850 ÷ 122=) 6.967 … x 10^{-4} (mol) n=(1.70 ÷ 122 =) 0.01393… (mol) n=(0.01393… x 0.05 =) 6.967 … x 10^{-4} (mol) N= (6.967 …x 10^{-4} x 6.02 x 10^{23}=) =4.19 x 10^{20} / 4.2 x 10^{20} Ignore sf except 1sf Penalise excessive (6+) SF Allow use of 6.0 x 10^{23} to give 4.18 x 10^{20} for (3) Correct final answer without working scores (3) <u>TE throughout</u>	**(3)**

Q32.

Question Number	Acceptable Answers	Additional Guidance	Mark
(i)	$C(CH_3)_3COOCH_3$ **or**  **(1)** $CH_3COOC(CH_3)_3$ **or**  **(1)**	Allow displayed or skeletal formulae	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(ii)	An answer that makes reference to the following points: • the chemical shift δ 2.2 identified **(1)** • four remaining chemical shifts identified **(2)** • two splitting patterns given **and** explained **(2)**	$CH_3C{=}O$ / methyl attached to C=O Identifies 2 or 3 chemical shifts correctly scores 1 δ 1.2 3.5 3.8 2.6 (2.2)  1 specific splitting patterns explained scores 1	**(5)**

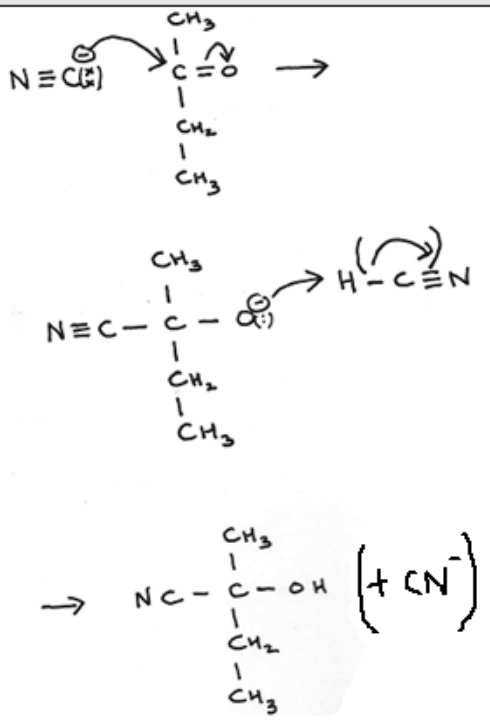
Q33.

Question Number	Acceptable Answers	Additional Guidance	Mark
	Identifications • structure of alcohol **B** **(1)** • structure of ester **A** **(1)** **Justification** • butan-2-ol / $CH_3CH_2CHOHCH_3$ is the **only** alcohol (with formula $C_4H_{10}O$) that (undergoes elimination and) produces (but-1-ene and) but-2-ene **(1)**	Allow any combination of structural, displayed or skeletal formulae / correct species in unbalanced equations Allow structures not labelled **A** and **B** Penalise missing H once only Examples of identification **(B)**  Ignore connectivity of the OH group unless horizontal **(A)**  Ignore incorrect name for **A** TE on incorrect alcohol Allow butan-2-ol can form a double bond either side of the C with OH / between the 1st and 2nd carbon atoms and the 2nd and 3rd carbon atoms – this can be shown on diagram / equation Allow OH must be on the 2nd carbon atom / secondary alcohol to form but-1-ene and but-2-ene Allow butan-1-ol gives but-1-ene **and** 2- methylpropan-1-ol / 2-methylpropan-2-ol gives (2-)methylpropene Allow the other alcohols (with formula $C_4H_{10}O$) do not give but-2-ene	**(3)**

Q34.

Question Number	Correct Answer	Reject	Mark
(a)(i)	Sodium/potassium dichromate ((VI)) **and** (Dilute/concentrated) sulfuric acid OR correct formulae / H^+ **and** $Cr_2O_7^{2-}$ ALLOW H^+ **and** $Cr_2O_7^{2-}$/acidified dichromate((VI)) **(1)** Reflux/distil Ignore 'heat', 'warm', and 'boil' alone. ALLOW Just 'under reflux' Just 'under distillation' **(1)** Second mark depends on mention of dichromate/$Cr_2O_7^{2-}$ in first part OR $KMnO_4$ and acid with heat **(1)**	Hydrochloric acid	**2**

Question Number	Correct Answer	Reject	Mark
(a)(ii)	Carbonyl group – addition of 2,4-dinitrophenylhydrazine / 2,4-DNP(H) / Brady's reagent **(1)** to give yellow/orange/red precipitate/ppt/ppte/solid/crystals ALLOW recognisable spelling e.g., percepitate **(1)** $CH_3C{=}O$ reaction with iodine in alkali/NaOH/KOH/OH^- ALLOW Iodoform/tri-iodomethane/haloform AND reaction/test **(1)** to form (pale) yellow / cloudy precipitate/solid/crystals **(1)**	2-DNP/4DNP Just DNP Brick red ppt	**4**
	Ignore references to smell Ignore heat in either part **Note** • In both cases result mark depends on test being recognisably correct even if it did not score a mark Examples: DNP gives yellow ppt Iodine test gives yellow ppt • Tests for aldehydes with correct results, no marks		

Question Number	Correct Answer	Reject	Mark
(b)(i)	 Arrow (from carbon) of CN^- to carbon of C=O AND Arrow from part of C=O double bond to oxygen ALLOW	CN without negative charge	**3**
	Two steps via a charged canonical form **(1)** Intermediate anion with C-CN bond. **(1)** Arrow from resulting O^- to hydrogen of $HCN/H^+/H_2O$ **(1)** **Note** Arrow directions must be correct to score each mark Penalise half-headed arrows each time in both parts ALLOW skeletal formulae.	...C-NC bond	

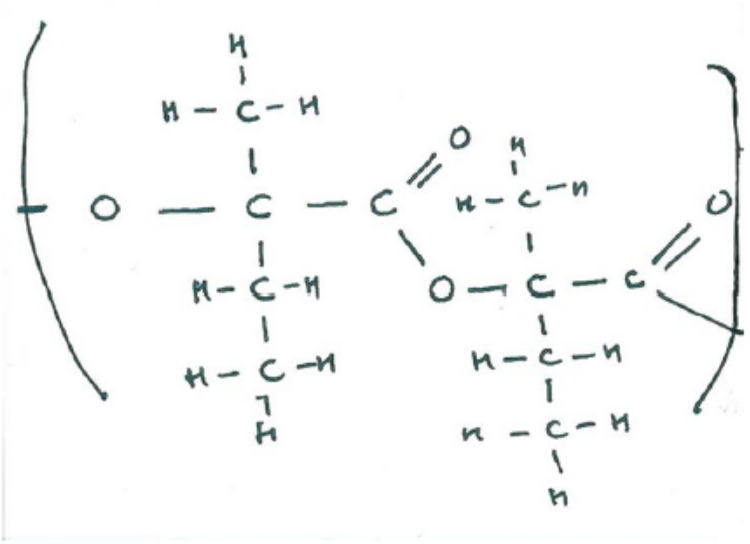
Question Number	Correct Answer	Reject	Mark
(b)(ii)	Forms a racemic mixture **(1)** Because bonds around C=O are planar OR Carbonyl group/reaction site is (trigonal) planar OR Bonds around carbonyl carbon are planar **(1)** Cyanide can attack from either side / above or below **(1)**	Butanone/molecule/it is planar C=O is planar Carbonyl bond is planar Intermediate is planar	**3**

Question Number	Correct Answer	Reject	Mark
(c)(i)	(Acid) hydrolysis OR Alkaline hydrolysis followed by acidification	Hydration	**1**

Question Number	Correct Answer	Reject	Mark
(c)(ii)	The O-H absorptions for alcohol and carboxylic acid overlap. OR OH absorption for an acid is very broad OR Quote data booklet values which must show some overlap, to include 3300 to 3200. ALLOW OH absorptions similar/the same.	Just 'both have OH groups' Just 'two OH groups present'	**1**

Question Number	Correct Answer	Reject	Mark
(c)(iii)	(Chemical shift δ) 2.0 - 4.0 (ppm) / any value within this range ALLOW Correct number followed by δ, eg 3δ		**1**

Question Number	Correct Answer	Reject	Mark
(c)(iv)	There is no hydrogen atom/proton on the adjacent/neighbouring carbon atom ALLOW No adjacent/neighbouring hydrogens/protons		**1**

Question Number	Correct Answer	Reject	Mark
(d)	 Ester linkage **(1)** Rest of molecule **(1)** ALLOW Attached chains as structural formulae Ignore n or other numbers outside bracket		**2**

Q35.

Question Number	Answer	Additional Guidance	Mark
	• 2-bromo-2-methylbutane reacts with Mg **(1)** • Dry ether **(1)** • $CH_3CH_2C(MgBr)(CH_3)CH_3$ **(1)** • react Grignard reagent with HCHO **(1)** • $CH_3CH_2C(CH_3)_2CH_2OMgBr$ **(1)** • (hydrolyse) with (dilute) acid **(1)** OR • 2-bromo-2-methylbutane reacts with KCN **(1)** • ethanol (as solvent) **(1)** • $CH_3CH_2C(CN)(CH_3)CH_3$ **(1)** • nitrile (hydrolysed) with (dilute) acid **(1)** • $CH_3CH_2C(COOH)(CH_3)CH_3$ **(1)** • carboxylic acid (reduced) with $LiAlH_4$ (in dry ether) **(1)**	Note – award of reagent or solvent marks must be in context of attempt to carry out an appropriate reaction e.g. use of **ethanolic** KCN to react with a ketone would not score OR M2 do not award HCOH Allow with water / H^+ Ignore HCN Allow methanol Allow H^+	(6)

Q36.

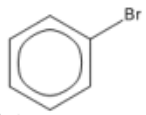
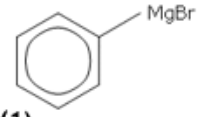
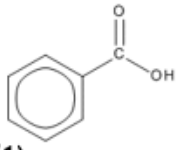
Question Number	Answer	Additional Guidance	Mark
(i)	An answer that makes reference to the following point: • the hydride ion will not attack / will be repelled by regions of high electron density	Allow the reduction by $LiAlH_4$ is a nucleophilic addition / alkenes do not undergo nucleophilic reactions / H^- is a nucleophile Allow alkenes react with H^+ / $H^{\delta+}$ / H• Allow the hydride ion will not attack a pi-bond / C=C Allow like charges repel Ignore hydride ions cannot reduce alkenes Ignore hydride ions can only reduce carbonyl compounds	(1)

Question Number	Answer	Additional Guidance	Mark
(ii)	An answer that makes reference to the following points: • hydrogen / H_2 **(1)** • nickel / Ni **or** platinum / Pt / palladium / Pd **(1)**	Mark independently Ignore reference to temperature	(2)

Question Number	Answer	Additional Guidance	Mark
(iii)	• 1-bromobutane / $CH_3CH_2CH_2CH_2Br$	If name and formula are given, both must be correct Allow Cl or I instead of Br Allow skeletal or displayed formulae	(1)

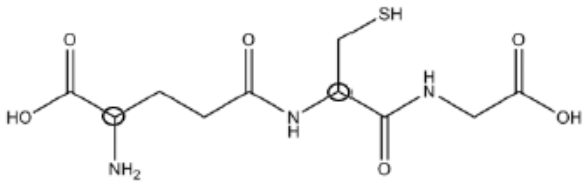
Question Number	Answer	Additional Guidance	Mark
(iv)	• hydrochloric acid / HCl / H^+	Allow any (dilute) strong acid Ignore concentration of acid Do not award any weak acid	(1)

Q37.

Question Number	Answer	Additional Guidance	Mark
	Step 1 • bromine **and** iron / iron(III) bromide **or** chlorine and aluminium chloride **(1)** •  **(1)** **Step 2** • magnesium **and** dry ether **(1)** •  **(1)** **Step 3** • carbon dioxide followed by a dilute acid **(1)** •  **(1)** **Step 4** • phosphorus(V) chloride / phosphorus pentachloride **(1)**	Allow names or formulae for reagents but if both are given, both must be correct Allow these drawn as a reaction scheme with reagents and conditions on arrows and intermediates in unbalanced equations The marks for the intermediate structures are stand-alone Allow carbon dioxide and dilute acid Ignore just carbon dioxide and water	**(7)**

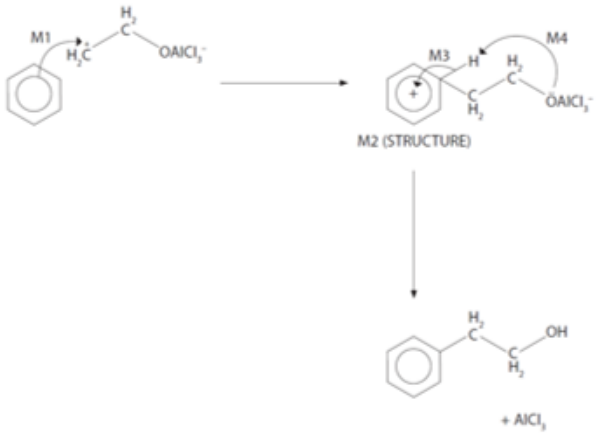
Q38.

Question Number	Answer	Mark
(i)	**The only correct answer is C** (oxidation) *A is incorrect as there is no evidence the species have added to the benzene ring* *B is incorrect as there is no evidence of chemical breakdown due to reaction with water* *D is incorrect as the -NH group and -OH group have lost hydrogen atoms*	(1)

Question Number	Answer	Additional guidance	Mark
(ii)	• both carbon atoms circled	 Allow any other labelling e.g. asterisk / arrow Do not award additional incorrect carbon atoms	(1)

Question Number	Answer	Mark
(iii)	**The only correct answer is B** (glutamic acid and cysteine) ***A*** *is incorrect as aspartic acid has only 4 carbon atoms* ***C*** *is incorrect as the sulfur atom in methionine has a methyl group attached* ***D*** *is incorrect as the sulfur atom in methionine has a methyl group attached and aspartic acid has only 4 carbon atoms*	(1)

Q39.

Question Number	Answer	Additional Guidance	Mark
(i)	A		1
(ii)	 • electron pair movement from ring to electrophile (1) • formula of intermediate ion (1) • movement of bond pair to reinstate delocalised ring (1) • movement of lone pair from oxygen to hydrogen (1)	Can show H^+ ion forming and reacting with lone pair from oxygen Can show O-Al bond breaking	4
(iii)	B		1
(iv)	• (concentrated) sulfuric acid / H_2SO_4 **or** • (concentrated) hydrochloric acid/HCl	Do not award dilute sulfuric acid	1