

Mark Scheme (Results) Summer 2014

IAL Chemistry (WCH04/01)
General Principles of Chemistry I

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Summer 2014

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General Marking Guidance

- All candidates must receive the same treatment. Examiners must mark the first candidate in exactly the same way as they mark the last.
- Mark schemes should be applied positively. Candidates must be rewarded for what they have shown they can do rather than penalised for omissions.
- Examiners should mark according to the mark scheme not according to their perception of where the grade boundaries may lie.
- There is no ceiling on achievement. All marks on the mark scheme should be used appropriately.
- All the marks on the mark scheme are designed to be awarded. Examiners should always award full marks if deserved, i.e. if the answer matches the mark scheme. Examiners should also be prepared to award zero marks if the candidate's response is not worthy of credit according to the mark scheme.
- Where some judgement is required, mark schemes will provide the principles by which marks will be awarded and exemplification may be limited.
- When examiners are in doubt regarding the application of the mark scheme to a candidate's response, the team leader must be consulted.
- Crossed out work should be marked UNLESS the candidate has replaced it with an alternative response.
- Mark schemes will indicate within the table where, and which strands of QWC, are being assessed. The strands are as follows:
 - i) ensure that text is legible and that spelling, punctuation and grammar are accurate so that meaning is clear
 - ii) select and use a form and style of writing appropriate to purpose and to complex subject matter
 - iii) organise information clearly and coherently, using specialist vocabulary when appropriate

Using the Mark Scheme

Examiners should look for qualities to reward rather than faults to penalise. This does NOT mean giving credit for incorrect or inadequate answers, but it does mean allowing candidates to be rewarded for answers showing correct application of principles and knowledge. Examiners should therefore read carefully and consider every response: even if it is not what is expected it may be worthy of credit.

The mark scheme gives examiners:

- an idea of the types of response expected
- how individual marks are to be awarded
- the total mark for each question
- examples of responses that should NOT receive credit.

/ means that the responses are alternatives and either answer should receive full credit.

() means that a phrase/word is not essential for the award of the mark, but helps the examiner to get the sense of the expected answer.

Phrases/words in **bold** indicate that the meaning of the phrase or the actual word is **essential** to the answer.

ecf/TE/cq (error carried forward) means that a wrong answer given in an earlier part of a question is used correctly in answer to a later part of the same question.

Candidates must make their meaning clear to the examiner to gain the mark. Make sure that the answer makes sense. Do not give credit for correct words/phrases which are put together in a meaningless manner. Answers must be in the correct context.

Quality of Written Communication

Questions which involve the writing of continuous prose will expect candidates to:

- write legibly, with accurate use of spelling, grammar and punctuation in order to make the meaning clear
- select and use a form and style of writing appropriate to purpose and to complex subject matter
- organise information clearly and coherently, using specialist vocabulary when appropriate.

Full marks will be awarded if the candidate has demonstrated the above abilities.

Questions where QWC is likely to be particularly important are indicated (QWC) in the mark scheme, but this does not preclude others.

Section A (multiple choice)

Question Number	Correct Answer	Reject	Mark
1	D		1

Question Number	Correct Answer	Reject	Mark
2	A		1

Question Number	Correct Answer	Reject	Mark
3	D		1

Question Number	Correct Answer	Reject	Mark
4	D		1

Question Number	Correct Answer	Reject	Mark
5	C		1

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

Question Number	Correct Answer	Reject	Mark
6 (b)	B		1

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

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

Question Number	Correct Answer	Reject	Mark
8	A		1

Question Number	Correct Answer	Reject	Mark
9	C		1

Question Number	Correct Answer	Reject	Mark
10	B		1

Question Number	Correct Answer	Reject	Mark
11	B		1

Question Number	Correct Answer	Reject	Mark
12	B		1

Question Number	Correct Answer	Reject	Mark
13	A		1

Question Number	Correct Answer	Reject	Mark
14	B		1

Question Number	Correct Answer	Reject	Mark
15 (a)	C		1

Question Number	Correct Answer	Reject	Mark
15(b)	A		1

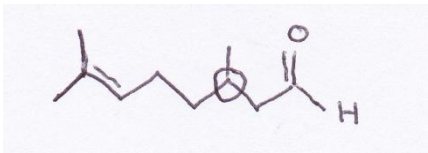
Question Number	Correct Answer	Reject	Mark
16	C		1

Question Number	Correct Answer	Reject	Mark
17	B		1

Total for Section A = 20 marks

Section B

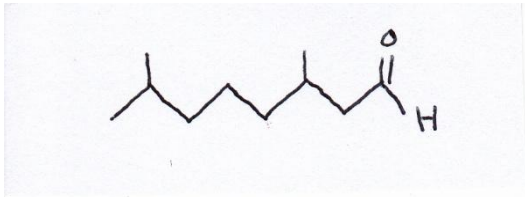
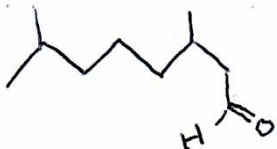
Question Number	Acceptable Answers	Reject	Mark
18(a)	$C_{10}H_{18}O$ ALLOW any order i.e. $C_{10} OH_{18} / H_{18} C_{10} O / H_{18} O C_{10} / OC_{10} H_{18} / OH_{18} C_{10}$ IGNORE $C_9H_{17}CHO$ and other structural formulae as working COMMENT Allow numbers not as subscripts e.g. $C_{10}H_{18}O$ Structural formula without correct molecular formula will not score.	superscripts	1

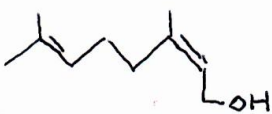
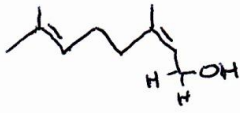
Question Number	Acceptable Answers	Reject	Mark
18(b)	 Circle as shown ALLOW * or any other clear indication of the correct carbon atom	more than one carbon atom indicated	1

Question Number	Acceptable Answers	Reject	Mark
18(c)(i)	Stand alone marks First mark restricted / barrier to rotation around/due to C=C/π bond ALLOW no/lack of/inhibits (free) rotation around/due to C=C/π bond (1) Second mark two different atoms/groups attached to each C in C=C /each C in C=C must not have two groups the same attached to it OR 4 different atoms/groups attached to C=C ALLOW 2 highest priority/molecular mass/atomic number atoms/groups on opposite sides (of C=C) is the <i>E</i> isomer ALLOW 2 highest priority/molecular mass/atomic number atoms/groups on the same side (of C=C) is the <i>Z</i> isomer ALLOW correct diagrams to show any of these points (1)	Just 'no rotation' without reference to C=C molecule does not rotate molecules/compounds attached to C atoms	2

Question Number	Acceptable Answers	Reject	Mark
18(c)(ii)	circle around double bond as shown  ALLOW any clear indication of the correct double bond or a circle around either of the two carbon atoms in this bond. ALLOW the circle being extended to the adjacent carbon atoms attached to the C=C.	both C=C bonds circled the circle extended to include the C=O and/or C-H bond(s) on the right	1

Question Number	Acceptable Answers	Reject	Mark
18(d)	Any reagent and matching observation from	Just an observation not linked to a reagent	2

Question Number	Acceptable Answers	Reject	Mark
18(e)(i)	In (e)(i) and (e)(ii), penalise any structure other than skeletal only once, in the item where it appears first  OR  ALLOW any unambiguous skeletal formula showing the aldehyde (with or without the H in CHO)	any structure with an OH group	1

Question Number	Acceptable Answers	Reject	Mark
18(e)(ii)	In (e)(i) and (e)(ii), penalise any structure other than skeletal only once, in the item where it appears first  ALLOW  ALLOW O⁻ for OH ALLOW -O-H for OH ALLOW the OH on either side of the structure ALLOW just 1 H shown on the C with the OH attached ALLOW any unambiguous skeletal formula showing the alcohol (with or without the 2Hs on end C)	any structure without both C=C the <i>E</i> isomer	1

(Total for Question 18 = 9 marks)

Question Number	Acceptable Answers	Reject	Mark
19(a)(i)	First marking point - Orders H_2O_2 first/1st order/order 1 H^+ zero/0 order/order 0 both correct (1) Explanations Second marking point H_2O_2 - as $[\text{H}_2\text{O}_2]$ doubles and $[\text{H}^+]$ and $[\text{I}^-]$ stay the same/other concentrations stay the same/using experiments 1 and 2 (this could be shown on the table) and the rate doubles/working to show this ALLOW reverse argument ie as $[\text{H}_2\text{O}_2]$ halves and $[\text{H}^+]$ and $[\text{I}^-]$ stay the same/other concentrations stay the same/using experiments 1 and 2 (this could be shown on the table) and the rate halves/working to show this (1) Third marking point H^+ - as $[\text{H}^+]$ doubles/halves and $[\text{H}_2\text{O}_2]$ and $[\text{I}^-]$ stay the same/other concentrations stay the same/using experiments 1 and 3 (this could be shown on the table) Note – do not penalise omission of this if it has been penalised in second marking point and the rate stays the same /working to show this OR As $[\text{H}^+]$ doubles and $[\text{H}_2\text{O}_2]$ halves and $[\text{I}^-]$ stays the same /using experiments 2 and 3 (this could be shown on the table) (also see note above) and rate halves due to $[\text{H}_2\text{O}_2]$ change so rate does not change due to $[\text{H}^+]$/working to show this ALLOW reverse argument (1)	Either/both explanations if inconsistent with order(s) stated above	3

Question Number	Acceptable Answers	Reject	Mark
19(a)(ii)	First marking point First/1st order /order 1 (1) Second marking point-consequential on correct order graph shows rate is (directly) proportional to $[I^-]$ OR as $[I^-]$ increases, the rate increases proportionally OR as $[I^-]$ doubles, the rate doubles ALLOW graph (of rate against $[I^-]$) is a straight line (through the origin) /gradient is constant ALLOW Increase in rate is constant (1)	Any other order scores zero overall iodine/I_2 Penalise once only in (ii) and (iii)	2

Question Number	Acceptable Answers	Reject	Mark
19(a)(iii)	rate/r/R = $k[H_2O_2][I^-]$ ALLOW $[H_2O_2]^1[I^-]^1$ ALLOW $[H^+]^0$ ALLOW upper case K consequential on their orders from (a)(i) and (ii)	$[I_2]$	1

Question Number	Acceptable Answers	Reject	Mark
19(a)(iv)	2.8×10^{-5} (1) $dm^3 mol^{-1} s^{-1}$ (1) ALLOW units in any order Note: value and units are consequential on their rate equation from (a)(iii) and must be consistent Ignore SF unless 1. Comment If zero order wrt $[I^-]$, $k = 1.4 \times 10^{-5} s^{-1}$		2

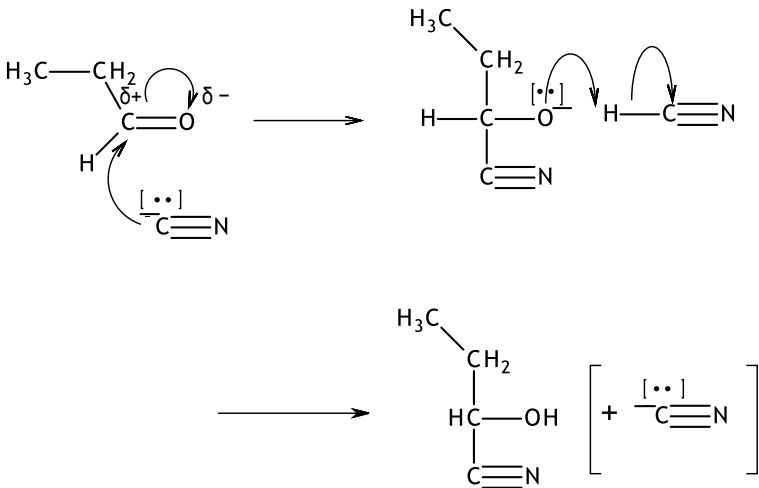
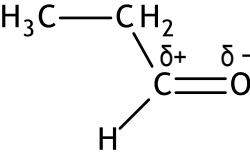
Question Number	Acceptable Answers	Reject	Mark
19(b)(i)	(Rate determining step) Any balanced equation that has just 2NO₂ on the LHS (1) (Step 2) Any balanced equation for which the two steps combine to the overall equation/double the overall equation (1) Examples of matching pairs: $2\text{NO}_2 \rightarrow \text{N}_2\text{O}_4$ $\text{N}_2\text{O}_4 + \text{CO} \rightarrow \text{NO} + \text{NO}_2 + \text{CO}_2/$ $\text{N}_2\text{O}_4 + 2\text{CO} \rightarrow 2\text{NO} + 2\text{CO}_2$ OR $2\text{NO}_2 \rightarrow 2\text{NO} + \text{O}_2$ $2\text{CO} + \text{O}_2 \rightarrow 2\text{CO}_2/\text{CO} + 1/2\text{O}_2 \rightarrow \text{CO}_2$ OR $2\text{NO}_2 \rightarrow \text{N}_2 + 2\text{O}_2$ $\text{N}_2 + 2\text{O}_2 + \text{CO} \rightarrow \text{NO} + \text{NO}_2 + \text{CO}_2$ OR $2\text{NO}_2 \rightarrow 2\text{NO} + 2\text{O}$ $\text{NO} + 2\text{O} + \text{CO} \rightarrow \text{NO}_2 + \text{CO}_2$ OR $2\text{NO}_2 \rightarrow \text{NO} + \text{NO}_3$ $2\text{CO} + \text{NO}_3 \rightarrow 2\text{CO}_2 + \text{NO}$ ALLOW NO₂ + NO₂ on LHS NOTE NO₂ → NO + 1/2O₂ then CO + 1/2O₂ → CO₂ Does not score the first mark but scores 1 for the consequential second equation IGNORE state symbols even if incorrect	NO ₂ or any multiple other than 2 of NO ₂ on LHS for first mark only	2

Question Number	Acceptable Answers	Reject	Mark
19(b)(ii)	In (b)(ii) penalise incorrect/missing units but allow J/mol K and J/mol/K and lower case k FIRST CHECK THE FINAL ANSWER, If answer is $-13.3 \text{ J mol}^{-1} \text{ K}^{-1}$ or $-0.0133 \text{ kJ mol}^{-1} \text{ K}^{-1}$, award 2 marks $13.3 \text{ J mol}^{-1} \text{ K}^{-1} / 0.0133 \text{ kJ mol}^{-1} \text{ K}^{-1}$ (sign omitted) (1) $-13.3 / -0.0133$ (units omitted) (1) If none of the above answers is given First mark for correct data used (1) Second mark value, sign and units consequential on incorrect entropy value(s) used in the correct expression $(\Delta S^\circ_{\text{system}} =) [210.7 + 213.6] - [197.6 + 240.0]$ (1) IGNORE SF except 1SF		2

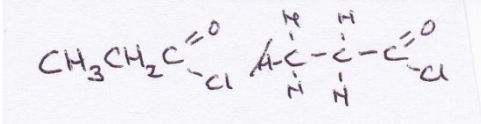
Question Number	Acceptable Answers	Reject	Mark
19(b)(iii)	FIRST CHECK THE FINAL ANSWER, If final answer is $+0.75839 \text{ kJ mol}^{-1} \text{ K}^{-1}$ (2) $+758.39 \text{ J mol}^{-1} \text{ K}^{-1}$ (2) EITHER $(\Delta S^\circ_{\text{surroundings}} =) \frac{-\Delta H}{T} \text{ OR } -\frac{(-226)}{298}$ (1) $= 0.75839 \text{ kJ mol}^{-1} \text{ K}^{-1}$ (1) Second mark is for answer with correct unit OR $(\Delta S^\circ_{\text{surroundings}} =) \frac{-\Delta H}{T} \text{ OR } -\frac{(-226000)}{298}$ (1) $= 758.39 \text{ J mol}^{-1} \text{ K}^{-1}$ (1) Second mark is for answer with correct unit ALLOW $-0.75839 \text{ kJ mol}^{-1} \text{ K}^{-1} / -758.39 \text{ J mol}^{-1} \text{ K}^{-1}$ (1) IGNORE SF except 1 SF	$-0.75839 /$ -758.39 with no units	2

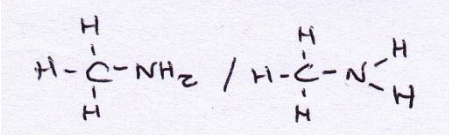
Question Number	Acceptable Answers	Reject	Mark
19(b)(iv)	First marking point $(\Delta S^{\circ}_{\text{total}} = \Delta S^{\circ}_{\text{system}} + \Delta S^{\circ}_{\text{surroundings}})$ $(= -13.3 + 758.39) / (-0.0133 + 0.75839)$ $= (+)745.09 \text{ J K}^{-1} \text{ mol}^{-1} / (+)0.74509 \text{ kJ K}^{-1} \text{ mol}^{-1}$ (1) TE on (ii) and (iii) added together with the same units IGNORE SF except 1 SF IGNORE units, even if incorrect Second marking point (sign is positive so) reaction is (thermodynamically) feasible / spontaneous (1) ALLOW feasible / will occur / reaction goes / it reacts (at 298 K) reactants thermodynamically unstable COMMENT If value for $\Delta S^{\circ}_{\text{total}}$ is negative, then allow consequential mark for (sign is negative so) reaction is not feasible / not spontaneous / will not occur / reaction / it does not take place (at 298 K)	(ii) and (iii) added together with different units for first mark only	2

(Total for Question 19 = 16 marks)

Question Number	Acceptable Answers	Reject	Mark
20(a)(i)	 Lone pairs are not needed Allow C₂H₅ First mark dipole on C=O  (1) Second mark arrow from anywhere on CN⁻ to carbon of C=O/space between the CN⁻ and carbon of C=O and arrow from C=O bond to O ALLOW CN⁻ without showing the triple bond/charge anywhere on CN ALLOW arrow from C=O bond to O to show the formation of charged canonical form (C⁺-O⁻) followed by attack of CN⁻ (1) Third mark correct intermediate with full negative charge (1) Fourth mark arrow from oxygen to H and from H-CN bond to C of CN ALLOW arrow from oxygen to H⁺ ALLOW arrow from oxygen to H of H₂O and from H-OH bond to OH (1)	Penalise incorrect number of C atoms in propanal once only Full charges Half arrows starting from KCN/HCN /CN^{δ-} ..C-NC bond	4

Question Number	Acceptable Answers	Reject	Mark
20(a)(ii)	nucleophilic (1) addition (1) Note Do not allow 'addition' if S_N1/ S_N2 are included in the answer. Words can be in either order		2

Question Number	Acceptable Answers	Reject	Mark
20(b)(i)	If name and formula given, both must be correct CH₃CH₂COCl / propanoyl chloride /  ALLOW skeletal formula/any combination of displayed/structural formula Ignore C₃H₅OCl Comment Molecular formula without correct structural formula or name will not score.		1

Question Number	Acceptable Answers	Reject	Mark
20(b)(ii)	If name and formula given, both must be correct methylamine / CH₃NH₂ / NH₂CH₃  Ignore CH₅N/ CNH₅ Note Allow the mark if the answer to this item is written by Step 3 in the flow chart on page 19	methyl amide	1

Question Number	Acceptable Answers	Reject	Mark
20(b)(iii)	4/four (peaks)		1

Question Number	Acceptable Answers	Reject	Mark
20(c)	$\text{CH}_3\text{CH}_2\text{COOH} + \text{CH}_3\text{CH}(\text{OH})\text{CH}_3 \rightleftharpoons$ $\text{CH}_3\text{CH}_2\text{COOCH}(\text{CH}_3)_2 + \text{H}_2\text{O}$ $\text{CH}_3\text{CH}_2\text{COOCH}(\text{CH}_3)_2$ (1) rest of equation correct including H_2O, conditional on correct structure for ester (1) ALLOW full displayed formulae or a combination of structural and displayed formulae ALLOW missing bracket around OH ALLOW $\rightarrow$ instead of $\rightleftharpoons$ ALLOW H^+ above the arrow or eqm sign OR on both sides of the equation. Note: If candidate uses propan-1-ol/$\text{C}_3\text{H}_7\text{OH}$ allow 1 mark for a completely correct equation $\text{CH}_3\text{CH}_2\text{COOH} + \text{CH}_3\text{CH}_2\text{CH}_2\text{OH} \rightleftharpoons$ $\text{CH}_3\text{CH}_2\text{COOCH}_2\text{CH}_2\text{CH}_3 + \text{H}_2\text{O}$ OR $\text{CH}_3\text{CH}_2\text{COOH} + \text{C}_3\text{H}_7\text{OH} \rightleftharpoons$ $\text{CH}_3\text{CH}_2\text{COOCH}_2\text{CH}_2\text{CH}_3 + \text{H}_2\text{O}$	molecular formulae penalise missing H once only any other alcohol or acid used for both marks	2

Question Number	Acceptable Answers	Reject	Mark
20(d)	First marking point propan-1-ol/correct structural/displayed/skeletal formula/ ALLOW propanol and primary alcohol /1°/1^y ALLOW C₃H₇OH (1) Second marking point – stand alone because the IR spectrum shows an absorption at 3750-3100 (cm⁻¹) due to the OH bond/OH group /alcohol/hydroxy(l) OR no peak at around 1700 / 2700-2775 (cm⁻¹) so it is not an aldehyde (1) Note – these could be shown on the spectrum as labelled peaks ALLOW any wavenumber or range within the ranges given above IGNORE any other peaks mentioned/references to bend/stretch/intensity	hydroxide	2

(Total for Question 20 = 13 marks)

Question Number	Acceptable Answers	Reject	Mark
21(a)(i)	$(K_p =) \frac{P_{\text{HI}}^2}{P_{\text{H}_2} \times P_{\text{I}_2}}$ ALLOW P_{HI}^2 ALLOW lower or upper case p /pp/curved brackets IGNORE state symbols even if incorrect IGNORE missing x	square brackets expressions without p/pp/P/PP to show partial pressure	1

Question Number	Acceptable Answers	Reject	Mark																				
21(a)* (ii)	<table border="1"> <tr> <td></td><td>H₂</td><td>I₂</td><td>2HI</td></tr> <tr> <td>initial mol</td><td>1</td><td>1</td><td>0</td></tr> <tr> <td>eqm mol</td><td>0.21</td><td>0.21</td><td>1.58</td></tr> <tr> <td>partial pressure</td><td>$\frac{0.21 \times 5}{2} = 0.525$</td><td>$\frac{0.21 \times 5}{2} = 0.525$</td><td>$\frac{1.58 \times 5}{2} = 3.95$</td></tr> <tr> <td>K_p</td><td colspan="3">$\frac{3.95^2}{0.525^2} = 56.6/57$ no units</td></tr> </table> First mark eqm mol of H₂ = 0.21 (1) Second mark eqm mol of HI = 1.58 (see note at end) (1) Third mark all 3 partial pressures, either working or answer (1) consequential on their equilibrium moles Fourth mark correct value (56.6/57) for K_p with or without working (1) consequential on their partial pressures and their expression for K_p in (a)(i) Fifth mark 'no units' stated / working to show that units cancel / statement that units cancel ALLOW - /atm⁰ or similar indication of no units ALLOW units based on expression for K_p in (i) or the expression they have used in the calculation in (ii) (1) Note Only award 5 marks if partial pressures are stated or working to show them If 0.21 mol H₂ (1) and 0.79 mol HI(0), then partial pressures H₂/I₂ = 0.868 and HI = 3.264 (1) K_p = 14/14.2 (1) no units (1) If 0.21 mol H₂ (1) and 0.42 mol HI(0), then partial pressures H₂/I₂ = 1.25 and HI = 2.5 (1) K_p = 4 (1) no units (1) Alternative method for marks 2 and 3 If initial P(H₂) and P(I₂) = 2.5 (atm) Eqm P(H₂) and P(I₂) = 2.5x0.21 = 0.525(atm) (1) P(HI) = 5-(2 x 0.525) = 3.95 (1) IGNORE SF except 1SF		H ₂	I ₂	2HI	initial mol	1	1	0	eqm mol	0.21	0.21	1.58	partial pressure	$\frac{0.21 \times 5}{2} = 0.525$	$\frac{0.21 \times 5}{2} = 0.525$	$\frac{1.58 \times 5}{2} = 3.95$	K _p	$\frac{3.95^2}{0.525^2} = 56.6/57$ no units				5
	H ₂	I ₂	2HI																				
initial mol	1	1	0																				
eqm mol	0.21	0.21	1.58																				
partial pressure	$\frac{0.21 \times 5}{2} = 0.525$	$\frac{0.21 \times 5}{2} = 0.525$	$\frac{1.58 \times 5}{2} = 3.95$																				
K _p	$\frac{3.95^2}{0.525^2} = 56.6/57$ no units																						

Question Number	Acceptable Answers	Reject	Mark
21(b)	No effect because (there are) equal numbers of (gas) mole(cule)s on each side of the equation	Just 'equal numbers of mole(cule)s'	1

Question Number	Acceptable Answers	Reject	Mark
21(c)(i)	First mark $(\Delta H \text{ is negative/exothermic so})$ $-\Delta H/T \text{ gets less positive}$ ALLOW decreases OR $(\Delta H \text{ is negative/exothermic so})$ $\Delta S_{\text{surroundings}} \text{ gets less positive}$ ALLOW decreases (1) Second mark $(\text{so, since } \Delta S_{\text{total}} = -\Delta H/T + \Delta S_{\text{system}})$ (1) ΔS_{total} decreases Mark independently No TE on incorrect $\Delta S_{\text{surroundings}}$ Ignore comments based on K_p		2

Question Number	Acceptable Answers	Reject	Mark
21(c)* (ii)	First mark $\ln K = \Delta S_{\text{total}}/R$ OR $K = e^{\Delta S_{\text{total}}/R}$ OR $\Delta S_{\text{total}} = R \ln K$ OR ΔS_{total} is (directly) proportional to $\ln K$ (1) Second mark K_p decreases and yield (of HI) decreases (1) consequential on their ΔS_{total} in (c)(i) Ignore comments based on Le Chatelier's principle	ΔS_{total} is (directly) proportional to K Just 'equilibrium position moves to the left' without reference to yield and K_p	2

(Total for Question 21 = 11 marks)

TOTAL FOR SECTION B = 49 MARKS

Section C

Question Number	Acceptable Answers	Reject	Mark
22(a)(i)	Proton donor/donates protons OR H ⁺ ion donor/donates H ⁺ ions Ignore just releases H ⁺ ions or protons.		1

Question Number	Acceptable Answers	Reject	Mark
22(a)(ii)	$\text{CH}_3\text{CH}(\text{OH})\text{COOH} + \text{H}_2\text{O} \rightleftharpoons \text{CH}_3\text{CH}(\text{OH})\text{COO}^- + \text{H}_3\text{O}^+$ OR $\text{CH}_3\text{CH}(\text{OH})\text{CO}_2\text{H} + \text{H}_2\text{O} \rightleftharpoons \text{CH}_3\text{CH}(\text{OH})\text{CO}_2^- + \text{H}_3\text{O}^+$ ALLOW → for ⇌ ALLOW $\text{CH}_3\text{CH}(\text{OH})\text{COOH} \rightleftharpoons \text{CH}_3\text{CH}(\text{OH})\text{COO}^- + \text{H}^+$ ALLOW $\text{CH}_3\text{CH}(\text{OH})\text{CO}_2\text{H} \rightleftharpoons \text{CH}_3\text{CH}(\text{OH})\text{CO}_2^- + \text{H}^+$ Ignore state symbols even if incorrect Ignore missing bracket around OH	HA and A ⁻ once only in (a)(ii) and (a)(iii) Penalise missing H once only in (a)(ii) and (a)(iii)	1

Question Number	Acceptable Answers	Reject	Mark
22(a)(iii)	$\frac{[\text{CH}_3\text{CH}(\text{OH})\text{COO}^-][\text{H}_3\text{O}^+]}{[\text{CH}_3\text{CH}(\text{OH})\text{COOH}]}$ OR $\frac{[\text{CH}_3\text{CH}(\text{OH})\text{CO}_2^-][\text{H}_3\text{O}^+]}{[\text{CH}_3\text{CH}(\text{OH})\text{CO}_2\text{H}]}$ OR $\frac{[\text{CH}_3\text{CH}(\text{OH})\text{COO}^-][\text{H}^+]}{[\text{CH}_3\text{CH}(\text{OH})\text{COOH}]}$ OR $\frac{[\text{CH}_3\text{CH}(\text{OH})\text{CO}_2^-][\text{H}^+]}{[\text{CH}_3\text{CH}(\text{OH})\text{CO}_2\text{H}]}$ Note Allow any of these for the mark, even if a different equation using H ⁺ /H ₃ O ⁺ has been given in (a)(ii)	H ₂ O in expression Lack of square brackets HA and A ⁻ once only in (a)(ii) and (a)(iii) Penalise missing H once only in (a)(ii) and (a)(iii)	1

Question Number	Acceptable Answers	Reject	Mark
22(a) (iv)	Comment Allow $[H_3O^+]$, $[HA]$, $[A^-]$ as alternative formula throughout Calculation Ignore sf, except 1 sf, throughout First check the final answer If pH = 2.34, award the first 3 marks If pH $\neq$ 2.34, award marks as follows ROUTE 1 $K_a = 10^{-3.86} = 1.3804 \times 10^{-4} (\text{mol dm}^{-3})$ (1) $[H^+] = \sqrt{K_a [CH_3CH(OH)COOH]}$ $= \sqrt{1.38 \times 10^{-4} \times 0.15}$ $= 4.5504 \times 10^{-3} (\text{mol dm}^{-3})$ (1) TE on their value for K_a pH = $-\log_{10}[H^+] = -\log_{10} 4.55 \times 10^{-3}$ $= 2.3420/2.34$ (1) TE on their value for $[H^+]$ provided pH > 1 and < 7 (pH = 0.12 if use 3.86 for K_a, scores 2) ROUTE 2 $[H^+] = \sqrt{K_a [CH_3CH(OH)COOH]}$ pH = $\frac{1}{2} pK_a - \frac{1}{2} \log [CH_3CH(OH)COOH]$ (1) $= \frac{1}{2} 3.86 - \frac{1}{2} \log 0.15$ (1) $= 2.34$ (1) TE on not halving (4.68 is worth 1 mark) Assumption 1 $[H^+] = [CH_3CH(OH)COO^-]$ OR no H^+ from the (ionization of) water/ionization of water is negligible OR H^+ is (only) from the acid (1) Assumption 2 Ionization/dissociation of the (weak) acid is negligible / very small / insignificant OR $[CH_3CH(OH)COOH]_{\text{initial}} = [CH_3CH(OH)COOH]_{\text{equilibrium}}$ OR $[CH_3CH(OH)COOH]_{\text{equilibrium}} = 0.15 (\text{mol dm}^{-3})$ OR $[H^+]/[CH_3CH(OH)COO^-] \ll [CH_3CH(OH)COOH]$ OR $[CH_3CH(OH)COOH]$/acid concentration remains constant (1)	Incorrect units for K_a and/or $[H^+]$, max 2 for calculation $[H^+]_{\text{initial}} = [H^+]_{\text{equilibrium}}/$	5

	ROUTE 3 First check the final answer If pH = 2.35, award the first 4 marks If pH $\neq$ 2.35, award marks as follows $K_a = 10^{-3.86} = 1.38 \times 10^{-4} \text{ (mol dm}^{-3}\text{)}$ (1) $[H^+]^2 = K_a([CH_3CH(OH)COOH] - [H^+])$ $[H^+]^2 = 1.38 \times 10^{-4} \times (0.15 - [H^+])$ (1) $[H^+] = 4.48 \times 10^{-3} \text{ (mol dm}^{-3}\text{)}$ (1) ecf on their value for K_a pH = $-\log_{10}[H^+]$ $= -\log_{10} 4.48 \times 10^{-3}$ $= 2.35$ (1) TE on their value for $[H^+]$ Assumption $[H^+] = [CH_3CH(OH)COO^-]$ OR no H^+ from the (ionisation of) water OR H^+ is (only) from the acid (1)	$[H^+]_{\text{initial}} =$ $[H^+]_{\text{equilibrium}}$	
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Question Number	Acceptable Answers	Reject	Mark
22(b)(i)	If answer is 13.2, with or without working, award 2 marks (13/13.17 score 1 mark, answer not to 1 dp) $[\text{H}^+] = \frac{1.0 \times 10^{-14}}{0.15}$ $= 6.67 \times 10^{-14} \text{ (mol dm}^{-3}\text{)} \quad \textbf{(1)}$ pH = $-\log_{10} 6.67 \times 10^{-14}$ = 13.176 = 13.2 (1) TE on their $[\text{H}^+]$, provided pH > 7 and < 14 OR pOH = 0.824 (1) pH = 14 - 0.824 = 13.176 = 13.2 (1)	Answer not given to 1 dp Answer not given to 1 dp	2

Question Number	Acceptable Answers	Reject	Mark
22(b)(ii)	Curve continues and finishes at any pH between 12 and 13.2 ALLOW this as standalone if they have no pH in (b)(i) or their pH is ≤ 10 TE on their pH in (b)(i) if it is > 10	finishing at >13.2 or <12 curves that 'dip' by more than 1 small square at the end stopping before 45 cm³	1

Question Number	Acceptable Answers	Reject	Mark
22(b)(iii)	Indicator and colour change named indicator (1) matching colour change (1) phenol red yellow to red/pink OR thymol blue (base) yellow to blue OR phenolphthalein colourless to red/pink /magenta ALLOW bromothymol blue yellow to blue ALLOW thymolphthalein if they have continued to vertical section to at least 10.6 with colour change colourless to blue, for both marks ALLOW correct colour change for thymolphthalein even if the vertical section does not continue to 10.6 for 1 mark. NO TE for colour change from any other indicator Justification pH range (of indicator) lies (completely) in the vertical jump (on the titration curve) OR Indicator will change colour in the vertical section of the graph OR pH range of indicator and pH range of vertical section of the graph stated as long as they overlap ALLOW pK_{in} (± 1) is in the vertical jump OR pK_{in} is nearest to the pH at the end/equivalence point ALLOW Indicator will change colour at the end/equivalence point ALLOW (because it is a) titration of a weak acid with a strong base (1)	Universal indicator loses all 3 marks	3

Question Number	Acceptable Answers	Reject	Mark
22(b)* (v)	Comment Allow [HA], [A⁻] as alternative formulae throughout First mark – statement or equations showing the buffer solution buffer solution contains a large amount/reservoir /excess of a weak acid and its conjugate base/salt OR a large amount/reservoir /excess of lactic acid and lactate ions/formulae for lactic acid and lactate ions OR $\text{CH}_3\text{CH}(\text{OH})\text{COOH} \rightleftharpoons \text{CH}_3\text{CH}(\text{OH})\text{COO}^- + \text{H}^+$ / $\text{CH}_3\text{CH}(\text{OH})\text{COOH} + \text{H}_2\text{O} \rightleftharpoons \text{CH}_3\text{CH}(\text{OH})\text{COO}^- + \text{H}_3\text{O}^+$ and $\text{CH}_3\text{CH}(\text{OH})\text{COO}^{(-)}\text{Na}^{(+)} \rightarrow \text{CH}_3\text{CH}(\text{OH})\text{COO}^- + \text{Na}^+$ Ignore definitions of a buffer solution (1) Second mark – identifying which species react with the added acid and alkali $\text{CH}_3\text{CH}(\text{OH})\text{COOH}$ reacts with added alkali/OH^- ions OR $\text{CH}_3\text{CH}(\text{OH})\text{COOH} + \text{OH}^- \rightarrow$ OR OH^- ions react with $\text{H}^+/\text{H}_3\text{O}^+$ ions and $\text{CH}_3\text{CH}(\text{OH})\text{COO}^-$ reacts with added acid/H^+ ions / H_3O^+ ions OR $\text{CH}_3\text{CH}(\text{OH})\text{COO}^- + \text{H}^+/\text{H}_3\text{O}^+ \rightarrow$ OR $(\text{pH} = \text{pK}_a + \lg \frac{[\text{salt}]}{[\text{acid}]})$ small additions of acid/alkali have little/no effect on $\lg \frac{[\text{salt}]}{[\text{acid}]}$ so pH hardly changes/no change ALLOW Ratio $[\text{acid}]:[\text{salt}]/[\text{salt}]:[\text{acid}]$ only changes a little so pH hardly changes/no change ALLOW HA and A⁻ in formulae/equations (1) Comment This mark may be given from the equations	Reservoir of H⁺ ions → in equation ⇌ in equation	4

	Third mark – ionic equation for OH⁻ ALLOW equations with reversible arrows $\text{CH}_3\text{CH}(\text{OH})\text{COOH} + \text{OH}^- \rightarrow \text{CH}_3\text{CH}(\text{OH})\text{COO}^- + \text{H}_2\text{O}$ ALLOW $\text{H}^+ + \text{OH}^- \rightarrow \text{H}_2\text{O} / \text{H}_3\text{O}^+ + \text{OH}^- \rightarrow 2\text{H}_2\text{O}$ (1) Fourth mark – ionic equation for H⁺ $\text{CH}_3\text{CH}(\text{OH})\text{COO}^- + \text{H}^+ \rightarrow \text{CH}_3\text{CH}(\text{OH})\text{COOH}$ OR $\text{CH}_3\text{CH}(\text{OH})\text{COO}^- + \text{H}_3\text{O}^+ \rightarrow \text{CH}_3\text{CH}(\text{OH})\text{COOH} + \text{H}_2\text{O}$ (1) Note Only penalise non ionic equations e.g. using NaOH, HCl once only. Comment Two completely correct ionic equations scores marks 2,3 and 4		
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Question Number	Acceptable Answers	Reject	Mark
22(c)	$\text{CH}_3\text{CH}(\text{OH})\text{COO}^- + \text{CH}_3\text{COOH}_2^+$ both needed for the mark ALLOW $[\text{CH}_3\text{CH}(\text{OH})\text{COO}]^- + [\text{CH}_3\text{COOH}_2]^+$ ALLOW $[\text{CH}_3\text{COOHH}]^+ / \text{CH}_3\text{COOHH}^+$ for the ethanoic acid ion $\text{CH}_3\text{CH}(\text{OH})\text{CO}_2^-$ for the lactic acid ion		1

(Total for Question 22 = 21 marks)

TOTAL FOR PAPER = 90 marks

