



Mark Scheme (Results)

June 2024

Pearson Edexcel International Advanced Level
In Chemistry (WCH14) Paper 01
Rates, Equilibria and Further Organic Chemistry

Section A

Question Number	Answer	Mark
1(a)	The only correct answer is A (colorimetry) <i>B is not correct because there is no change in mass</i> <i>C is not correct because titration is not a continuous monitoring method</i> <i>D is not correct because no gas is produced</i>	1

Question Number	Answer	Mark
1(b)	The only correct answer is D ($\text{dm}^3 \text{mol}^{-3} \text{s}^{-1}$) <i>A is not correct because these are the units of rate</i> <i>B is not correct because these are the units of the rate constant for a second order reaction</i> <i>C is not correct because these are the units of the rate constant for a third order reaction</i>	1

Question Number	Answer	Mark
1(c)	The only correct answer is D (1/16) <i>A is not correct because the rate would change by this factor for an overall first order reaction</i> <i>B is not correct because the rate would change by this factor for an overall second order reaction</i> <i>C is not correct because the rate would change by this factor for an overall third order reaction</i>	1

Question Number	Answer	Mark
1(d)	The only correct answer is C (Step 3) <i>A is not correct because 1 mol of Br^- and 2 mol of H^+ are also involved up to and including the rate-determining step</i> <i>B is not correct because 1 mol of Br^- is also involved up to and including the rate-determining step</i> <i>D is not correct because 1 mol of Br_2O_2 is not involved in the rate-determining step</i>	1

Question Number	Answer	Mark
2	The only correct answer is B (AgBr) <i>A is not correct because the difference between the lattice energies is not as great as for AgBr</i> <i>C is not correct because the difference between the lattice energies is not as great as for AgBr</i> <i>D is not correct because the difference between the lattice energies is not as great as for AgBr</i>	1

Question Number	Answer	Mark
3(a)	The only correct answer is C (the enthalpy change of hydration of a lead(II) ion is more exothermic than that of a nitrate ion) <i>A is not correct because this is the lattice energy of lead(II) nitrate</i> <i>B is not correct because the enthalpy change of solution of lead(II) nitrate is endothermic</i> <i>D is not correct because the entropy change of the surroundings is negative (as the enthalpy change is positive)</i>	1

Question Number	Answer	Mark
3(b)	The only correct answer is D (–314) <i>A is not correct because the wrong sign has been used for the enthalpy change of hydration of lead(II) ions and this is for 2 mol of nitrate ions</i> <i>B is not correct because the wrong sign has been used for the enthalpy change of hydration of lead(II) ions</i> <i>C is not correct because this is the enthalpy change for hydrating 2 mol of nitrate ions</i>	1

Question Number	Answer	Mark
4a)	The only correct answer is C (32) <i>A is not correct because 6 mol of unreacted N₂ and 18 mol of unreacted H₂ are also present</i> <i>B is not correct because the reaction is an equilibrium and does not go to completion</i> <i>D is not correct because 4 mol of N₂ and 12 mol of H₂ have reacted</i>	1

Question Number	Answer	Mark
4(b)	$\frac{p(\text{NH}_3)^2}{p(\text{N}_2) \times p(\text{H}_2)^3}$ The only correct answer is C <i>A is not correct because the reactant partial pressures should be multiplied, and the expression should be inverted</i> <i>B is not correct because the reactant partial pressures should be multiplied</i> <i>D is not correct because the expression should be inverted</i>	1

Question Number	Answer	Mark
4(c)	The only correct answer is A (decreasing the temperature) <i>B is not correct because only temperature affects the value of K_p</i> <i>C is not correct because only temperature affects the value of K_p</i> <i>D is not correct because only temperature affects the value of K_p</i>	1

Question Number	Answer	Mark
5	The only correct answer is A (the value of K is less than 1) <i>B is not correct because this would give a positive total entropy change</i> <i>C is not correct because the value of K cannot be negative</i> <i>D is not correct because the position of equilibrium would lie to the left</i>	1

Question Number	Answer	Mark
6	The only correct answer is D (5.4) <i>A is not correct because this is the pH of 1 mol dm⁻³ CH₃COOH</i> <i>B is not correct because this is the pH when the ratio is inverted</i> <i>C is not correct because this is the pH when the concentrations of CH₃COOH and CH₃COONa are equal</i>	1

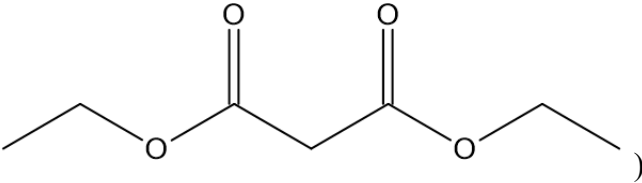
Question Number	Answer	Mark
7	The only correct answer is B ($\text{HCO}_3^- + \text{H}^+ \rightarrow \text{H}_2\text{CO}_3$) <i>A is not correct because this reaction provides buffer action when the pH is raised</i> <i>C is not correct because HCO_3^- does not dissociate when the pH is reduced</i> <i>D is not correct because CO_3^{2-} is not present at significant concentrations in blood and in cells</i>	1

Question Number	Answer	Mark
8	The only correct answer is C (6) <i>A is not correct because there are 6 chiral centres</i> <i>B is not correct because there are 6 chiral centres</i> <i>D is not correct because there are 6 chiral centres</i>	1

Question Number	Answer	Mark
9	The only correct answer is A (the mechanism involves a carbocation intermediate) <i>B is not correct because the mechanism is $\text{S}_{\text{N}}1$</i> <i>C is not correct because primary halogenoalkanes do not react by $\text{S}_{\text{N}}1$</i> <i>D is not correct because the main nucleophile is OH^-</i>	1

Question Number	Answer	Mark
10	The only correct answer is B (a racemic mixture is formed) <i>A is not correct because CN^- acts as a nucleophile</i> <i>C is not correct because the product is not optically active</i> <i>D is not correct because the product is 2-hydroxy-2-methylpropanenitrile</i>	1

Question Number	Answer	Mark
11	The only correct answer is B (Only 1 and 2) <i>A is not correct because acyl chlorides do not react with tertiary amines</i> <i>C is not correct because acyl chlorides also form amides with primary amines and do not react with tertiary amines</i> <i>D is not correct because acyl chlorides also form amides with secondary amines</i>	1

Question Number	Answer	Mark
12	The only correct answer is A () <i>B is not correct because the acid hydrolysis of this ester forms ethanoic acid and propan-1-ol</i> <i>C is not correct because the acid hydrolysis of this ester forms propanoic acid and ethanol</i> <i>D is not correct because the acid hydrolysis of this ester forms propanoic acid and ethane-1,2-diol</i>	1

Question Number	Answer	Mark
13	The only correct answer is B ($\text{CH}_3\text{COCH}_2\text{CH}_3$) <i>A is not correct because CH_3COCH_3 has only two peaks in its ^{13}C NMR spectrum</i> <i>C is not correct because $\text{CH}_3\text{CH}_2\text{COCH}_2\text{CH}_3$ has only three peaks in its ^{13}C NMR spectrum</i> <i>D is not correct because $\text{CH}_3\text{COCH}_2\text{CH}_2\text{COCH}_3$ has only three peaks in its ^{13}C NMR spectrum</i>	1

Question Number	Answer	Mark
14	The only correct answer is D () <i>A is not correct because the singlet would have a relative peak area of 3H and a chemical shift in the range for $H-C-C=O$</i> <i>B is not correct because the chemical shifts of the quartet and singlet would be in the ranges for $H-C-C=O$ and for $H-C-O-$ respectively, and the singlet would have a relative peak area of 3H</i> <i>C is not correct because the quartet would have a chemical shift in the range for $H-C-C=O$</i>	1

Total for Section A = 20 marks

Section B

Question Number	Answer	Additional Guidance	Mark
15(a)(i)	An answer that makes reference to the following points: - any one or two types of bonding (1) - third type of bonding (1)	Ignore giant throughout - covalent (in SiO₂) Ignore macromolecular Do not award simple/molecular Do not award dative/coordinate - metallic (in Mg) Allow metal - ionic (in MgO) Allow ion	2

Question Number	Answer	Additional Guidance	Mark
15(a)(ii)	An answer that makes reference to the following points: (as) moles (decreases) from 5 to 3 (1) - decreases in disorder (1)	Accept reverse arguments Allow particles or molecules for moles Ignore any reference to standard entropies of reactants and products Allow just number of moles decreases Do not award incorrect numbers of moles Do not award incorrect explanation relating to states Accept fewer ways of distributing energy (in products) Accept fewer ways of arranging moles (in products) Ignore just less arranged for less disordered Ignore randomness for disorder Ignore just decreases in entropy	2

Question Number	Answer	Additional Guidance	Mark
15(a)(iii)	- expression for $\Delta S_{\text{surroundings}}$ (1) - value of $\Delta S_{\text{surroundings}}$ (1)	<u>Example of calculation:</u> $\Delta S_{\text{surroundings}} = \frac{-\Delta H}{T} = \frac{-(-370 \times 10^3)}{(23.0 + 273)}$ Allow just $-(-370)/-(-370000)/370/370000$ divided by any temperature in K or °C (+)1250 (J K⁻¹ mol⁻¹) Allow (+)1.25 kJ K⁻¹ mol⁻¹ Ignore SF except 1 SF Do not award any other answer Correct answer with some working scores (2) If neither mark awarded, -1250 (J K⁻¹ mol⁻¹) / -1.25 kJ K⁻¹ mol⁻¹ scores (1)	2

Question Number	Answer	Additional Guidance	Mark
15(a)(iv)	- expression for ΔS_{total} (1) - calculation of ΔS_{total} to 2, 3 or 4 SF (1)	<u>Example of calculation:</u> $\Delta S_{\text{total}} = \Delta S_{\text{system}} + \Delta S_{\text{surroundings}} = -43.8 + \text{answer to (a)(iii)}$ where answer to (a)(iii) is 1250 (J K⁻¹ mol⁻¹) $\Delta S_{\text{total}} = (+)1206 / 1210 / 1200$ (J K⁻¹ mol⁻¹) Allow (+)1.206 / 1.21 / 1.2 kJ K⁻¹ mol⁻¹ where answer to (a)(iii) is -1250 (J K⁻¹ mol⁻¹) $\Delta S_{\text{total}} = -1294 / -1290 / -1300$ (J K⁻¹ mol⁻¹) Allow $-1.294 / -1.29 / -1.3$ kJ K⁻¹ mol⁻¹ TE on transcription error of -48.3 for -43.8 No TE on incorrect expression from M1	2

Question Number	Answer	Additional Guidance	Mark
15(a)(v)	An answer that makes reference to the following point: • bonding / electrostatic attraction (in SiO₂) is strong or a large amount of energy is needed to break bond(s) (in SiO₂)	Ignore SiO₂/reaction/reactants is/are kinetically stable Ignore reactions between solids are slow Allow Mg/reactants for SiO₂ Allow a large amount of energy is needed to break covalent / metallic bond(s) Do not award any reference to the breaking of ionic bonds / intermolecular forces	1

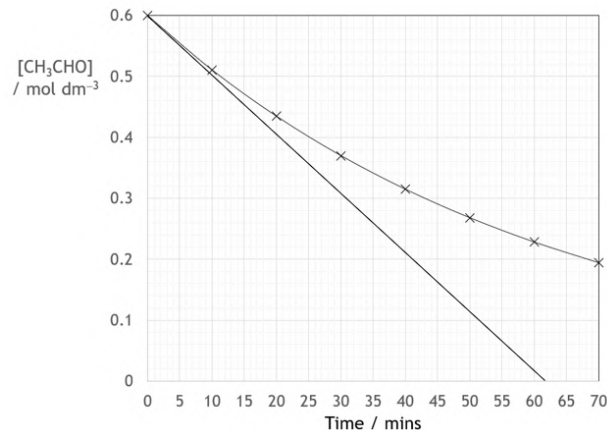
Question Number	Answer	Additional Guidance	Mark
15(b)(i)	An answer that makes reference to the following point: • correct equation	<u>Examples of equation:</u> $\text{Mg}_2\text{Si} + 4\text{HCl} \rightarrow \text{SiH}_4 + 2\text{MgCl}_2$ Allow ionic equations: $\text{Mg}_2\text{Si} + 4\text{H}^+ \rightarrow \text{SiH}_4 + 2\text{Mg}^{2+}$ $\text{Mg}_2\text{Si} + 4\text{H}^+ + 4\text{Cl}^- \rightarrow \text{SiH}_4 + 2\text{Mg}^{2+} + 4\text{Cl}^-$ Allow multiples Allow reversible arrow Ignore state symbols even if incorrect	1

Question Number	Answer	Additional Guidance	Mark
15(b)(ii)	An answer that makes reference to the following points: • name of shape (1) • bond angle (1)	tetrahedral Allow tetrahedron 109.5^(o) Allow 109^(o) No TE on incorrect shape	2

Question Number	Answer	Additional Guidance	Mark
15(c)(i)	• use of $\Delta S_{\text{system}} = \Sigma S^{\circ}_{\text{products}} - \Sigma S^{\circ}_{\text{reactants}}$ (1) • calculation of ΔS_{system} (1)	<u>Example of calculation:</u> $\Delta S_{\text{system}} = (41.8 + 2 \times 69.9) - (204.5 + 2 \times 205.0)$ Allow just $\Delta S_{\text{system}} = \Sigma S^{\circ}_{\text{products}} - \Sigma S^{\circ}_{\text{reactants}}$ –432.9 TE on $\Delta S_{\text{system}} = \Sigma S^{\circ}_{\text{reactants}} - \Sigma S^{\circ}_{\text{products}}$ TE on incorrect numbers of moles and transcription errors Ignore units, even if incorrect Ignore SF except 1SF Correct answer with some working scores (2) +432.9 / –297.8 / +297.8 scores (1)	2

Question Number	Answer	Additional Guidance	Mark
15(c)(ii)	An answer that makes reference to the following point: O–H bonds are strong(er than Si–H bonds)	Accept reverse arguments Ignore $\Delta S_{\text{surroundings}}$ is (very) positive Ignore reaction is (highly) exothermic / ΔH is (very) negative Allow Si–O bonds are strong(er than Si–H bonds) Allow (covalent) bonding in H_2O / SiO_2 / products is strong Allow formation of product bonds releases more energy (than is required to break reactant bonds) Allow more energy required to break product bonds (than reactant bonds) Ignore any reference to O=O bond strength (which is greater than O–H / Si–O) Do not award intermolecular forces for bonds Do not award $\Delta S_{\text{surroundings}}$ is negative Do not award reaction is endothermic / ΔH is positive	1

(Total for Question 15 = 15 marks)

Question Number	Answer	Additional Guidance	Mark
16(a)(i)	- tangent drawn at $t = 0$ (1) - calculation of gradient of tangent (1) - calculation of rate in $\text{mol dm}^{-3} \text{s}^{-1}$ (1)	<u>Example of calculation:</u>  gradient = $(-)0.6 \div 62 = (-)0.0096774 / (-)9.6774 \times 10^{-3}$ Allow value in range of 0.0086 to 0.011 TE on any tangent Ignore sign and units Ignore SF except 1SF rate = $(-)0.0096774 \div 60$ $= (-)0.00016129 / (-)1.6129 \times 10^{-4} (\text{mol dm}^{-3} \text{s}^{-1})$ Allow value in range of 0.00014 to 0.00019 / 1.4×10^{-4} to 1.9×10^{-4} TE on any concentration $\div$ time value from M2 Ignore sign Ignore SF except 1SF Correct answer with tangent drawn at $t = 0$ scores (3) Correct answer with no tangent at $t = 0$ scores (2)	3

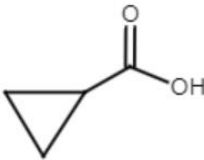
Question Number	Answer	Additional Guidance	Mark
16(a)(ii)	An answer that makes reference to the following points: working to show determination of two (or more) half-life values	(1) eg, time for $[\text{CH}_3\text{CHO}]$ to fall from 0.6 to 0.3 = $43 - 0 = 43$ eg, time for $[\text{CH}_3\text{CHO}]$ to fall from 0.4 to 0.2 = $68 - 25 = 43$ Allow half-lives in range of 42 to 44 (mins) Allow half-lives in range of 2520 to 2640 (s) Accept working from either a statement in words or from working on the graph. Ignore $86 - 43 = 43$ (mins) Ignore any attempt to find half-lives by extrapolation of the graph beyond 70 mins Standalone mark Do not award any other rate equation Do not award omission of k	2
	(constant half-life so first order and rate =) $k[\text{CH}_3\text{CHO}]^{(1)}$	(1)	

Question Number	Answer	Additional Guidance	Mark
16(b)	- calculation of gradient (1) - use of $E_a = -\text{gradient} \times R$ (1) - calculation of E_a (1) - calculated answer to 3SF and units (1)	<u>Example of calculation:</u> gradient = $\frac{(-8.2 - 9.4)}{(0.0010 - 0.000588)} = -42718 \text{ (K)}$ Allow value in range of -40500 to -44500 Ignore units Ignore SF except 1SF Do not award omission of negative sign $E_a = -(-42718) \times 8.31$ $= (+)354990$ TE on M1 TE on M2 for omission of negative sign only Accept use of 8.314 for 8.31 Ignore SF except 1SF Ignore units in M3 $(+)355000 \text{ J mol}^{-1}$ OR $(+)355 \text{ kJ mol}^{-1}$ TE on M3 Calculated final answer to 3SF with correct units in allowed range scores (4) gradient of -40500 gives $337000 \text{ J mol}^{-1}$ / 337 kJ mol^{-1} gradient of -44500 gives $370000 \text{ J mol}^{-1}$ / 370 kJ mol^{-1}	4

(Total for Question 16 = 9 marks)

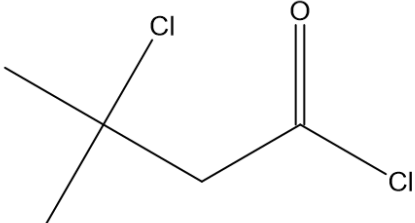
Question Number	Answer	Additional Guidance	Mark
17(a)(i)	An answer that makes reference to the following points: • but-3-enoic acid (for first isomer) (1) • 2-methylpropenoic acid (for second isomer) (1)	Ignore missing or incorrect hyphens, spaces or commas and use of capitals Accept 3-butenic acid Allow buten-3-oic acid Allow but-3-en-1-oic acid / 3-buten-1-oic acid Allow “ene” for “en” Do not award “butan” or “butyl” for “but” Accept 2-methylprop-2-enoic acid Accept 2-methyl-2-propenoic acid Allow 2-methylpropen-2-oic acid Allow “ene” for “en” Do not award “propan” or “propyl” for “prop”	2

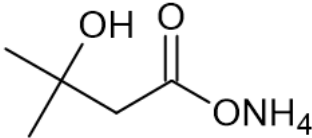
Question Number	Answer	Additional Guidance	Mark
17(a)(ii)	An answer that makes reference to the following points: • correct structure of <i>Z</i>-but-2-enoic acid (1) • correct structure of <i>E</i>-but-2-enoic acid (1)	<u>Example of structures:</u>  Allow displayed formula, or any correct combination of formulae Ignore bond lengths and bond angles	2

Question Number	Answer	Additional Guidance	Mark
17(a)(iii)	An answer that makes reference to the following point: correct structure of cyclopropanecarboxylic acid	<u>Example of structure:</u>  Allow displayed or structural formula, or any correct combination of formulae Ignore bond lengths and bond angles	1

Question Number	Answer	Additional Guidance	Mark
17(b)(i)	An answer that makes reference to the following points: $\text{K}_2\text{Cr}_2\text{O}_7$ / potassium dichromate(VI) and H_2SO_4 / sulfuric acid and (heat under) reflux	If name and formula given both must be correct Accept sodium salts Allow dichromate(VI) ions) / $\text{Cr}_2\text{O}_7^{2-}$ for $\text{K}_2\text{Cr}_2\text{O}_7$ Allow acidified / H^+ Ignore concentration of acid Do not award use of HCl Do not award mention of acid as catalyst Do not award incorrect oxidation states Ignore distillation	1

Question Number	Answer	Additional Guidance	Mark
17(b)(ii)	An answer that makes reference to the following points: - H₂O and HCl reactants - NH₄Cl product and organic species and balanced	<u>Example of equation:</u> $(\text{CH}_3)_2\text{C}(\text{OH})\text{CH}_2\text{CN} + 2\text{H}_2\text{O} + \text{HCl} \rightarrow (\text{CH}_3)_2\text{C}(\text{OH})\text{CH}_2\text{COOH} + \text{NH}_4\text{Cl}$ (1) Allow H⁺ for HCl Allow H₃O⁺ for H₂O and HCl Allow H₂O in equation and HCl shown above arrow Ignore just HCl(aq) (1) M2 dependent on M1 Allow NH₄⁺ for NH₄Cl where H⁺ used for HCl Allow multiples Allow structural, displayed, skeletal or molecular formulae for organic species Ignore connectivity in organic species Ignore state symbols, even if incorrect $(\text{CH}_3)_2\text{C}(\text{OH})\text{CH}_2\text{CN} + 2\text{H}_2\text{O} + \text{H}^+ \rightarrow (\text{CH}_3)_2\text{C}(\text{OH})\text{CH}_2\text{COOH} + \text{NH}_4^+ \text{ scores (2)}$	2

Question Number	Answer	Additional Guidance	Mark
17(b)(iii)	An answer that makes reference to the following points: • RCOOH group converted to RCOCl group • (CH₃)₂C(OH)CH₂R group converted to (CH₃)₂C(Cl)CH₂R	Allow displayed or structural formula, or any correct combination of formulae If more than one type of formula given all must be correct <u>Examples of structure:</u> (1) (CH₃)₂CClCH₂COCl scores (2) (1)  scores (2)	2

Question Number	Answer	Additional Guidance	Mark
17(b)(iv)	An answer that makes reference to the following point: • correct structure of ammonium salt	Allow displayed or structural formula, or any correct combination of formulae If more than one type of formula given all must be correct <u>Examples of structure:</u> $(\text{CH}_3)_2\text{C}(\text{OH})\text{CH}_2\text{COO}^{(-)}\text{NH}_4^{(+)}$  Allow $(\text{CH}_3)_2\text{C}(\text{OH})\text{CH}_2\text{COO}^{-}$ (+ NH_4^{+}) Do not award covalent O–NH₄ Do not award sodium/potassium salt	1

(Total for Question 17 = 11 marks)

Question Number	Answer	Additional Guidance	Mark
18(a)	An answer that makes reference to the following points: Formula of lithium tetrahydridoaluminate(III): - LiAlH₄ and Essential reaction conditions: (dry) ether Type of reaction: - reduction Name of organic product with propanal: - propan-1-ol Name of organic product with propanone: - propan-2-ol	Do not award any other answer (1) Allow anhydrous / no water Ignore any reference to heat / temperature Do not award any reference to aqueous / acid (1) Ignore redox Ignore (nucleophilic) addition (1) Allow 1-propanol Allow 1-hydroxypropane Ignore propanol / <i>n</i>-propanol / <i>n</i>-propyl alcohol Ignore primary alcohol (1) Allow 2-propanol Allow 2-hydroxypropane Ignore isopropanol / isopropyl alcohol / sec-propyl alcohol Ignore secondary alcohol Penalise structures for names in M3 and M4 once only	4

Question Number	Answer	Additional Guidance	Mark
18(b)	An answer that makes reference to the following points: - silver mirror with propanal (1) - no change with propanone (1)	Allow aldehyde for propanal Allow precipitate/coating for mirror Allow black/grey solid for silver mirror Allow ketone for propanone Allow any of the following for no change: no reaction / no observation / nothing / solution remains colourless / no silver mirror	2

Question Number	Answer	Additional Guidance	Mark
18(c)	An answer that makes reference to the following points: - CHI₃ product (1) - CH₃COONa product (1) - remaining species and balanced and state symbols (1)	<u>Examples of equation:</u> $\text{CH}_3\text{COCH}_3(\text{aq}) + 3\text{I}_2(\text{aq}) + 4\text{NaOH}(\text{aq}) \rightarrow \text{CH}_3\text{COO}^{(-)}\text{Na}^{(+)}(\text{aq}) + \text{CHI}_3(\text{s}) + 3\text{Na}^{(+)}\text{I}^{(-)}(\text{aq}) + 3\text{H}_2\text{O}(\text{l})$ $\text{CH}_3\text{COCH}_3(\text{aq}) + 3\text{I}_2(\text{aq}) + (4\text{Na}^{+}(\text{aq})) + 4\text{OH}^{-}(\text{aq}) \rightarrow \text{CH}_3\text{COO}^{-}(\text{aq}) + (\text{Na}^{+}(\text{aq})) + \text{CHI}_3(\text{s}) + (3\text{Na}^{+}(\text{aq})) + 3\text{I}^{-}(\text{aq}) + 3\text{H}_2\text{O}(\text{l})$ Accept CH₃COO⁻ Do not award CH₃COOH Do not award any other organic species Allow multiples Allow CH₃COCH₃(l) Allow H₂O(aq)	3

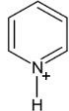
Question Number	Answer	Additional Guidance	Mark
18(d)	An answer that makes reference to the following points: • filter (to collect precipitate) • recrystallise • (measure) melting temperature (of derivatives) and compare to database / data book	(1) Allow collect (precipitate) using Buchner funnel Ignore any reference to colour of precipitate (1) Allow purify and crystallise Allow melting point for melting temperature Do not award boiling temperature (1) Allow known set of values for database / data book Ignore (record) IR / NMR / mass spectrum	3

Question Number	Answer	Additional Guidance	Mark
18(e)	An answer that makes reference to the following points: 8 curly arrows (4) 6 or 7 curly arrows (3) 4 or 5 curly arrows (2) 2 or 3 curly arrows (1)	<u>Example of mechanism:</u> A1 and A6 curly arrows must start from N lone pairs Do not award A1 curly arrow if incorrect C=O dipole Ignore incorrect C=O dipole for A2 curly arrow Ignore N–H dipole for A3/A8 curly arrows Do not award A3/A8 curly arrows from N–H bond to H Allow curly arrow A4 from negative charge on O⁻ Do not award A4/A5 curly arrows starting at H⁺ If more than 8 curly arrows shown, each incorrect arrow negates one correct arrow	4

(Total for Question 18 = 16 marks)

Total for Section B = 51 marks

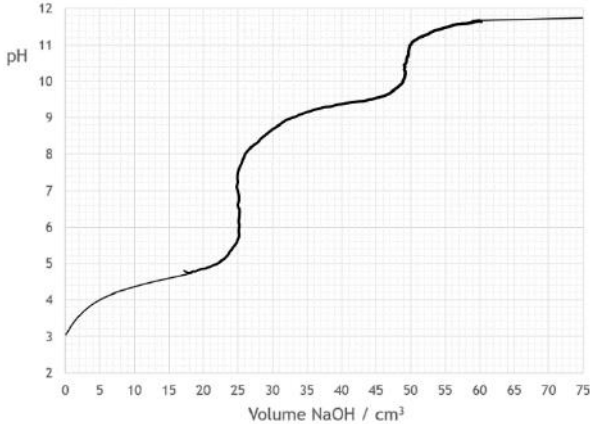
Question Number	Answer	Additional Guidance	Mark
19(a)(i)	$\text{C}_5\text{H}_5\text{NH}^+$ K_a: - calculation of inverse $\log(-5.25)$ to 2SF (1) CHCl_2COOH pK_a: - calculation of $-\log(4.5 \times 10^{-2})$ to 3SF (1)	<u>Example of calculation:</u> $(5.6234 \times 10^{-6}) = 5.6 \times 10^{-6}$ Do not award 6×10^{-6} $(1.3468) = 1.35$ Do not award 1.4 or 1.34 Penalise inconsistent SF once only Penalise incorrect rounding once only	2

Question Number	Answer	Additional Guidance	Mark
19(a)(ii)	An answer that makes reference to the following point: $(K_a =) \frac{[\text{H}^+][\text{C}_5\text{H}_5\text{N}]}{[\text{C}_5\text{H}_5\text{NH}^+]}$	Do not award C_6 for C_5 Do not award non-square brackets Allow $[\text{H}_3\text{O}^+]$ for $[\text{H}^+]$ Allow use of  for $\text{C}_5\text{H}_5\text{N}$ Do not award $\text{C}_5\text{H}_4\text{NH}$ for $\text{C}_5\text{H}_5\text{N}$ Do not award charged $\text{C}_5\text{H}_5\text{N}$, eg $\text{C}_5\text{H}_5\text{N}^-$ Allow use of  for $\text{C}_5\text{H}_5\text{NH}^+$ Allow $\text{C}_5\text{H}_6\text{N}^+$ for $\text{C}_5\text{H}_5\text{NH}^+$ Do not award omission of charge from $\text{C}_5\text{H}_5\text{NH}^+$	1

Question Number	Answer	Additional Guidance	Mark
19(a)(iii)	An answer that makes reference to the following points: • $\text{CH}_3\text{CH}_2\text{COOH}_2^+$ and HCOO^- (1) • HCOOH A1 and $\text{HCOO}^{(-)}$ B1 and $\text{CH}_3\text{CH}_2\text{COOH}$ B2 and $\text{CH}_3\text{CH}_2\text{COOH}_2^{(+)}$ A2 (1)	Allow COOH^- Allow A2 and B2 for A1 and B1 Allow B1 and A1 for B2 and A2 TE on M1 for $\text{HCOOH}_2^{(+)}$ and $\text{CH}_3\text{CH}_2\text{COO}^{(-)}$ only	2

Question Number	Answer	Additional Guidance	Mark																				
19(a)(iv)	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><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 and sustained lines of reasoning</th></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>	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		Number of marks awarded for structure and sustained lines 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	The mark for indicative content should be added to the mark for lines of reasoning. For example, an answer with five indicative marking points that is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning). If there are no linkages between points, the same five indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages). If there is any incorrect chemistry, deduct mark(s) from the reasoning. If no reasoning mark(s) awarded, do not deduct mark(s). Comment: Look for the indicative marking points first, then consider the mark for the structure of the answer and sustained line of reasoning.	6
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																						
	Number of marks awarded for structure and sustained lines 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 points: • IP1: use of $[H^+] = \sqrt{K_a \times [HA]}$ • IP2: use of $pH = -\log[H^+]$ • IP3: indication that $[HA]_{\text{equilibrium}}$ is lower than $[HA]_{\text{initial}}$ • IP4: (because) dissociation (of both acids) is significant • IP5: (calculated pH values lower than measured pH values because) $[HA]$ is overestimated in the calculations • IP6: (difference greatest for) CHCl_2COOH (as is) stronger acid or two Cl atoms in CHCl_2COOH are more electron withdrawing than one / stabilise anion more / weaken O–H bond more	If calculations shown, pH values are 2.0775 and 1.3239 Ignore $[H^+] = [A^-]$ assumption is not valid Ignore $[H^+] > [A^-]$ Do not award $[A^-] > [H^+]$ Allow dissociation is not negligible Allow dissociation occurs Do not award dissociation is negligible Do not award dissociation is complete Do not award $[H^+]$ overestimated in calculation due to dissociation of water Allow more dissociated for stronger Ignore strong acid for stronger acid Ignore CHCl_2COOH has larger K_a / smaller pK_a	
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Question Number	Answer	Additional Guidance	Mark
19(b)	An answer that makes reference to the following points: • vertical section at 25 cm³ and with height in the range of 1 to 4 pH units (1) • vertical section at 50 cm³ and with height greater than 0.4 pH units (1) • (buffered section with) pH 9.3 at 37.5 cm³ (1)	<u>Example of completed titration curve:</u>  Allow slight slope in range of 24 cm³ to 26 cm³ Allow any pH between 9.0 and 9.6 Allow reading of pH from midpoint volume between two vertical sections as TE on M1/M2	3

Question Number	Answer	Additional Guidance	Mark
19(c)	M1 and M2: - calculation of $[H^+]$ at both pH values or calculation of pOH at both pH values (1) - calculation of $[OH^-]$ at both pH values (1) M3, M4 and M5 (Method 1): - calculation of moles of NaOH in 50.0 cm³ at pH 12.43 (1) - calculation of volume of NaOH required at pH 12.00 (1) - volume of water required in cm³ (1) M3, M4 and M5 (Method 2): - expression for dilution (1) - calculation of volume of NaOH required at pH 12.00 (1) - volume of water required in cm³ (1)	<u>Example of calculation:</u> $[H^+] = 10^{-12.43} = 3.7154 \times 10^{-13}$; $[H^+] = 10^{-12.00} = 1 \times 10^{-12}$ or pOH = 14 – 12.43 = 1.57; pOH = 14 – 12.00 = 2.00 $[OH^-] = 1 \times 10^{-14} \div 3.7154 \times 10^{-13} = 10^{-1.57} = 0.026915$ $[OH^-] = 1 \times 10^{-14} \div 1 \times 10^{-12} = 10^{-2.00} = 0.01$ $0.026915 \times \frac{50.0}{1000} = 1.3458 \times 10^{-3}$ $1.3458 \times 10^{-3} \div 0.01 = 0.13458 \text{ dm}^3 = 134.58 \text{ cm}^3$ $134.58 - 50.0 = 84.58 / 84.6 / 85 \text{ (cm}^3\text{)}$ TE on M4 $c_1V_1 = c_2V_2$ $V_2 = \frac{c_1V_1}{c_2} = \frac{0.026915}{0.01} \times 50.0 = 134.58 \text{ cm}^3$ $134.58 - 50.0 = 84.58 / 84.6 / 85 \text{ (cm}^3\text{)}$	5

	M3, M4 and M5 (Method 3): - calculation of moles of NaOH in 50.0 cm³ at pH 12.43 (1) - calculation of moles of NaOH in 50.0 cm³ at pH 12.00 and difference in moles of NaOH (1) - calculation of volume of NaOH required (1) M3, M4 and M5 (Method 4): - difference in concentrations of NaOH (1) - difference in moles of NaOH (1) - calculation of volume of NaOH required (1) OTHER METHODS MAY BE POSSIBLE	$0.026915 \times \frac{50.0}{1000} = 1.3458 \times 10^{-3}$ $0.01 \times \frac{50.0}{1000} = 5 \times 10^{-4}$ and $1.3458 \times 10^{-3} - 5 \times 10^{-4} = 8.458 \times 10^{-4}$ $8.458 \times 10^{-4} \div 0.01 = 84.58 \text{ (cm}^3\text{)}$ $0.026915 - 0.01 = 0.016915$ $0.016915 \times \frac{50.0}{1000} = 8.458 \times 10^{-4}$ $8.458 \times 10^{-4} \div 0.01 = 84.58 \text{ (cm}^3\text{)}$ If no other marks awarded, calculation of [H⁺]/pOH and calculation of [OH⁻] at either pH scores (1)	
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(Total for Question 19 = 19 marks)

Total for Section C = 19 marks

Total for Paper = 90 marks