Pearson Edexcel

Mark Scheme (Results)

Summer 2021

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

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Summer 2021
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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.

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	Mark
1	**The only correct answer is D** (SO_2) ***A*** *is incorrect as although it has four atoms, it has ten electrons* ***B*** *is incorrect as it has two atoms and two electrons* ***C*** *is incorrect as it has two atoms and only fourteen electrons*	1

Question Number	Correct Answer	Mark
2	**The only correct answer is A** (– 198.8) ***B*** *is incorrect as number of moles of NH_3 and H_2 have not been considered* ***C*** *is incorrect as number of moles of NH_3 and H_2 have not been considered and the expression to find the standard entropy of the system is the wrong way round* ***D*** *is incorrect as expression to find the standard entropy of the system is the wrong way round*	1

Question Number	Correct Answer	Mark
3	**The only correct answer is C** (enthalpy change of formation of Na_2SO_4) ***A*** *is incorrect as lattice energy is used to find the enthalpy change of solution* ***B*** *is incorrect as enthalpy change of hydration is used to find the enthalpy change of solution* ***D*** *is incorrect as enthalpy change of hydration is used to find the enthalpy change of solution*	1

Question Number	Correct Answer	Mark
4 (a)	**The only correct answer is C** (0.1 mol dm^{-3} HCl) ***A*** *is incorrect as final pH would be greater than 2 (weak acid)* ***B*** *is incorrect as final pH would be greater than 2 (weak acid)* ***D*** *is incorrect as final pH would be less than 1 (strong acid)*	**1**

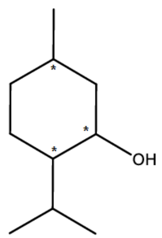
Question Number	Correct Answer	Mark
4 (b)	**The only correct answer is A** (NH_3) ***B*** *is incorrect as strong base so vertical section would begin at a higher pH / curve has a buffer region* ***C*** *is incorrect as strong base so vertical section would begin at a higher pH / curve has a buffer region* ***D*** *is incorrect as strong base so vertical section would begin at a higher pH / curve has a buffer region*	**1**

Question Number	Correct Answer	Mark
4 (c)	**The only correct answer is C** (3) ***A*** *is incorrect as only methyl orange, bromophenol blue and bromocresol green would change colour in the vertical section of the 'curve'* ***B*** *is incorrect as only methyl orange, bromophenol blue and bromocresol green would change colour in the vertical section of the 'curve'* ***D*** *is incorrect as methyl orange, bromophenol blue and bromocresol green would change colour in the vertical section of the 'curve'*	**1**

Question Number	Correct Answer	Mark
5	**The only correct answer is D** (S_N1 ; Two steps in mechanism) ***A*** *is incorrect as the halogenoalkane is tertiary so mechanism would be* S_N1 *which has two steps* ***B*** *is incorrect as although the mechanism has two steps the halogenoalkane is tertiary so mechanism would be* S_N1 ***C*** *is incorrect as although the mechanism is* S_N1*, it would have two steps*	**1**

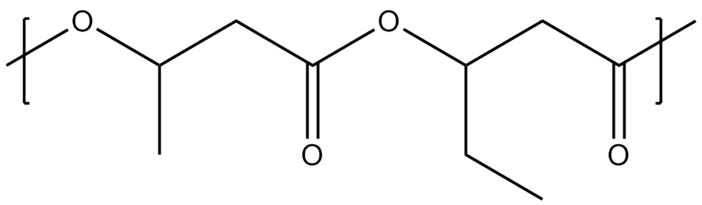
Question Number	Correct Answer	Mark
6	**The only correct answer is D** (Step 2 is the rate determining step, the overall order is 3) ***A*** *is incorrect as Step 3 is fast* ***B*** *is incorrect as Step 3 is fast* ***C*** *is incorrect as the overall order is 3*	**1**

Question Number	Correct Answer	Mark
7	**The only correct answer is C (**– gradient x *R*) ***A*** *is incorrect the Arrhenius equation has been rearranged incorrectly* ***B*** *is incorrect as the gradient of the graph is negative, so this expression would give a negative value for an activation energy* ***D*** *is incorrect as the gradient of the graph is negative, so this expression would give a negative value for an activation energy*	**1**

Question Number	Correct Answer	Mark
8 (a)	**The only correct answer is C** (3)  ***A*** *is incorrect as menthol has 3 chiral carbon atoms* ***B*** *is incorrect as menthol has 3 chiral carbon atoms* ***D*** *is incorrect as menthol has 3 chiral carbon atoms*	**1**

Question Number	Correct Answer	Mark
8 (b)	**The only correct answer is B** (Q) ***A*** *is incorrect as this carbon would produce a peak between 0 and 60 ppm* ***C*** *is incorrect as this carbon would produce a peak between 0 and 60 ppm* ***D*** *is incorrect as this carbon would produce a peak between 0 and 60 ppm*	**1**

Question Number	Correct Answer	Mark
8 (c)	**The only correct answer is B** (Two) ***A*** *is incorrect as the oxidation product is a ketone, so would not react with* PCl_5 ***C*** *is incorrect as the oxidation product is a ketone, so would not react with Fehling's solution* ***D*** *is incorrect as the oxidation product is a ketone, so would not react with* PCl_5 *but would react with 2,4-dinitrophenylhydrazine*	**1**

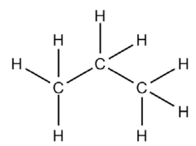
Question Number	Correct Answer	Mark
9 (a)	**The only correct answer is B**  ***A*** *is incorrect as the repeat unit has an extra oxygen* ***C*** *is incorrect as there is an extra carbon at the left-hand end of the repeat unit* ***D*** *is incorrect as the repeat unit has an extra oxygen and the structure is incorrect*	**1**

Question Number	Correct Answer	Mark
9 (b)	**The only correct answer is B (**hydrolysis) ***A*** *is incorrect as condensation is the reaction when the polymer forms* ***C*** *is incorrect as hydration is the addition of water to a C=C bond* ***D*** *is incorrect as hydrogen has not been added in a reduction reaction*	**1**

Question Number	Correct Answer	Mark
10	**The only correct answer is D** (CH_3COCl) ***A*** *is incorrect as the reaction with ketone would NOT form an N-substituted amide* ***B*** *is incorrect as any reaction with the carboxylic acid would be too slow at RT* ***C*** *is incorrect as any reaction with the ester would be too slow at RT*	**1**

Question Number	Correct Answer	Mark
11(a)	**The only correct answer is B** (68 mm) ***A*** *is incorrect as it is a factor of 10 to large* ***C*** *is incorrect as it is the distance moved by the amino acids* ***D*** *is incorrect as it is the expression for* R_f *has been inverted*	**1**

Question Number	Correct Answer	Mark
11 (b)	**The only correct answer is A** (argon) ***B*** *is incorrect as the carrier gas must be inert* ***C*** *is incorrect as the carrier gas must be inert* ***D*** *is incorrect as the carrier gas must be inert*	**1**

Question Number	Correct Answer	Mark
12	**The only correct answer is C**  ***A*** *is incorrect as the molar mass to 4 dp is 44.0265* ***B*** *is incorrect as the molar mass to 4 dp is 44.0265* ***D*** *is incorrect as the molar mass to 4 dp is 43.9898*	**1**

Question Number	Correct Answer	Mark
13	**The only correct answer is D** (8) ***A*** *is incorrect as the number of optical isomers =* 2^n*, where n = number of chiral centres* ***B*** *is incorrect as the number of optical isomers =* 2^n*, where n = number of chiral centres* ***C*** *is incorrect as the number of optical isomers =* 2^n*, where n = number of chiral centres*	1

Question Number	Correct Answer	Mark
14	**The only correct answer is D** (Structure D) ***A*** *is incorrect as it is identical to B and C* ***B*** *is incorrect as it is identical to A and C* ***C*** *is incorrect as it is identical to A and B*	1

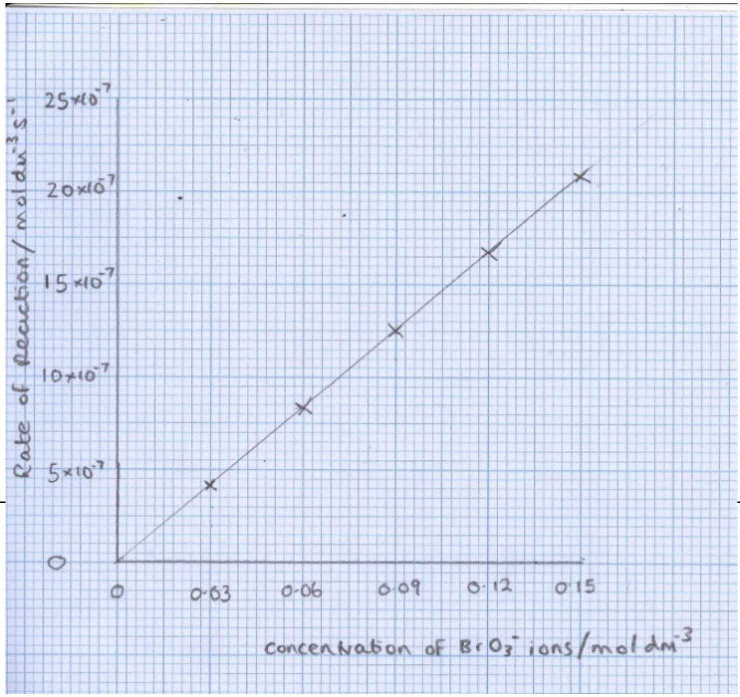
(Total for Section A = 20 marks)

Section B

Question Number	Acceptable Answers	Additional Guidance	Mark
15 (a)	• correct expression for $\Delta S_{surroundings}$ **(1)** • correct evaluation **and** correct units **and** correct sign **(1)**	Example of calculation $- \Delta H \div T = - 25.7 \div 298$ $- 0.086242$ kJ K^{-1} mol^{-1} / $- 86.242$ J K^{-1} mol^{-1} Ignore SF except 1 SF Correct answer with no working scores (2) Allow TE in M2 for use of $\Delta H \div T$ Comment Mark value first – if correct, with units and sign award 2 marks For units allow kJ K^{-} mol^{-} / J K^{-} mol^{-}	**2**

Question Number	Acceptable Answers	Additional Guidance	Mark
15(b)	An explanation that makes reference to: • ΔS_{system} must be positive **(1)** • ΔS_{system} > 86.24 J mol^{-1} / answer to (a) **(1)** • (as compound does dissolve) ΔS_{total} is > 0 / positive **(1)**	Allow 'ΔS_{system} is more positive' Allow $T\Delta S_{system}$ is greater in magnitude / more negative than ΔH ΔG is negative If answer to (a) is positive , then M1 and M2 will be • ΔS_{system} could be positive or negative • ΔS_{system} smaller in magnitude than answer to (a) / $T\Delta S_{system}$ is greater than ΔH	**3**

(Total for Question 15 = 5 marks)

Question Number	Acceptable Answers		Additional Guidance	Mark
16(a)(i)	• rate against concentration graph with axes labelled, inc. units	(1)	Do not award M1 if axes are the other way around Allow $[BrO_3^-]$ / mol dm^{-3} Ignore 'initial'	3
	• suitable scale chosen including the origin	(1)	Points cover at least half available space in both directions	
	• all points plotted correctly and straight line of best fit. 	(1)	Allow ±½ a square Allow if line does not extend to the origin Do not award M3 if scale is non-linear	

Question Number	Acceptable Answers	Additional Guidance	Mark
16(a)(ii)	• justification of first order	(First order with respect to BrO_3^-) as straight line (through origin / 0,0) Allow line with constant gradient Allow rate is (directly) proportional to concentration Allow use of data from graph to justify order Do not award 'constant half life'	**1**

Question Number	Acceptable Answers	Additional Guidance	Mark
16(b)(i)	• deduce order wrt Br^- ions **(1)** • deduce order wrt H^+ ions **(1)**	1st order 2nd order	**2**

Question Number	Acceptable Answers	Additional Guidance	Mark
16(b)(ii)	• rate equation shown	rate **=** $k[BrO_3^-][Br^-][H^+]^2$ Allow TE from (b)(i)	**1**

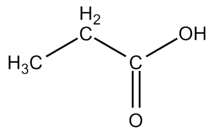
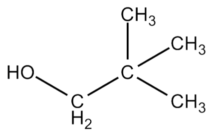
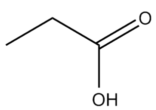
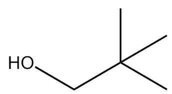
Question Number	Acceptable Answers	Additional Guidance	Mark
16(b)(iii)	• rearrangement of rate equation **(1)** • evaluation of *k* **(1)** • units for *k* **(1)**	<u>Example of calculation</u> k = rate/$[BrO_3^-][Br^-][H^+]^2$ / $k = 1.52 \times 10^{-5} \div (0.062 \times 0.21 \times 0.4^2)$ 7.2965×10^{-3} ignore SF except 1SF M1 can be subsumed within award of M2 $dm^9\ mol^{-3}\ s^{-1}$ allow in any order Correct answer with no working scores (3) TE on (b)(ii) Allow use of data from Run 2 or Run 3	**3**

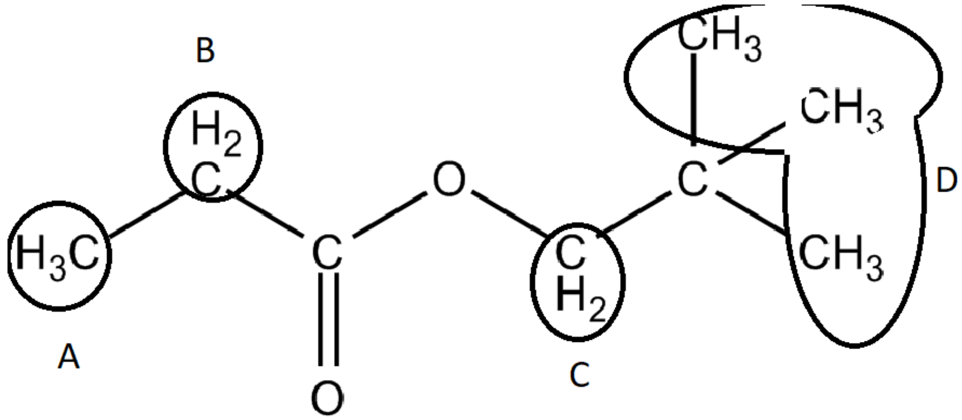
Question Number	Acceptable Answers	Additional Guidance	Mark
16(c)	An answer that makes reference to: • reactants a**d**sorb onto palladium/catalyst surface **(1)** • this weakens bonds in reactants **(1)** • products then desorb (from catalyst surface) **(1)**	Allow bromate ((V)) ions for reactants Allow 'bond/bind onto catalyst surface' Do not award a**b**sorb Ignore comments related to orientation Allow 'products de-adsorb' / products released (from catalyst surface) If no other mark is awarded allow one for: reaction follows an alternative pathway / route / mechanism of lower activation energy	**3**

(Total for Question 16 = 13 marks)

<table>
<tr><th>Question Number</th><th>Acceptable Answers</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr>
<td rowspan="5">17(a)</td>
<td>• calculation of moles of C, H and O (1)</td>
<td>
<table>
<tr><td>element</td><td>moles</td><td>ratio</td></tr>
<tr><td>C</td><td>66.7÷12
=5.56</td><td>5.56÷1.3875
= 4</td></tr>
<tr><td>H</td><td>11.1÷1
= 11.1</td><td>11.1÷1.3875
= 8</td></tr>
<tr><td>O</td><td>22.2÷16
=1.3875</td><td>1.3875÷1.3875
= 1</td></tr>
</table>
</td>
<td rowspan="5">2</td>
</tr>
<tr><td>• calculation of ratio and identify that ratio matches molecular formula (1)</td><td>Ratio C_4H_8O matches $C_8H_{16}O_2$</td></tr>
<tr><td>OR</td><td></td></tr>
<tr><td>• calculate molar mass of Y (1)</td><td>Molar mass = 144 (g mol^{-1})</td></tr>
<tr><td>• calculate % of each element (1)</td><td>C=96÷144x100 = 66.7%
H=16÷144x100 = 11.1%
O=32÷144x100 = 22.2%</td></tr>
</table>

Question Number	Acceptable Answers	Additional Guidance	Mark
17(b)(i)	2,2-dimethylpropyl propanoate **(2)**	Any name with '-propyl propanoate' scores 1 propyl-2,2-dimethyl propanoate scores 1 2,2-dimethyl propanoate scores 1 2,2-dimethylpropyl ethanoate scores 1	**2**

Question Number	Acceptable Answers	Additional Guidance	Mark
17(b)(ii)	  **OR**  	Both structures required for mark Allow structures of propanoyl chloride / propanoic anhydride Allow any combination of correct skeletal, structural or displayed formulae. Ignore names even if incorrect Do not award connectivity to hydroxyl group via H atom	**1**

Question Number	Acceptable Answers	Additional Guidance	Mark
17(c)(i)		Labels B C and D can be used interchangeably as long as the three proton environments are identified correctly. Allow 3 methyl groups to be circled individually but with a single label / labels pointing to all 3	1

<table>
<tr><th>Question Number</th><th>Acceptable Answers</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td>17(c)(ii)</td><td>

Hydrogen environment	Splitting pattern of peak	Relative peak area
(A)	(triplet)	(3)
B	quartet	2
C	singlet	2
D	singlet	9

Note : allow ‘quadruplet’ as alternative for quartet /
‘single’ as alternative for singlet

Do not award ‘quadrat’</td><td>1 mark for each row.

But If two or more rows are incorrect then award whichever of these alternatives is higher
Allow 2 marks for 3 correct splitting patterns.
OR
Allow 1 mark for 3 correct peak areas.
OR
Allow 1 mark for correct row

marked consequentially on the labelling in 17(c)(i)</td><td>3</td></tr>
</table>

(Total for Question 17 = 9 marks

<table>
<tr><th>Question Number</th><th>Acceptable Answers</th><th>Additional Guidance</th><th>Mark</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><th>Number of indicative marking points seen in answer</th><th>Number of marks awarded for indicative marking points</th></tr>
<tr><td>6</td><td>4</td></tr>
<tr><td>5-4</td><td>3</td></tr>
<tr><td>3-2</td><td>2</td></tr>
<tr><td>1</td><td>1</td></tr>
<tr><td>0</td><td>0</td></tr>
</table>

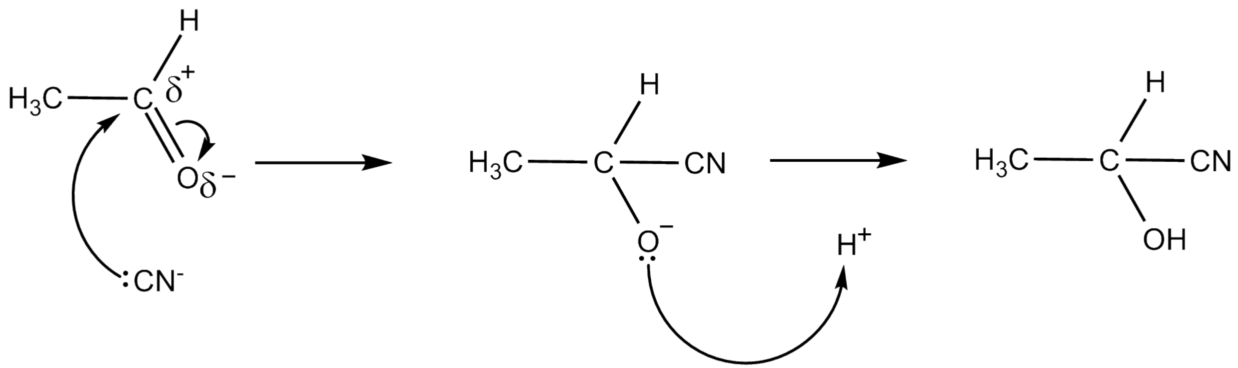
The following table shows how the marks should be awarded for structure and lines of reasoning
<table>
<tr><th></th><th>Number of marks awarded for structure of answer and sustained lines of reasoning</th></tr>
<tr><td>Answer shows a coherent logical structure with linkages and fully sustained lines of reasoning demonstrated throughout</td><td>2</td></tr>
<tr><td>Answer is partially structured with some linkages and lines of reasoning</td><td>1</td></tr>
<tr><td>Answer has no linkages between points and is unstructured</td><td>0</td></tr>
</table>

Indicative Points</td><td>Guidance on how the mark scheme should be applied:
The mark for indicative content should be added to the mark for lines of reasoning. For example, a response with four indicative marking points that is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning).
If there were no linkages between the points, then the same indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and zero marks for linkages).</td><td>6</td></tr>
</table>

	• **IP1** Bonding in sodium chloride is (almost) 100% ionic bonds **and** as the theoretical and Born-Haber values are (very) similar • **IP2** Bonding in magnesium iodide has some covalent character **and** as theoretical and Born-Haber values are (significantly) different • **IP3** Anion is (more) polarised in magnesium iodide (than sodium chloride) • **IP4** Magnesium ion has a greater charge density (than sodium ion), so greater polarising power • **IP5** Iodide ion is larger (than chloride ion), so is more easily polarised • **IP6** Magnesium iodide has stronger bonding than sodium chloride because the charge on the magnesium ion is twice as large (as the charge on the sodium ion)	If neither IP1 or IP2 scored can get 1IP for Bonding in sodium chloride is (almost) 100% ionic bonds and bonding in magnesium iodide has some covalent character ALLOW Magnesium ion has a greater charge/smaller than sodium ion, so greater polarising power polarisation must be mentioned at least once in IP3, IP4 and IP5 Penalise use of 'atoms' instead of ions once only in IP3 IP4 and IP5 Penalise lack of comparative language once only in IP4, IP5 and IP6 Allow magnesium iodide has stronger bonding (than expected) due to polarisation / covalent character Allow both compounds have strong bonds as large amounts of energy needed to break up lattice / released when lattice forms / needed to break many strong bonds	

(Total for Question 18 = 6 marks)

Question Number	Acceptable Answers	Additional Guidance	Mark
19(a)(i)	• arrow from lone pair on carbon of cyanide ion to carbonyl carbon **(1)** • dipoles on carbon and oxygen in carbonyl bond **and** arrow from carbonyl bond to oxygen or just beyond **(1)** • structure of intermediate, including charge **(1)** • arrow from lone pair of oxygen in intermediate to hydrogen ion / H in HCN **(1)**	Penalise absence of lone pair only once in M1, M3 and M4 If HCN used to protonate in step 2, dipole on HCN and curly arrow to break HCN bond are **not** required Ignore product	4



Question Number	Acceptable Answers	Additional Guidance	Mark
19(a)(ii)	The prediction is incorrect because • ethanal is planar around the carbonyl carbon atom / planar around the CHO **(1)** • (so in Step 1) the (carbonyl) carbon can be attacked from above or below **(1)** • hence both stereoisomers (of intermediate / product) will form in equal amounts **or** so product mixture is racemic / rotates the plane of plane-polarised light equally in both directions **(1)**	Accept planar at the site of the nucleophilic attack / planar about C=O Do not award planar molecule / cation / intermediate Allow attack from any direction / either side Ignore 'has no effect on the plane of plane-polarised light' Ignore comments related to SN1 or SN2 If no other mark scored allow 1 mark for idea that product will rotate plane of plane polarised light as it has a chiral centre / carbon	**3**

Question Number	Acceptable Answers	Additional Guidance	Mark
19(a)(iii)	• hydrolysis **(1)** • (dilute) hydrochloric acid / HCl((aq)) **(1)** • heat (under reflux) / reflux **(1)** • $CH_3CH(OH)CN + 2H_2O + H^+ \rightarrow CH_3CH(OH)COOH + NH_4^+$ **(1)** OR $CH_3CH(OH)CN + 2H_2O \rightarrow CH_3CH(OH)COOH + NH_3$ OR $CH_3CH(OH)CN + 2H_2O + HCl \rightarrow CH_3CH(OH)COOH + NH_4Cl$ OR $CH_3CH(OH)CN + H_2O + OH^- \rightarrow CH_3CH(OH)COO^- + NH_3$ **and** $CH_3CH(OH)COO^- + H^{+\,-} \rightarrow CH_3CH(OH)COOH$	Allow any strong acid by name or formula Allow sodium hydroxide **followed by** any (strong) acid Ignore conc / concentrated Allow 'boil' for heat Ignore 'warm' Allow NaOH for OH^- Allow HCl for H^+ Ignore state symbols even if incorrect	**4**

Question Number	Acceptable Answers	Additional Guidance	Mark
19(b)	• $CH_3CH(OH)COOH + NaHCO_3 \rightarrow CH_3CH(OH)COO^-Na^+ + H_2O + CO_2$ OR $H^+ + HCO_3^- \rightarrow H_2O + CO_2$	Allow $CH_3CH(OH)COONa$ Allow H_2CO_3 Ignore state symbols even if incorrect Do not award if covalent bond shown between O and Na	**1**

Question Number	Acceptable Answers	Additional Guidance	Mark
19(c)(i)	• (large concentration of) HCO_3^- react with (extra) H^+ ions **(1)** • equilibrium 1 moves to the RHS to keep concentration of H^+ ions constant / H_2CO_3 forms to keep concentration of H^+ ions constant **(1)** • equilibrium 2 moves to RHS to form CO_2 (which can be excreted from the body) / H_2CO_3 then forms CO_2 (and water) **(1)**	Allow ratio of [HCO_3-] to [H_2CO_3] remains constant / ratio of [salt] to [acid] remains constant Allow H_3O^+ for H^+ Allow equilibrium 1 moves to the RHS to remove excess H^+ ions / H_2CO_3 forms to remove excess H^+ ions If no reference to H^+ and CO_2 in M2 and M3 but direction of movement of equilibria are correct in both cases, allow 1 mark	**3**

Question Number	Acceptable Answers	Additional Guidance	Mark
19(c)(ii)	• calculation of $[H^+]$ / $[H_3O^+]$ **(1)** • K_a expression **(1)** • rearrangement of K_a expression and calculation of $[HCO_3^-] : [H_2CO_3]$ **(1)** OR • calculation of pK_a **(1)** • Henderson Hasselbach expression **(1)** • rearrangement of K_a expression and calculation of $[HCO_3^-] : [H_2CO_3]$ **(1)**	$[H^+] = 10^{-7.41}$ / = 3.8905×10^{-8} $K_a = \frac{[HCO_3^-][H^+]}{[H_2CO_3]}$ Allow $[H_3O^+]$ in K_a Do not award $[H_2O]$ in K_a expression $[HCO_3^-] : [H_2CO_3]$ $= 4.5 \times 10^{-7} \div 3.8905 \times 10^{-8} = 11.567 : 1 = 11.6$ (: 1) Ignore SF except 1 Allow correct rounding of $[H^+]$ to 3.9×10^{-8} Allow 1 : 0.086444 if it's clear that 1 relates to $[HCO_3^-]$ $pK_a = -\log 4.5 \times 10^{-7} = 6.3468$ $pH = pK_a + \log([HCO_3^-] \div [H_2CO_3])$ $7.41 - 6.3468 = \log([HCO_3^-] \div [H_2CO_3])$ $[HCO_3^-] : [H_2CO_3] = 11.567$ (: 1) Correct answer with no working scores (3) If final answer close, check for and allow correct rounding	3

(Total for Question 19 = 18 marks)

(Total for Section B = 51 marks)

Question Number	Acceptable Answers	Additional Guidance	Mark
20(a)(i)	When the pressure is increased • equilibrium moves to RHS and yield (of chlorine) increases **(1)** • as fewer gas molecules on the RHS (5:4) **(1)** • K_p remains constant **(1)**	Marking points are independent Allow 'forward reaction favoured so yield (of chlorine) increases' If numbers are given they must be correct Allow use of 4/5 ratio to justify decrease in quotient / greater increase in denominator as total pressure increases, (so eqm moves (to RHS) to restore Kp) Allow 'change in pressure has no effect on value for K_p'	**3**

Question Number	Acceptable Answers	Additional Guidance	Mark
20(a)(ii)	When the temperature increases • equilibrium moves to LHS as (forward) reaction is exothermic **(1)** • K_p decreases and so yield (of chlorine) decreases **(1)**	Marking points are independent Allow reaction moves in endothermic direction Allow increase in T reduces ΔS_{surr} and hence ΔS_{total} decreases	**2**

Question Number	Acceptable Answers	Additional Guidance	Mark
20(a)(iii)	When a catalyst is used • rate of backward and forward reactions increases by same amount **(1)** • so K_p **and** yield (of chlorine) is unchanged **(1)**		**2**

Question Number	Acceptable Answers	Additional Guidance	Mark
20(b)(i)			3

Substance	Initial amount / mol	Equilibrium amount / mol	Mole fraction at equilibrium
HCl	0.850	**0.350**	**0.26415**
O_2	0.600	**0.475**	**0.35849**
H_2O	0	**0.250**	**0.18868**
Cl_2	0	0.250	0.189
Total moles at equilibrium = **1.325**			

For mole fractions allow e.g. 0.350 ÷ 1.325

allow correct rounding

All values correct scores (3)

M1 1 correct equilibrium amount **(1)**

Ignore SF except 1 SF

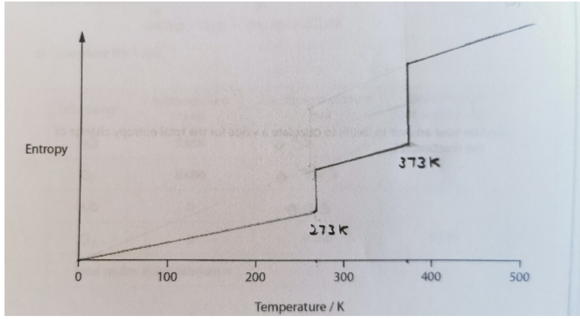
M2 other 2 correct equilibrium amounts **(1)**

M3 Consequential total moles and mol fraction **(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
20(b)(ii)	$K_p = p(H_2O)^2\, p(Cl_2)^2 \div p(HCl)^4\, p(O_2)$	Ignore parentheses Do not award square brackets	**1**

Question Number	Acceptable Answers	Additional Guidance	Mark
20(b)(iii)	• mole fractions converted to partial pressure **(1)**	Example of calculation allow TE from 20b(i) **substance** / **pp**: HCl 0.39623; O_2 0.53774; H_2O 0.28302; Cl_2 0.28302 Allow e.g. for pp(HCl) ; 0.26415 x 1.5	**3**
	• final value for K_p given to 2 or 3SF **(1)**	$\frac{(0.28302)^2(0.28302)^2}{(0.39623)^4(0.53770)}$ = 0.48407 (Note = 0.48408 if no rounding) = 0.48 / 0.484 No TE for M2 for incorrect expression Check final answer if close, and allow if correct rounding used in working	
	• correct units given **(1)**	atm^{-1} allow TE for M3 from incorrect expression in (b)(ii)	

Question Number	Acceptable Answers	Additional Guidance	Mark
20(b)(iv)	• recall of expression for ΔS_{total} **(1)** • calculation of ΔS_{total} **(1)**	$\Delta S_{total} = R \ln K$ = 8.31 x – 0.726 = – 6.033 (J K^{-1} mol^{-1}) Allow TE / rounded value from (iii) No TE for M2 from incorrect expression Ignore SF except 1 SF Ignore units even if incorrect NOTE ΔS_{total} = – 6.0289 if no rounding from (b)(iii) ΔS_{total} = – 6.0993 if 0.48 used from b(iii)	**2**

Question Number	Acceptable Answers	Additional guidance	Mark
20(c)	• general shape of increase from left to right **ALLOW** straight line **(1)** • two vertical stages for melting and boiling **(1)** • include the use of 273K for melting and 373K for boiling temperature either by labelling or position on x axis **(1)**	Allow horizontal sections allowed between phase changes for M1 M3 is independent of M2, providing a line is drawn <u>Example of graph</u>  	**3**

(Total for Question 20 = 19 marks)
(Total for Section C = 19 marks)
Total for Paper = 90 marks

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