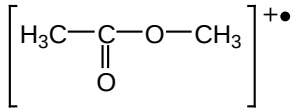
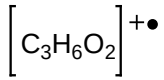
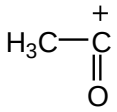
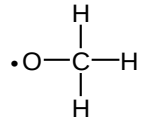
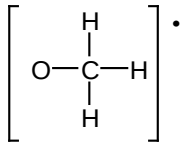
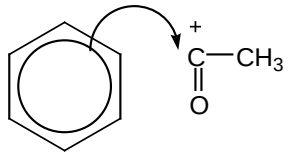
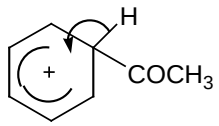
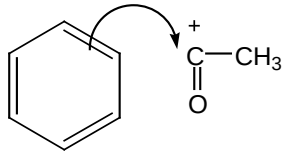
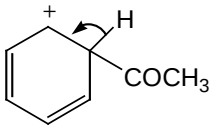
Question 1: N/A

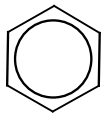
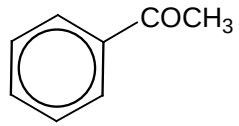
Question 2: N/A

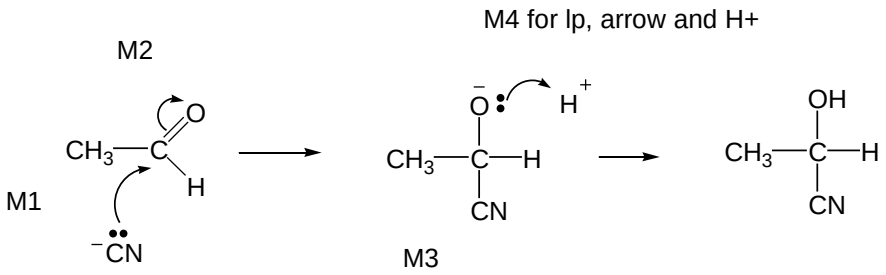
Question 3: N/A

Question	Marking Guidance	Mark	Comments
4(a)	  ***OR***	1	NOT penalise missing brackets. If wrong ester, no further mark.
	→  +  (1) Radical dot must be on O Ignore lone pair(s) on O in addition to single electron	1	Allow radical with brackets as  Ignore errors in acylium ion.

4(b)(i)	$AlCl_3$ or $FeCl_3$	1	If wrong no further marks.
	$CH_3COCl + AlCl_3 \longrightarrow CH_3\overset{+}{C}O + AlCl_4^-$	1	Correct equation scores 2 - contrast with 4(b)(iii) Allow + on C or O in equation.

4(b)(ii)	Electrophilic substitution	1	Ignore Friedel crafts.
	M1  M3  M2 ***OR*** M1  M3  M2	3	• + must be on C of RCO here • M1 arrow from within hexagon to C or to + on C • Gap in horseshoe must approximately be centred around C1 and not extend towards C1 beyond C2 and C6 • + not too close to C1 • M3 arrow into hexagon unless Kekule • allow M3 arrow independent of M2 structure, i.e. + on H in intermediate loses M2 not M3 • ignore base removing H for M3

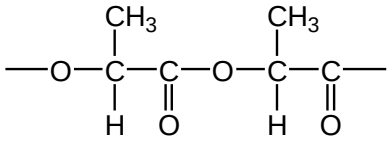
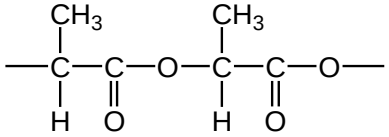
4(b)(iii)	$(CH_3CO)_2O + C_6H_6 \rightarrow C_6H_5COCH_3 + CH_3COOH$ ***OR*** $(CH_3CO)_2O) +$   $+ CH_3COOH$	1	Correct equation scores 1 – contrast with 4(b)(i) Not allow molecular formula for ethanoic anhydride or ethanoic acid.

Question	Marking Guidance	Mark	Comments
5(a)(i)	2-hydroxypropanoic acid ***OR*** 2-hydroxypropan(-1-)oic acid	1	Do not penalise different or missing punctuation or extra spaces. Spelling must be exact and order of letters and numbers as here. Can ignore -1- before –oic, but penalise any other numbers here.
5(a)(ii)	$C_{12}H_{22}O_{11} + H_2O \rightarrow 4CH_3CH(OH)COOH$ ***OR*** $C_{12}H_{22}O_{11} + H_2O \rightarrow 2CH_3CH(OH)COOH + C_6H_{12}O_6$	1	Allow $4C_3H_6O_3$ Allow $2C_3H_6O_3$
5(b)(i)	Nucleophilic addition	1	
		4	• M1 lp and minus must be on C • M1 and M4 include lone pair and curly arrow. • M2 not allowed independent of M1, but allow following some attempt at attack on carbonyl C • allow M1 for correct attack on C+ • + rather than δ+ on C=O loses M2 • M3 is for correct structure including minus sign but lone pair is part of M4 • Allow arrow in M4 to H of H-CN with arrow forming cyanide ion.
5(b)(ii)	Equal mixture of enantiomers / (optical) isomers	1	
5(b)(iii)	(Plane) polarized light	1	If missing no further mark.
	(Polarised light) rotated by single enantiomer but unaffected by racemate	1	Both needed; not allow bend, twist etc.

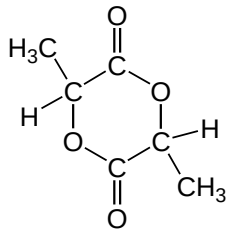
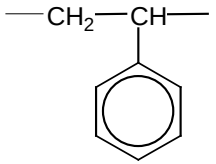
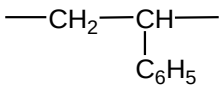
5(c)(i)	$CH_3CH(OH)COOH + NaOH \rightarrow CH_3CH(OH)COONa + H_2O$ ***OR*** $CH_3CH(OH)COOH + OH^- \rightarrow CH_3CH(OH)COO^- + H_2O$	1	Not ambiguous mol formulae for product - must show COONa or CO_2Na or COO^- or CO_2^-

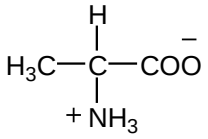
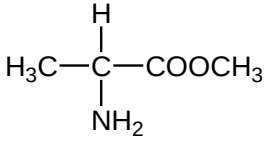
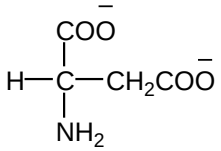
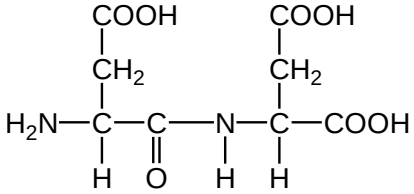
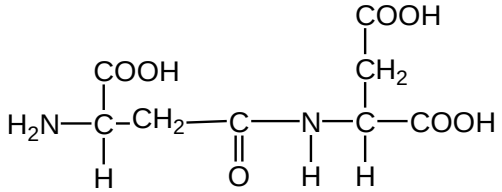
5(c)(ii)	$[H^+] = K_a$ ***OR*** $pH = pK_a$	1	
	pH = 3.86	1	Allow more than 2 decimal places but not fewer.

5(c)(iii)	M1	buffer	1	Ignore acidic but penalise alkaline or basic.
	Any two out of the three marks M2 , M3 & M4			
	M2	Large lactate concentration in buffer ***OR*** sodium lactate completely ionised	Max 2	
	M3	added acid reacts with/is removed by lactate ion or A^- or sodium lactate or salt ***OR*** equation $H^+ + A^- \rightarrow HA$		Ignore reaction of H^+ with OH^- Ignore reference to equilibrium unless it is shown.
	M4	ratio $[HA]/[A^-]$ stays almost constant		Ignore H^+ or pH remains constant.

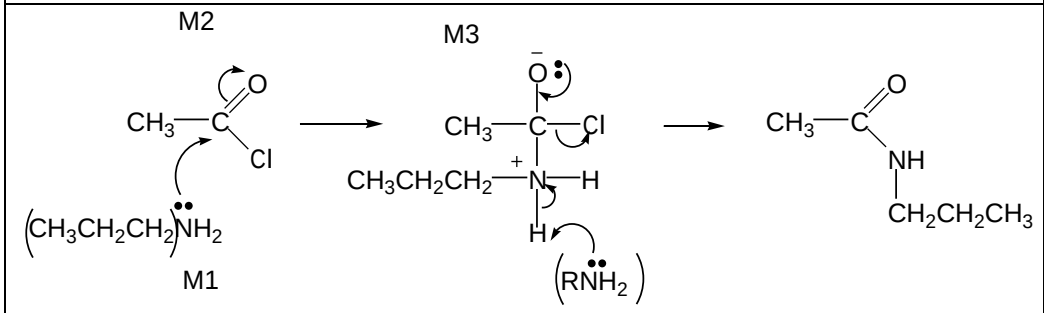
5(d)(i)	 ***OR*** 	No marks if ester link missing Correct ester link allow —COO— All rest correct with trailing bonds	1 1	**NB Correct answer scores 2** Ignore *n* here (compare with 5(d)(iv). Ignore brackets. If OH or COOH on either or both ends, lose one, ie dimer scores 1 If more than two repeating units, lose 1

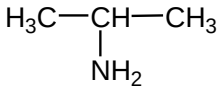
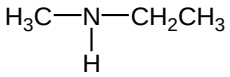
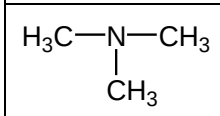
5(d)(ii)	(Poly)ester ie allow ester	1	Not terylene. Ignore spaces and brackets in answer.

5(d)(iii)		1	Allow any <u>cyclic $C_6H_8O_4$</u>
5(d)(iv)	 ***OR*** 	1	Penalise *n* here (compare with 5(d)(i) Ignore brackets. Not allow Ph for phenyl.
5(d)(v)	In landfill, no air or UV, to assist decay ***OR*** not enough water or moisture (to hydrolyse polyester)	1	Allow landfill has/contains: no or few bacteria / micro-organisms / enzymes compared with compost heap ***OR*** less oxygen ***OR*** <u>lower</u> temperature.

Question	Marking Guidance	Mark	Comments
6(a)		1	Allow $-NH_3^+$ and $^+NH_3-$
6(b)		1	Allow protonated form, i.e. $-NH_3^+$ or $^+NH_3-$
6(c)		1	Allow $-CO_2^-$
6(d)		1	Allow zwitterion with any COO^- Allow use of "wrong" COOH 

Question	Marking Guidance	Mark	Comments
7(a)(i)	$CDCl_3$ or CD_2Cl_2 or C_6D_6 or CCl_4	1	Not D_2O Allow CD_3Cl
7(a)(ii)	4 or four	1	
7(a)(iii)	Triplet or 3 or three	1	
7(a)(iv)	1,4-dichloro-2,2-dimethylbutane	1	Do not penalise different or missing punctuation or extra spaces. Spelling must be exact and order of letters and numbers as here.
7(b)(i)	3 or three	1	
7(b)(ii)	190-220 (cm^{-1})	1	Allow a single number within the range. ***OR*** a smaller range entirely within this range.
7(b)(iii)	hexan**e**-2,5-dione	1	Do not penalise different or missing punctuation or extra spaces. Spelling must be exact and order of letters and numbers as here. NB so must have middle e

Question	Marking Guidance	Mark	Comments
8(a)	(nucleophilic) addition-elimination	1	
	 M4 for 3 arrows and lp Allow wrong amine in M1 but penalise in M3 Allow C_3H_7 in M3 Minus sign on NH_3 loses M1 (but not M4 if NH_3 also shown here)	4	• Allow attack by **:**$NH_2CH_2CH_2CH_3$ • M2 not allowed independent of M1, but allow M1 for correct attack on C+ • + rather than δ+ on C=O loses M2 • If Cl lost with C=O breaking, max1 for M1 • M3 for correct structure <u>with charges</u> but lone pair on O is part of M4 • 3 arrows in M4 can be shown in two separate steps. • If M3 drawn twice, mark first answer eg ignore missing + if missed off second structure • Only allow M4 after correct / very close M3 • For M4, ignore RNH_2 removing H^+ but lose M4 for Cl^- removing H^+ in mechanism, • but ignore HCl shown as a product.
	<u>N-propylethanamide</u> must be this name even if wrong amine used	1	NOT N-propylethaneamide

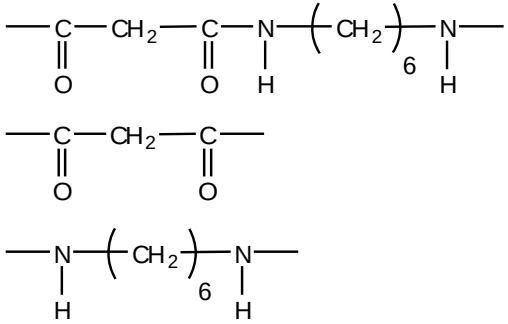
8(b)(i)	 Primary	Not allow ambiguous $C_3H_7NH_2$ BEWARE No mark for the original amine $CH_3CH_2CH_2NH_2$	1	Label and structure must both be correct for each type to score the mark. Penalize wrong number of carbons but otherwise correct, first time only.
	 secondary	Allow C_2H_5	1	
	 tertiary		1	

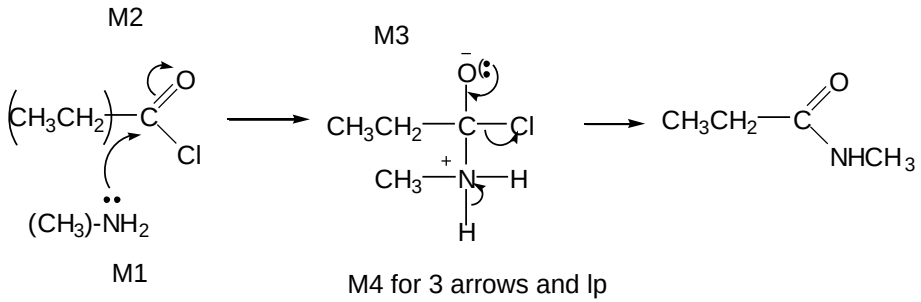
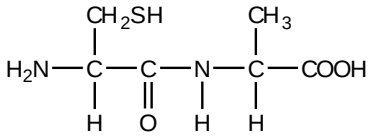
8(b)(ii)	Absorption at <u>3300-3500</u> (cm^{-1}) in spectrum	1	Allow trough, peak, spike. Ignore absorption at 750 – 1100 for C—C bond in secondary - this is within fingerprint region. Allow any number in this range. If range missing, no further marks. If range linked to tertiary, no further marks.
	N—H (bond) (only) present in secondary amine or not present in tertiary amine ***OR*** This peak or N—H absorption (only) present in spectrum of secondary amine or not present in spectrum of tertiary amine	1	

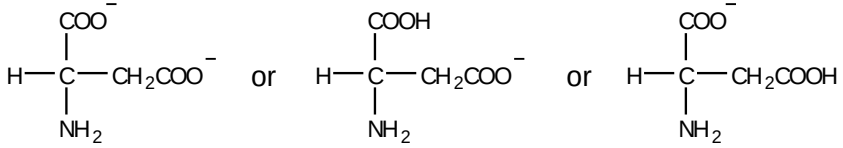
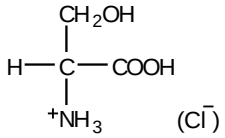
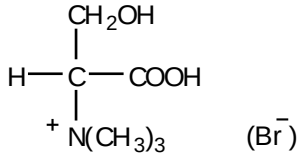
8(c)(i)	M1	Route **A** : stage 1	KCN		1	Apply list principle for extra reagents or catalysts NOT HCN NOT KCN/acid Not KCN/HCN
	M2		Aqueous or ethanolic		1	M2 only scores after correct M1 ignore warm; acid here loses M1 & M2
	M3	Route **A** Intermediate	CH_3CH_2CN or propanenitrile Name alone must be exactly correct to gain M1 but mark on if name close correct formula gains M1 (ignore name if close) contradiction of name and formula loses mark		1	If M3 intermediate wrong, max 2 for M1 & M2 ie no mark for stage 2 But if M3 intermediate close, eg "nitrile" or wrong nitrile, can award marks in stage 2 If stage 1 correct and intermediate is missing, can award marks in stage 2 stage 1 wrong & intermediate missing, no marks.
	M4	Route **A** : stage 2	H_2 H loses M4 but mark on	$LiAlH_4$	1	Apply list principle for extra reagents or catalysts. M5 only scores after correct M4 Not $NaBH_4$ not Sn or Fe / HCl Allow (dil) acid after but not with $LiAlH_4$ Penalise conc acid.
	M5		Ni or Pt or Pd	ether	1	
	M6	Route **B**	NH_3		1	With acid loses M6 & M7 Apply list principle for extra reagents or catalysts.
	M7		Excess NH_3		1	Ignore conc, ignore high P, ignore solvent.

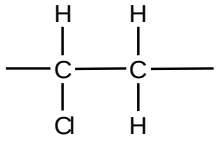
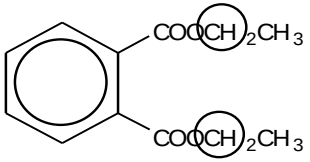
8(c)(ii)	Route **A** disadv	Toxic /poisonous KCN or cyanide or CN^- or HCN	Expensive $LiAlH_4$ Ignore acidified	1	Allow H_2 flammable/explosive etc. Not just dangerous. Ignore time reasons.
		OR lower <u>yield</u> because 2 steps			
	Route **B** disadv	Further reaction/substitution likely		1	Allow impure product.

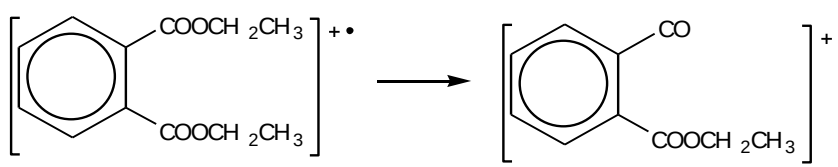
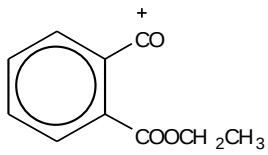
Question		Marking Guidance	Mark	Comments
9(a)	M1	Lone pair on N labelled b more available / more able to be donated than lone pair on N labelled *a*	1	Ignore N(b) more readily accepts protons. Ignore N(b) is stronger base.
	M2	lp or electrons or electron density on N labelled *a:* delocalized into (benzene) ring	1	QoL
	M3	lp or electrons or electron density on N labelled *b:* methyl/alkyl groups electron releasing or donating or (positive) inductive effect or push electrons or electron density	1	QoL
9(b)		$C_{19}H_{24}N_2$	1	Any order.
		11	1	

Question	Marking Guidance	Mark	Comments
10(a)(i)		1 1	Allow –CONH- or - COHN - Mark two halves separately lose 1 each for missing trailing bonds at one or both ends or error in peptide link or either or both of H or OH on ends Not allow $-(C_6H_{12})-$ Ignore *n*
10(a)(ii)	**M1** in polyamides - H bonding **M2** in polyalkenes - van der Waals forces **M3** Stronger forces (of attraction) in polyamides Or H bonding is stronger (must be a comparison of correct forces to score M3)	1 1 1	 Penalise forces between atoms or van der Waals bonds Do not award if refer to stronger bonds

10(b)(i)	(nucleophilic) addition elimination  M4 for 3 arrows and lp Not allow N–H_2	1 4	Minus sign on NH_2 loses M1 M2 not allowed independent of M1, but allow M1 for correct attack on C+ + rather than δ+ on C=O loses M2 If Cl lost with C=O breaking, max 1 for M1 M3 for correct structure <u>with charges</u> but lp on O is part of M4 only allow M4 after correct/ very close M3 For M4, ignore NH_3 removing H^+ but lose M4 for Cl^- removing H^+ in mechanism, but ignore HCl as a product
10(b)(ii)	<u>N-methylpropanamide</u>	1	Not N-methylpropaneamide
10(c)	 	1	Allow –CONH- or - COHN -
10(d)(i)	<u>2-amino-3-hydroxypropanoic acid</u>	1	

10(d)(ii)	 or or Must be salts of aspartic acid	1	allow $-CO_2^-$ allow NH_2-
10(d)(iii)	Penalise use of aspartic acid once in d(iii) and d(iv) 	1	allow $-CO_2H$ allow $^+NH_3-$ don't penalize position of + on NH_3
10(d)(iv)	Penalise use of aspartic acid once in d(iii) and d(iv) 	1	allow $-CO_2^-$ must show C-N bond don't penalize position of + on $N(CH_3)_3$

Question	Marking Guidance	Mark	Comments
11(a)	Benzene-1,2-dicarboxylic acid	1	Allow 1,2-benzenedicarboxylic acid
11(b)		1	Must show all bonds including trailing bonds Ignore *n*
11(c)(i)	2 C_2H_5OH H_2O	1 1	*NB Two ethanols* *but only one water*
11(c)(ii)	6 or six	1	
11(c)(iii)		1	Ignore overlap with O to the left or H to the right, but must only include this one carbon. either or allow both (as they are identical)

11(d)	 $\bullet OCH_2CH_3$ $[DEP]^{+\bullet}$ OR $[C_{12}H_{14}O_4]^{+\bullet} \rightarrow [C_{10}H_9O_3]^{+} + [C_2H_5O]^{\bullet}$	1 LHS 1 RHS	Allow + on C or O in  Dot must be on O in radical
11(e)(i)	Rate = k[DEP]	1	Must have brackets but can be ( )
11(e)(ii)	Any **two** of • experiment repeated/continued <u>over a long period</u> • repeated by independent body/other scientists/avoiding bias • investigate breakdown products • results made public	2 Max	Not just repetition Ignore animal testing