Pearson Edexcel

Mark Scheme (Results)

Summer 2022

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

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Summer 2022
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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.

Section A

Question Number	**Answer**	**Mark**
1(a)	**The only correct answer is B** (two) ***A*** *is not correct because 2-methylpropan-2-ol has a peak for the 3* CH_3 *groups and one for the OH group making 2 in total* ***C*** *is not correct because 2-methylpropan-2-ol has a peak for the 3* CH_3 *groups and one for the OH group making 2 in total* ***D*** *is not correct because 2-methylpropan-2-ol has a peak for the 3* CH_3 *groups and one for the OH group making 2 in total*	**(1)**

Question Number	**Answer**	**Mark**
1(b)	**The only correct answer is A** (propanal) ***B*** *is not correct because propane has 2 peaks in the ratio 3:1* ***C*** *is not correct because propan-1-ol has 4 peaks in the ratio 3:2:2:1* ***D*** *is not correct because propan-2-ol has 3 peaks in the ratio is 6:1:1*	**(1)**

Question Number	**Answer**	**Mark**
1(c)	**The only correct answer is C** (butanal) ***A*** *is not correct because butanoic acid has a singlet due to the COOH* ***B*** *is not correct because butanone has a singlet due to the* CH_3 *adjacent to the C=O* ***D*** *is not correct because butan-1-ol has a singlet due to the OH*	**(1)**

Question Number	Answer	Mark
2	**The only correct answer is B** (CH_3CH_2CHO) ***A*** *is not correct because there will not be a peak at m/z 29.0390* ***C*** *is not correct because there will not be a molecular ion peak a m/z 58.0417* ***D*** *is not correct because there will not be molecular ion peak at m/z 58.0417 nor a peak at m/z 29.0390*	**(1)**

Question Number	Answer	Mark
3	**The only correct answer is D** (octan-1-ol, octanal, octane,) ***A*** *is not correct because octan-1-ol is the most polar so would have the shortest retention time* ***B*** *is not correct because octan-1-ol is more polar than octanal and so would have a shorter retention time* ***C*** *is not correct because octane is non-polar so would have the longest retention time*	**(1)**

Question Number	Answer	Mark
4	**The only correct answer is C** (0.75) ***A*** *is not correct because the calculation has used the distance from the solvent front to the sample not the baseline* ***B*** *is not correct because the calculation has used the length of the plate, not the distance the solvent travelled* ***D*** *is not correct because the calculation has been inverted*	**(1)**

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

Question Number	**Answer**	**Mark**
6	**The only correct answer is C** (3-methylpentan-3-ol) ***A*** *is not correct because this is a primary alcohol and so can be formed by the reduction of an aldehyde* ***B*** *is not correct because this is a secondary alcohol and so can be formed by the reduction of a ketone* ***D*** *is not correct because this is a secondary alcohol and so can be formed by the reduction of a ketone*	**(1)**

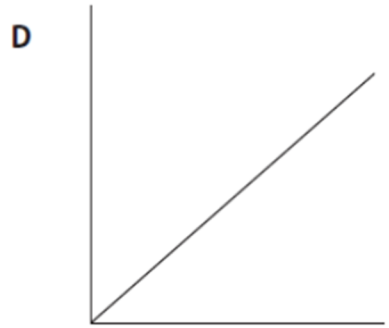
Question Number	**Answer**	**Mark**
7	**The only correct answer is B** (4.17) ***A*** *is not correct because this is the −log of the concentration* ***C*** *is not correct because this is the −log of the* K_a ***D*** *is not correct because this is the −log of the* K_a *multiplied by the concentration*	**(1)**

Question Number	Answer	Mark
8	**The only correct answer is B** (13.43) ***A*** *is not correct because this is the* $-\log [OH^-]$ ***C*** *is not correct because it does not produce 2 x* OH^- ***D*** *is not correct because the* $-\log [OH^-]$ *has been added to* pK_w	**(1)**

Question Number	Answer	Mark
9(a)	**The only correct answer is D** (hydrochloric acid added to ammonia) ***A*** *is not correct because it is a weak acid and strong base* ***B*** *is not correct because it is a strong acid and strong base* ***C*** *is not correct because it is a weak acid and weak base*	**(1)**

Question Number	Answer	Mark
9(b)	**The only correct answer is C** (methyl red) ***A*** *is not correct because malachite green would change colour at about pH 1* ***B*** *is not correct because methyl yellow would change colour at about pH 3.5* ***D*** *is not correct because thymol blue would change colour at about pH 9*	**(1)**

Question Number	Answer	Mark
10(a)	**The only correct answer is C** (Graph 3)  ***A*** *is not correct because it is a rate v concentration graph for a second order reaction* ***B*** *is not correct because it is a concentration v time graph for a zero order reaction* ***D*** *is not correct because it is a rate v concentration graph for a first order reaction*	**(1)**

Question Number	Answer	Mark
10(b)	**The only correct answer is D** (Graph 4)  ***A*** *is not correct because it is a graph of rate against concentration for a second order reaction* ***B*** *is not correct because it is a graph of concentration against time for a zero order reaction* ***C*** *is not correct because it is a graph of rate of reaction against concentration of the reactant for a zero order reaction*	**(1)**

Question Number	Answer	Mark
11(a)	**The only correct answer is A** (colorimetry) ***B*** *is not correct because the solution would not go cloudy* ***C*** *is not correct because there is no base to titrate against* ***D*** *is not correct because starch is an indicator and would immediately turn blue-black*	**(1)**

Question Number	Answer	Mark
11(b)	**The only correct answer is B** (1.98) ***A*** *is not correct because the concentration of the acid has been increased three times* ***C*** *is not correct because the concentration of the acid has been decreased six times* ***D*** *is not correct because the pH has been multiplied by three*	**(1)**

Question Number	Answer	Mark
12	**The only correct answer is A** (+38.8 kJ mol^{-1}) ***B*** *is not correct because the units are incorrect* ***C*** *is not correct because the gradient has been divided by R* ***D*** *is not correct because the gradient has been divided by R and the units are incorrect*	**(1)**

Question Number	Answer	Mark
13	**The only correct answer is D** (decreasing the temperature would increase the equilibrium yield of sulfur trioxide) ***A*** *is not correct because vanadium oxide is a heterogeneous catalyst* ***B*** *is not correct because decreasing pressure would decrease the equilibrium yield of sulfur trioxide* ***C*** *is not correct because increasing the surface area of the catalyst will affect the rate not the equilibrium yield of sulfur trioxide*	**(1)**

Question Number	Answer	Mark
14	**The only correct answer is A** ($CaO(s) < H_2O(l) < CO_2(g) < SO_2(g)$) ***B*** *is not correct because* $SO_2(g)$ *has a greater standard molar entropy than* $CO_2(g)$ ***C*** *is not correct because* $SO_2(g)$ *has the greatest standard molar entropy* ***D*** *is not correct because* $SO_2(g)$ *has the greatest standard molar entropy*	**(1)**

Question Number	Answer	Mark
15	**The only correct answer is B** (PS) ***A*** *is not correct because R is smaller than S* ***C*** *is not correct because Q is larger than P and R is smaller than S* ***D*** *is not correct because Q is larger than P*	**(1)**

(Total for Section A = 20 Marks)

Section B

Question Number	Answer	Additional Guidance	Mark
16(a)(i)	$K_p = \frac{p^2NH_3}{pN_2\ p^3H_2}$	Allow round or no brackets Allow upper case Allow pp/PP Allow $p(NH_3)^2$ $p\,NH_3^2$ etc Ignore units even if incorrect Do not award square brackets	**(1)**

Question Number	Answer	Additional Guidance	Mark
16(a)(ii)	• mole fraction of N_2 **(1)** • mole fraction of H_2 **(1)** • both partial pressures **(1)**	Example of completed table Substance / Mole fraction / Partial pressure/atm N_2 / 0.18 / 36 H_2 / 0.54 / 108 NH_3 / 0.28 / 56 TE for M3 on calculated mole fractions multiplied by 200	**(3)**

Question Number	Answer	Additional Guidance	Mark
16(a)(iii)	An answer that makes reference to the following points: • correct use of K_p expression **(1)** • correct answer **and** 1 or 2 SF **(1)** • correct units **(1)**	Example of calculation $56^2 \div (108^3 \times 36)$ 7 or 6.9×10^{-5} / 0.00007 or 0.000069 Allow 3SF 6.92×10^{-5} /0.0000692 Do not award 7.0×10^{-5} / 0.000070 atm^{-2} Allow TE from (a)(i) and (a)(ii) If mole fractions are used for the calculation max score 1 for the correct answer **and** 1-3 SF Correct answer with or without working scores 3	**(3)**

Question Number	Answer	Additional Guidance	Mark
16(a)(iv)	An answer that makes reference to the following points: • the (forward) reaction is/ must be exothermic **(1)** • (more ammonia shows that) the equilibrium has moved/shifted to the right **OR** (more ammonia shows that) a new K_p is established which is larger **(1)**	Allow reverse argument Allow favours forward reaction/shifts to the product side Allow K_p increases/eqm constant increases Ignore just 'more ammonia produced' or 'yield increases'	**(2)**

Question Number	Answer	Additional Guidance	Mark
16(b)(i)	• $NH_4^+(aq) + Cl^-(aq)$	Do not award $NH_4^+Cl^-(aq)$ Do not award $NH_4Cl(aq)$ Do not award any other state symbols	**(1)**

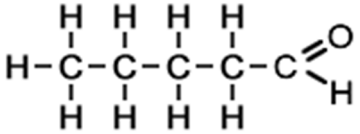
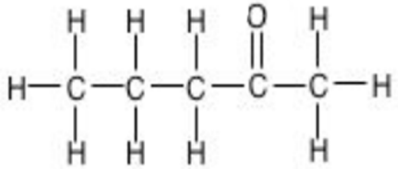
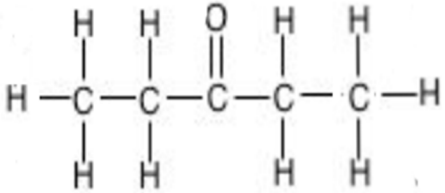
Question Number	Answer	Additional Guidance	Mark
16(b)(ii)	• $\Delta_{sol} H = \Delta_{hyd} H$ – Lattice Energy or $\Delta_{sol} H = -$ Lattice Energy + $\Delta_{hyd} H$	Allow LE for Lattice Energy Allow $\Delta_{sol} H = -$ Lattice Energy + hydration enthalpies Allow $\Delta_{sol} H = -$ Lattice Energy + hydration enthalpies Allow ΔH_{hyd} etc Ignore standard signs	**(1)**

Question Number	Answer		Additional Guidance	Mark
16(b)(iii)	• enthalpy change of hydration of ammonium chloride	**(1)**	Example of calculation $-307 + (-378) = -685$ (kJ mol^{-1}) Allow (kJ mol^{-})	**(2)**
	• enthalpy change of solution	**(1)**	$705 + (-685) = (+)20$ (kJ mol^{-1}) Allow TE on arithmetical errors Do not award use of incorrect expression Correct answer with or without working scores 2 Units are not required but if wrong penalise only once.	

Question Number	Answer		Additional Guidance	Mark
16(b)(iv)	An explanation that makes reference to three of the following points • M1 the bromide (ion) is larger than the chloride (ion) And any 2 of the following • M2 hydration enthalpy of the bromide ion less exothermic/less negative (than the chloride) • M3 lattice energy of ammonium bromide would be less exothermic/less negative (than ammonium chloride) • M4 the enthalpy of solutions depends on the values of both hydration and lattice energies (so the enthalpies of solution should be similar)	**(1)** **(1)** **(1)** **(1)**	Allow bromine ion larger than the chlorine ion Do not award larger atomic radius Allow smaller/lower Allow hydration enthalpy of bromine would be less exothermic/less negative (than the chlorine) Allow hydration enthalpy of ammonium bromide would be less exothermic/less negative (than ammonium chloride) Allow smaller/lower Accept because we don't know the magnitude of the reduction in hydration and lattice energies it is not possible to assess the overall effect Allow reverse arguments for MP1, MP2 and MP3 Ignore any reference to reactivity, polarisation and charge density	**(3)**

Question Number	Answer	Additional Guidance	Mark
16(c)	• $NH_4^+ + H_2O \longrightarrow NH_3 + H_3O^+$	Accept $NH_4^+ \longrightarrow NH_3 + H^+$ Allow eqm sign Ignore $NH_4Cl \longrightarrow NH_4^+ + Cl^-$ Ignore NH_4Cl + aq $\longrightarrow$ $NH_4^+ + Cl^-$ Ignore state symbols even if incorrect Do not award NH_4Cl + aq $\longrightarrow$ $NH_3 + HCl$ Do not award $NH_4Cl \longrightarrow NH_3 + HCl$ Do not award $NH_4Cl \longrightarrow NH_3 + H^+ + Cl^-$ Do not award $NH_4^+ + OH^- \longrightarrow NH_3 + H_2O$	(1)

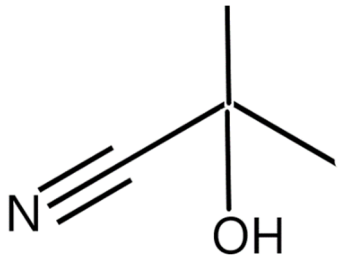
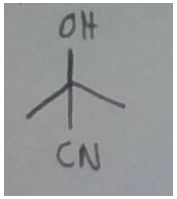
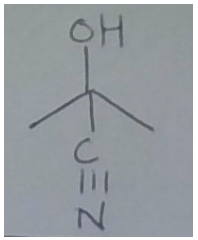
(Total for Question 16 = 17 Marks)

Question Number	Answer	Additional Guidance	Mark
17(a)	An answer that makes reference to the following points: • **A**  **(1)** • **B**  **(1)** • **C**  **(1)**	Allow structural or skeletal formulae for max 2 marks Ignore any names even if incorrect Ignore bond angles/lengths Penalise missing Hs only once	**(3)**

Question Number	Answer	Additional Guidance	Mark
17(b)(i)	• 2-hydroxybutanenitrile	Allow 2-hydroxy(l)buta(n)nitrile Allow 2-hydroxy(l)butane-1-nitrile Do not award 2-hydroxobutanenitrile Do not award 2-oxobutanenitrile Do not award cyanides or other non IUPAC names Ignore any extra hyphens, commas and spaces	**(1)**

Question Number	Answer	Additional Guidance	Mark
17(b)(ii)	• one isomer rotates (the plane of monochromatic) plane-polarised light in one direction and the other in the opposite direction/ the isomers rotate (the plane of) plane-polarised light in opposite directions/clockwise and anticlockwise	Do not award bends Allow different directions Allow PPL for plane polarised light Allow the direction of rotation of plane polarised light Allow see which way the sample rotates PPL	**(1)**

Question Number	Answer	Additional Guidance	Mark
17(b)(iii)	An answer that makes reference to the following points: • propanal is planar around the CHO/reaction site/C=O/carbonyl **(1)** • CN^- / nucleophile can attack on either side/both sides/above and below (giving a racemic/equimolar/ 50/50 mixture) **(1)**	Do not award just propanal is planar Do not award planar intermediate/carbocation Do not award any reference to nucleophilic substitution (S_N1/S_N2)	**(2)**

Question Number	Answer	Additional Guidance	Mark
17(c)(i)		Ignore displayed or structural formulae Ignore bond lengths and bond angles Allow   Ignore connectivity if vertical bond	(1)

Question Number	Answer	Additional Guidance	Mark
17(c)(ii)	• no carbon atom has 4 different groups or (central) carbon atom is bonded to two CH_3/same groups or no asymmetric/chiral carbon atom or the compound is superimposable on its mirror image or it does not have a chiral centre	Ignore symmetrical Do not award 2 of the same molecules/compounds attached to the carbon atom Do not award racemic mixture	**(1)**

Question Number	Answer	Additional Guidance	Mark
17(d)(i)	• correct chemical shift **and** carbon environment	<table><tr><th>Chemical shift range</th><th>Carbon environment</th></tr><tr><td>190-225 (ppm)</td><td>C=O</td></tr><tr><td colspan="2">OR</td></tr><tr><td>0-60 (ppm)</td><td>C—C</td></tr></table> Both range **and** carbon environment required. Allow the full range or a number/ smaller range within the range. Allow for carbon environment C-**C**=O **and** C-**C**=O | | C H Ignore any splitting patterns	**(1)**

Question Number	Answer	Additional Guidance	Mark
17(d)(ii)	• Propanal: 3/three **and** • Propanone: 2/two		**(1)**

(Total for Question 17 = 11 Marks)

<table>
<tr><th>Question Number</th><th>Answer</th><th>Additional Guidance</th></tr>
<tr>
<td>18*</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><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 lines of reasoning</td></tr>
<tr><td>Answer shows a coherent logical structure with linkages and fully sustained lines of reasoning demonstrated throughout</td><td>2</td></tr>
<tr><td>Answer is partially structured with some linkages and lines of reasoning</td><td>1</td></tr>
<tr><td>Answer has no linkages between points and is unstructured</td><td>0</td></tr>
</table>
</td>
<td>
Guidance on how the mark scheme should be applied.
The mark for indicative content should be added to the mark for lines of reasoning. For example, a response with five indicative marking points that is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning).

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

In general it would be expected that 5 or 6 indicative points would get 2 reasoning marks, and 3 or 4 indicative points would get 1 mark for reasoning, and 0, 1 or 2 indicative points would score zero marks for reasoning.
If there is any incorrect chemistry, deduct mark(s) from the reasoning. If no reasoning mark(s) awarded do not deduct mark(s).
Comment: Look for the indicative marking points first, then consider the mark for the structure of the Answer and sustained line of reasoning.
</td>
</tr>
</table>

	Indicative content Similarities IP1 the Cl is lost in all reactions IP2 water, ethanol and ammonia all contain a lone pair that attacks the delta+ carbon atom in ethanoyl chloride IP3 all reactions are very vigorous/violent Differences IP4 water: forms ethanoic acid/ CH_3COOH ($CH_3COCl + H_2O$) ⟶ CH_3COOH (+ HCl) IP5 ethanol: forms ethyl ethanoate/ $CH_3COOCH_2CH_3$ ($CH_3COCl + CH_3CH_2OH$) ⟶ $CH_3COOCH_2CH_3$ (+ HCl) IP6 Ammonia: forms ethanamide/ CH_3CONH_2 ($CH_3COCl + 2NH_3$) ⟶ CH_3CONH_2 (+ NH_4Cl)	 Allow all produce HCl IP1 can be scored by the equations in IP4, IP5 and IP6 Allow water, ethanol and ammonia are all nucleophiles/ they are all nucleophiles/all reactions are nucleophilic Allow all reactions take place at room temperature/ are very fast/spontaneous/ do not require catalysts If name or formula are given, they must both be correct but only penalise once in IP4, IP5 and IP6. Penalise minor slips e.g. missing H, pentavalent C once only in IP4, IP5 and IP6. Note the mark is for the organic product not the equation. Allow $CH_3COCl + NH_3$ ⟶ $CH_3CONH_2 + HCl$ Ignore nature of the reactions e.g. esterification/ hydrolysis/elimination/addition/substitution/condensation. Polymerisation is incorrect chemistry so will penalise a reasoning mark.

(Total for Question 18 = 6 Marks)

Question Number	Answer	Additional Guidance	Mark
19(a)(i)	An answer that makes reference to the following point: • $HCOOH + KOH \longrightarrow HCOOK + H_2O$	Allow $HCOO^- K^+$ / $HCOO^- + K^+$ Allow $HCOOH + OH^- \longrightarrow HCOO^- + H_2O$ Allow Na in place of K Ignore state symbols even if incorrect Do not award HCOO – K	**(1)**

Question Number	Answer		Additional Guidance	Mark
19(a)(ii)	• correct volume read off the graph	**(1)**	Example of calculation 22 (cm^3) This may be noted on the graph	**(2)**
	• correct concentration	**(1)**	$25.0 \times 0.15/22.0 = 0.17045$ (mol dm^{-3}) Ignore SF except 1SF Allow TE on wrong volume Correct answer scores 2	

Question Number	Answer	Additional Guidance	Mark
19(a)(iii)	An answer that makes reference to the following points: • volume at half-neutralisation **(1)** • pH value at half-neutralisation **(1)** • calculation of K_a **(1)**	11 cm^3 (Allow TE from volume in (a)(ii)) pH = 3.8 (± 0.1) (Hydrogen ion concentration = $10^{-3.8}$) $K_a = 1.5849 \times 10^{-4}$ / 0.00015849 (mol dm^{-3}) Correct answer with no working scores 3 Allow TE throughout Ignore SF If 3.9 used (Hydrogen ion concentration = $10^{-3.9}$) $K_a = 1.2589 \times 10^{-4}$ / 0.00012589 (mol dm^{-3}) If 3.7 used (Hydrogen ion concentration = $10^{-3.7}$) $K_a = 1.9953 \times 10^{-4}$ / 0.00019953 (mol dm^{-3}) Allow TE from wrong pH	**(3)**

	Alternative method 1 • pH at half-neutralisation • p K_a value • calculation of K_a	 **(1)** **(1)** **(1)**	 3.8 (± 0.1) 3.8 (± 0.1) $K_a = 10^{-3.8}$ $= 1.5849 \times 10^{-4}$ / 0.00015849 (mol dm^{-3}) Correct answer with no working scores 3 If 3.9 used Hydrogen ion concentration = $10^{-3.9}$ $= 1.2589 \times 10^{-4}$ / 0.00012589 (mol dm^{-3}) $= K_a$ If 3.7 used Hydrogen ion concentration = $10^{-3.7}$ $= 1.9953 \times 10^{-4}$ / 0.00019953 (mol dm^{-3}) $= K_a$ Allow TE from wrong pH for M2 and M3	

	Alternative method 2 (using pH of the methanoic acid at the start)			
	• pH at the start	**(1)**	2.3 Allow 2.0-2.5	
	• convert pH into H^+ concentration	**(1)**	Hydrogen ion concentration = $10^{-2.3}$ = 5.0119×10^{-3} / 0.0050119 (mol dm^{-3})	
	• calculation of K_a	**(1)**	$K_a = \frac{(5.0119 \times 10^{-3})^2}{0.15} = 1.6746 \times 10^{-4}$ / 0.00016746 (mol dm^{-3}) Correct answer with no working scores 3	
	2.0 gives a value of 6.667×10^{-4} (mol dm^{-3}) 2.1 gives a value of 4.206×10^{-4} (mol dm^{-3}) 2.2 gives a value of 2.654×10^{-4} (mol dm^{-3}) 2.3 gives a value of 1.674×10^{-4} (mol dm^{-3}) 2.4 gives a value of 1.057×10^{-4} (mol dm^{-3}) 2.5 gives a value of 3.162×10^{-3} (mol dm^{-3})		Allow TE from wrong pH (i.e. not in the range of 2.0-2.5) Ignore SF	

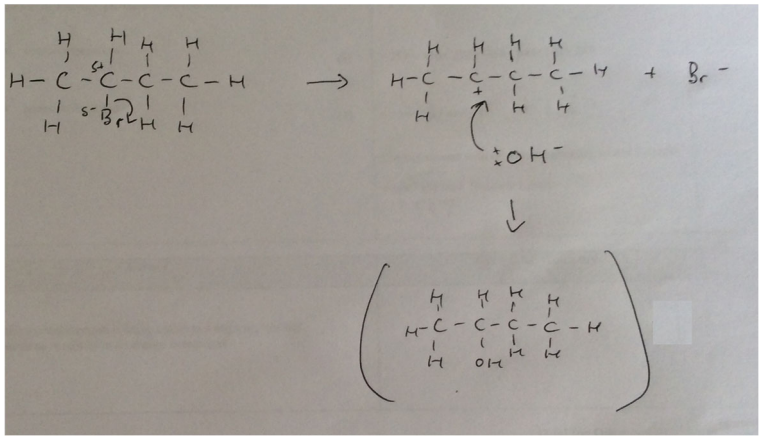
Question Number	Answer	Additional Guidance	Mark
19(b)	An answer that makes reference to the following points: • calculation of $[H^+]$ **(1)** • correct ratio **(1)**	Example of calculation $[H^+] = K_a \times \frac{[HA]}{[A^-]}$ OR $\frac{[H^+]}{K_a} = \frac{[HA]}{[A^-]}$ 2.5119×10^{-5} / 0.000025119 $\frac{[HA]}{[A^-]} = \frac{2.5118864 \times 10^{-5}}{1.3 \times 10^{-5}} = 1.9322:1$ Correct answer with no working scores 2 Allow just 1.9322 Allow rounding to 2:1 Ignore SF Reciprocal ratio correctly identified 0.5175:1 scores 2 Correct answer with no working scores 2 Allow Henderson-Hasselbach equation $pH = pKa - \log \frac{[HA]}{[A^-]}$ $4.6 = 4.8861 - \log \frac{[HA]}{[A^-]}$ **(1)** $\frac{[HA]}{[A^-]} = 1.9322:1$ **(1)** Allow just 1.9322 Ignore SF Reciprocal ratio correctly identified 0.5175:1 scores 2	**(2)**

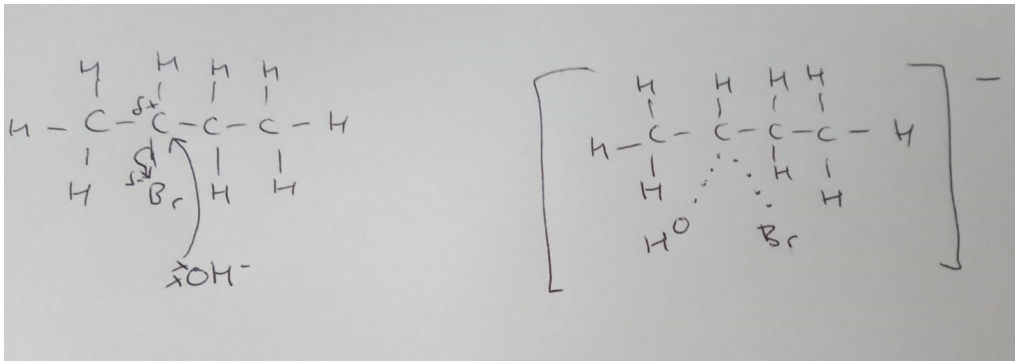
(Total for Question 19 = 8 Marks)

Question Number	Answer	Additional Guidance	Mark
20(a)(i)	An answer that makes reference to two of the following points: • 2-bromobutane: first order as doubling the concentration (in experiments 1 and 2 where OH^- is constant) the rate doubles **(1)** • hydroxide ions: zero order as doubling the concentration (in experiments 1 and 3 where 2-bromobutane is constant) the rate does not change **OR** hydroxide ions: zero order as doubling the concentration (in experiments 2 and 3) where the concentration of 2-bromobutane is halved the rate halves. **(1)**	Two correct orders with no or incorrect reasoning scores 1 Note the reasoning can be shown on the table	**(2)**

Question Number	Answer	Additional Guidance	Mark
20(a)(ii)	• rate / r = k $[C_4H_9Br]$	TE on (i) Allow displayed or structural formulae Allow rate = k $[C_4H_9Br]^1[OH^-]^0$ Allow upper case K Allow reactants in any order Do not award round brackets	**(1)**

Question Number	Answer	Additional Guidance	Mark
20(a)(iii)	An answer that makes reference to the following points: • correct calculation **(1)** • correct units **(1)**	Allow the calculation from any experiment Example of calculation from experiment 1 $1.01 \times 10^{-3} / 0.100 = 0.0101 / 1.01 \times 10^{-2}$ TE on (ii) Ignore SF s^{-1} Allow s^{-} TE on (ii)	**(2)**

Question Number	Answer	Additional Guidance	Mark
20(b)	An answer that makes reference to the following points: • M1 dipole on C-Br **and** curly arrow from bond to Br **(1)** • M2 correct intermediate **and** Br^- **(1)** • M3 curly arrow going from the lone pair on OH^- to the C^+ **(1)** 	If mechanism is inconsistent with rate equation in (a)(ii) then 2 max (for fully correct mechanism) Allow skeletal formula Ignore final product	**(3)**

	Note if the calculated order is 2 or over allow full marks for S_N2 mechanism • M1 dipole on C-Br **and** curly arrow from bond to Br $^{\delta-}$ **(1)** • M2 curly arrow going from lone pair on OH^- to C $^{\delta+}$ **(1)** • M3 correct intermediate with both Br and OH attached with ------ and negative charge **(1)** 	Ignore final product	

(Total for Question 20 = 8 Marks)

Section C

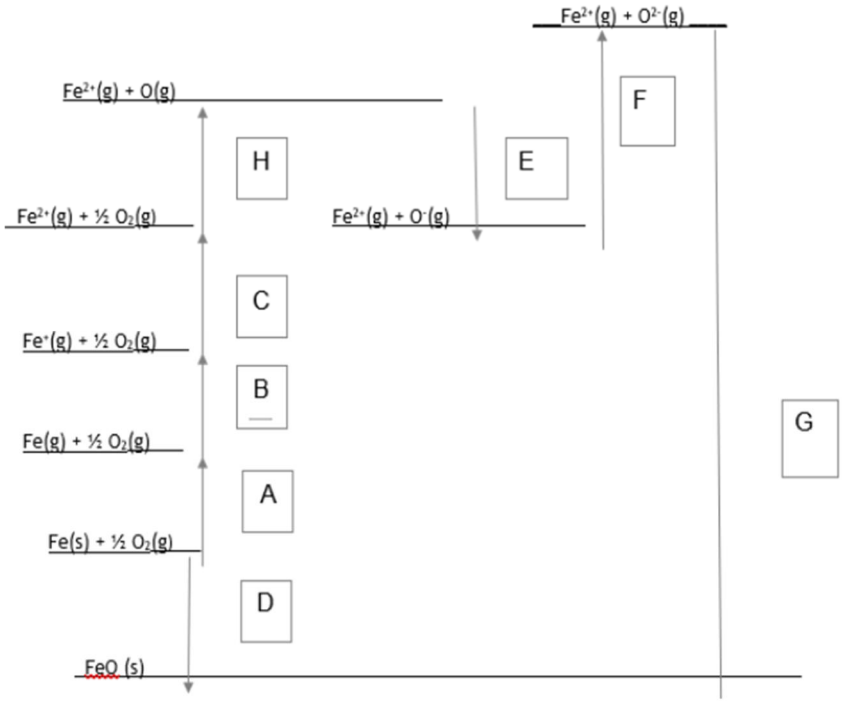
Question Number	Answer	Additional Guidance	Mark
21(a)(i)	• correct use of enthalpy data **(1)** • correct enthalpy change **(1)**	Example of calculation − (−824.2) + (3 × −110.5) = (+)492.7 (kJ mol^{-1}) Correct answer with or without working scores 2 The following score 1 for a single error: (+) 713.7 (kJ mol^{-1}) not x3 −492.7 (kJ mol^{-1}) signs reversed Allow 3SF Penalise wrong units once only in (a)(i) and (ii)	**(2)**

Question Number	Answer	Additional Guidance	Mark
21(a)(ii)	• $\sum S$ products **(1)** • $\sum S$ reactants **(1)** • $\Delta S_{system} = \sum S$ products − $\sum S$ reactants **(1)**	Example of calculation S = products (2 x 27.3) + (3 x 197.6) = 647.4 (J K^{-1} mol^{-1}) S = reactants 87.4 + (3 x 5.7) = 104.5 (J K^{-1} mol^{-1}) ΔS_{system} = 647.4 − 104.5 = (+)542.9 (J K^{-1} mol^{-1}) Correct answer with no working scores 3 Allow TE for M3	**(3)**

Question Number	Answer	Additional Guidance	Mark
21(a)(iii)	• use of $\Delta S_{surroundings} = -\frac{\Delta H}{T}$ **(1)** • at equilibrium $\Delta S_{total} = 0 = \Delta S_{surroundings} + \Delta S_{system}$ **(1)** • calculation of temperature **(1)**	Example of calculation $\Delta S_{surroundings} = -(+492.7) \times 1000/T$ $0 = -492.7 \times 1000/T + 542.9$ ≥ 907.53(K) 0.90753 scores 2 (not x 1000) Ignore SF TE on (a)(i) and (a)(ii) Correct answer based on ai and aii without working scores 3 Allow use of $\Delta G = \Delta H - T\Delta S_{system}$	**(3)**

Question Number	Answer		Additional Guidance	Mark
21(b)(i)	An answer that makes reference to the following points: • $\Delta S_{surroundings}$ **and** ΔS_{system} are positive • so ΔS_{total} will always be positive (so reaction will be feasible) **OR** Using $\Delta G = \Delta H - T\Delta S_{system}$ • Allow ΔH is negative **and** ΔS_{system} is positive • so ΔG will always be negative (so reaction will be feasible)	**(1)** **(1)** **(1)** **(1)**	Allow ΔH is negative/reaction exothermic **and** ΔS_{system} is positive M2 **dependent** on M1 M2 **dependent** on M1	**(2)**

Question Number	Answer		Additional Guidance	Mark
21(b)(ii)	An answer that makes reference to the following points: • at a higher temperature $\Delta S_{surroundings}$ will decrease • ΔS_{system} does not change (significantly) • so ΔS_{total} will decrease/become less positive	**(1)** **(1)** **(1)**	Ignore reference to $\Delta S_{total} = R\ln k$	**(3)**

Question Number	Answer	Additional Guidance	Mark
21(c)(i)	 All 7 correct 3 marks 4−6 correct 2 marks 2−3 correct 1 mark	Allow values instead of letters	(3)

Question Number	Answer	Additional Guidance	Mark
21(c)(ii)	• correct expression **(1)** • correct calculation **(1)**	Example of calculation − 759 – 416 – 272 + 3920 – 798 + 141 − 249 = (+)1567 (kJ mol^{-1}) Allow 3SF Correct answer with or without working scores 2 marks Allow 1 mark for one mistake	**(2)**

Question Number	Answer	Additional Guidance	Mark
21(c)(iii)	• the electron is being added to a negative ion **(1)** • and so there is repulsion (so energy is required) **(1)**	This can be shown by an equation Allow repulsion between the electrons	**(2)**

(Total for Question 21 = 20 Marks)

(Total for Section C = 20 Marks)

TOTAL FOR PAPER = 90 MARKS

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