Mark Scheme (Results)

January 2021

Pearson Edexcel International Advanced Level In Chemistry (WCH14)
Paper 1: Rates, Equilibria and Further Organic Chemistry

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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

Question Number	Answer	Mark
1	**The only correct answer is A** (carbon dioxide, CO_2) ***B*** *is not correct because copper is a solid at 298 K and 1 atm pressure so has the lowest entropy* ***C*** *is not correct because ethanol is a liquid at 298 K and 1 atm pressure and has a lower entropy than a gas* ***D*** *is not correct because hydrogen is also a gas at 298 K and 1 atm pressure, but its molecules are smaller than carbon dioxide molecules*	**(1)**

Question Number	Answer	Mark
2	**The only correct answer is B** (reactions **P** and **Q** only) ***A*** *is not correct because both reactions* ***P*** *and* ***Q*** *have a positive value for* ΔS_{total} ***C*** *is not correct because reaction* ***R*** *has a negative value for* ΔS_{total} *so is not feasible* ***D*** *is not correct because both reactions* ***R*** *and* ***S*** *have a negative value for* ΔS_{total} *so are not feasible*	**(1)**

Question Number	Answer	Mark
3	**The only correct answer is A** ($\frac{1}{2}Br_2(l) \rightarrow Br(g)$) ***B*** *is not correct because the standard enthalpy change of atomisation refers to the formation of 1 mol of atoms* ***C*** *is not correct because bromine's standard state is as a liquid* ***D*** *is not correct because bromine exists as diatomic molecules in the liquid state in its standard state and only 1 mol of atoms should be formed*	**(1)**

Question Number	Answer	Mark
4(a)	**The only correct answer is C** (potassium bromide) ***A*** *is not correct because the least exothermic lattice energy is between the largest ions with the smallest charge and calcium ions are smaller and have a higher charge than potassium ions* ***B*** *is not correct because the least exothermic lattice energy is between the largest ions with the smallest charge and magnesium ions are smaller and have a higher charge than potassium ions* ***D*** *is not correct because sodium ions are smaller than potassium ions*	**(1)**

Question Number	Answer	Mark
4(b)	**The only correct answer is B** (magnesium chloride) ***A*** *is not correct because* Ca^{2+} *ions are larger than magnesium ions so will polarise less* ***C*** *is not correct because* K^{+} *ions are larger than magnesium ions and have a lower charge so will polarise less* ***D*** *is not correct because* Na^{+} *ions are larger than magnesium ions and have a lower charge so will polarise less*	**(1)**

Question Number	Answer	Mark
5	**The only correct answer is C** (the total entropy when KCl dissolves is positive) ***A*** *is not correct because the enthalpy change of hydration for all ions and lattice energy for all ionic compounds are exothermic so this does not explain why KCl is soluble* ***B*** *is not correct because the enthalpy change of hydration for all ions and lattice energy for all ionic compounds are exothermic* ***D*** *is not correct because the total entropy must be positive for a spontaneous reaction*	**(1)**

Question Number	Answer	Mark
6	**The only correct answer is A** (3.61×10^{-5}) ***B*** *is not correct because R and* ΔS_{total} *are the wrong way up* ***C*** *is not correct because the temperature should not be included* ***D*** *is not correct because the negative sign for* ΔS_{total} *has been omitted*	**(1)**

Question Number	Answer	Mark
7	**The only correct answer is A** ($CH_3COCH_3 + H^+ \rightleftharpoons CH_3C(O^+H)CH_3$ fast, $CH_3C(O^+H)CH_3 \rightarrow CH_3C(OH)=CH_2 + H^+$ slow, $CH_3C(OH)=CH_2 + I_2 \rightarrow CH_3COCH_2I + HI$ fast) ***B*** *is not correct because the steps up to and including the slow step must include* CH_3COCH_3 *and* H^+ *ions and* I_2 *must only be involved in a fast step* ***C*** *is not correct because the steps up to and including the slow step must include* CH_3COCH_3 *and* H^+ *ions and* I_2 *must only be involved in a fast step* ***D*** *is not correct because the steps up to and including the slow step must include* CH_3COCH_3 *and* H^+ *ions and* I_2 *must only be involved in a fast step*	**(1)**

Question Number	Answer	Mark
8	**The only correct answer is C** (1.0×10^{-3}) ***A*** *is not correct because the initial rate and the rate constant have been mixed up* ***B*** *is not correct because [A] has not been squared* ***D*** *is not correct because [B] has been included*	**(1)**

Question Number	Answer	Mark
9(a)	**The only correct answer is B** (1.95) ***A*** *is not correct because* pK_a *has not been converted to* K_a ***C*** *is not correct because this is the pH of 0.100 mol* dm^{-3} *ethanoic acid* ***D*** *is not correct because the square root of* K_a *x* $[CH_2ClCOOH]$ *has not been used to calculate* $[H^+]$	**(1)**

Question Number	Answer	Mark
9(b)	**The only correct answer is C** (Acid: $CH_2ClCOOH$, Conjugate base: CH_2ClCOO^-) ***A*** *is not correct because ethanoic acid has a higher* pK_a *than chloroethanoic acid so acts as a base in this reaction* ***B*** *is not correct because ethanoic acid has a higher* pK_a *than chloroethanoic acid so acts as a base in this reaction* ***D*** *is not correct because chloroethanoic acid loses a proton when it acts as an acid*	**(1)**

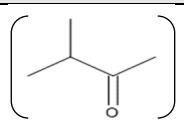
Question Number	Answer	Mark
10(a)	**The only correct answer is B** (region **U**) ***A*** *is not correct because in region* ***T*** *there is only aqueous ammonia at the start of the titration* ***C*** *is not correct because in region* ***V****, the vertical part of the graph, represents the end-point of the titration* ***D*** *is not correct because in region* ***W*** *all the aqueous ammonia has been neutralised*	**(1)**

Question Number	Answer	Mark
10(b)	**The only correct answer is A** (methyl red) ***B*** *is not correct because phenol red has a pH range of 6.8 to 8.4 and 8.4 is not in the vertical region* ***C*** *is not correct because phenolphthalein has a pH range of 8.2 to 10.0 and this is not in the vertical region* ***D*** *is not correct because thymol blue has a pH range of 1.2 to 2.8 and this is not in the vertical region*	**(1)**

Question Number	Answer	Mark
10(c)	**The only correct answer is B** (5.8) ***A*** *is not correct because this is the approximate pH when excess hydrochloric acid has been added* ***C*** *is not correct because this is the approximate pH near the start of the end point when there is still excess aqueous ammonia* ***D*** *is not correct because this is the approximate pH of aqueous ammonia*	**(1)**

Question Number	Answer	Mark
11	**The only correct answer is B** (9.77×10^{-2} (mol dm^{-3})) ***A*** *is not correct because the two volumes have been reversed* ***C*** *is not correct because a mole ratio of 1:1 has been used instead of 1 mol of acid : 2 mol NaOH* ***D*** *is not correct because a mole ratio of 2 mol of acid : 1 mol NaOH has been used*	**(1)**

Question Number	Answer	Mark
12	**The only correct answer is C** (tertiary only) ***A*** *is not correct because primary bromoalkanes react by an S_N2 mechanism and the product would be optically active* ***B*** *is not correct because secondary bromoalkanes react by an S_N1 or an S_N2 mechanism and the product could be optically active* ***D*** *is not correct because primary and secondary bromoalkanes react by S_N1 and S_N2 mechanisms and the products could be optically active*	**(1)**

Question Number	Answer	Mark
13	**The only correct answer is D**  ***A*** *is not correct because this is an aldehyde and it would give a silver mirror with Tollens' reagent* ***B*** *is not correct because this is an aldehyde and it would give a silver mirror with Tollens' reagent* ***C*** *is not correct because this is an aldehyde and it would give a silver mirror with Tollens' reagent*	**(1)**

Question Number	Answer	Mark
14	**The only correct answer is C** (CH_3COONa and $CH_3CH_2CH_2OH$) ***A*** *is not correct because ethanoic acid reacts with NaOH to form the sodium salt* ***B*** *is not correct because ethanoic acid reacts with NaOH to form the sodium salt and propan-1-ol does not react with NaOH* ***D*** *is not correct because propan-1-ol does not react with NaOH*	**(1)**

Question Number	Answer	Mark
15	**The only correct answer is C** (90.5 %) ***A*** *is not correct because the molar masses have been used for the incorrect substances and the amount of ethanoic acid should be the numerator of the fraction* ***B*** *is not correct because the masses have not been converted into moles and the amount of ethanoic acid should be the numerator of the fraction* ***D*** *is not correct because the masses have not been converted into moles*	**(1)**

Question Number	Answer	Mark
16	**The only correct answer is D** (weak attraction to stationary phase, strong attraction to mobile phase) ***A*** *is not correct because if there was a strong attraction to the stationary phase the component would not move very far and would have a low* R_f *value* ***B*** *is not correct because if there was a weak attraction to the mobile phase the component would not move very far and would have a low* R_f *value* ***C*** *is not correct because if there was a weak attraction to the mobile phase the component would not move very far and would have a low* R_f *value*	**(1)**

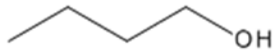
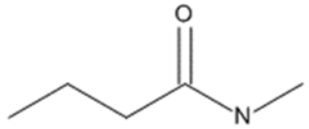
(Total for Section A = 20 marks)

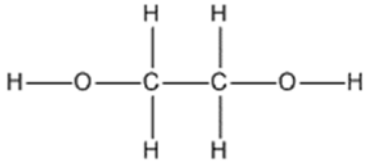
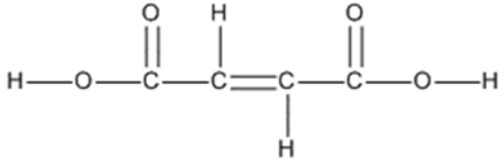
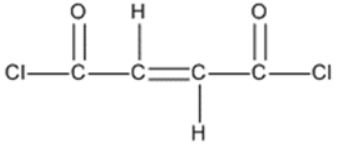
Section B

Question Number	Answer	Additional Guidance	Mark
17(a)(i)	An answer that makes reference to the following point: • it / lactic acid is non-superimposable on its mirror image	Allow there are four different atoms / groups attached to a carbon (atom) Allow it is chiral / has a chiral centre / has a chiral carbon (atom) / has an asymmetric carbon (atom) Ignore rotates the plane of plane-polarised light Do not award four different molecules attached to a carbon (atom)	**(1)**

Question Number	Answer	Additional Guidance	Mark
17(a)(ii)	An answer that makes reference to the following point: • it is a racemic mixture **or** contains equal amounts of the two enantiomers / (optical) isomers	Allow rotations caused by both enantiomers / isomers cancel Ignore just contains two enantiomers / isomers Do not award plane-polarised light cannot pass through the solution	**(1)**

Question Number	Answer	Additional Guidance	Mark
17(a)(iii)	• CH_2=CHCOOH	Allow any combination of structural or displayed formulae or skeletal formulae / COOHCH=CH_2	**(1)**

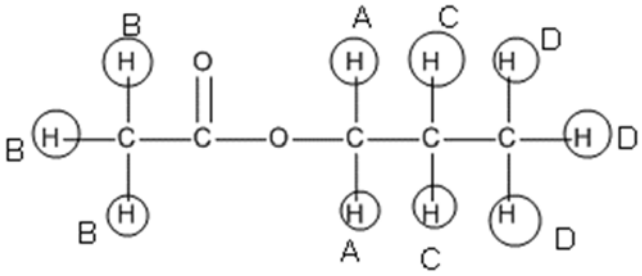
Question Number	Answer	Additional Guidance	Mark
17(b)	• **X**: butan-1-ol **or**  **or** $CH_3CH_2CH_2CH_2OH$ / $CH_3(CH_2)_2CH_2OH$ **(1)** • **Y**: phosphorus(V) chloride / phosphorus pentachloride / PCl_5 **(1)** • **Z**: *N*-methylbutanamide **or**  **or** $CH_3CH_2CH_2CONHCH_3$ / $CH_3(CH_2)_2CONHCH_3$ **(1)**	Mark independently If names and formulae are given, both must be correct but penalise missing H from carbon chain displayed formulae once only Allow any combination of skeletal, structural or displayed formulae Ignore molecular formulae for **X**, **Y** and **Z** Ignore butanol / C_4H_9OH Do not award $CH_3CH_2CH_2CH_3O$ Do not award butanal Allow phosphorus(III) chloride / PCl_3 / thionyl chloride / $SOCl_2$ Do not award hydrochloric acid / HCl Ignore methylbutanamide / butanamide in addition to a correct structure Allow NH in skeletal formula Do not award $CH_3CH_2CH_2COHNCH_3$ / $CH_3CH_2CH_2COCH_3NH$	**(3)**

Question Number	Answer	Additional Guidance	Mark
17(c)	• Monomer 1  **(1)** • Monomer 2  **or**  **(1)**	Allow monomers in either order Allow any combination of structural or displayed formulae / skeletal formulae Allow OH Ignore bond lengths and bond angles Penalise OH-C on left of molecules once only Penalise missing H from carbon chain displayed formulae once only Accept cis isomers	**(2)**

Question Number	Answer	Additional Guidance	Mark
17(d)(i)	• $C_5H_{10}O_2$	Allow symbols in any order Ignore any working Ignore + charge	**(1)**

Question Number	Answer	Additional Guidance	Mark
17(d)(ii)	• **E** is not a carboxylic acid **or** does not contain COOH (group)	If name and formula are given, both must be correct Allow **E** is not an acid Do not award additional functional groups	**(1)**

Question Number	Answer	Additional Guidance	Mark
17(d)(iii)	• **E** is an ester	Ignore saturated / -COO- / C=O Do not award additional functional groups	**(1)**

Question Number	Answer	Additional Guidance	Mark
17 (d)(iv)	• structure of **E** **(1)** • 2 or 3 proton environments correct **(1)** • 4th proton environment correct **(1)**	Example of structure:  Protons can be circled and labelled or just labelled Allow labels using data from the table Only 1 proton from each group needs to be labelled Allow whole groups to be labelled, including the carbon atom	**(3)**

(Total for Question 17 = 14 marks)

Question Number	Answer	Additional Guidance	Mark
18(a)(i)	• no effect / none / nothing / no change	Ignore references to rate	(1)

Question Number	Answer	Additional Guidance	Mark
18(a)(ii)	An explanation that makes reference to the following points: • (equilibrium) yield (of sulfur trioxide / SO_3 / product) decreases **(1)** • the equilibrium constant / K_p / K_c / K decreases (as temperature increases) **and** because the (forward / right) reaction is exothermic / releases heat (energy) / ΔH is negative **(1)**	Allow less sulfur trioxide / SO_3 / product forms Ignore equilibrium position shifts to the left Ignore more reactants formed Allow the equilibrium constant / K_p / K_c / K decreases (as temperature increases) **and** because the reverse / backward / left reaction is endothermic / absorbs heat (energy) Allow K decreases because $\Delta S_{surroundings}$ / ΔS_{total} decreases / becomes less positive (as temperature increases and assuming ΔS_{system} is constant) Ignore reference to rate	(2)

Question Number	Answer	Additional Guidance	Mark
18(a)(iii)	• expression for K_p	Example of expression for K_p: $K_p = \frac{p(SO_3(g))^2}{p(SO_2(g))^2 \text{ (x) } p(O_2(g))}$ Allow *P / PP / pp* etc for partial pressure and this can be inside the brackets Allow e.g. p^2SO_3 Ignore missing (g) / brackets around formulae Do not award square brackets	**(1)**

<table>
<tr><th>Question Number</th><th>Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr>
<td>18(a)(iv)</td>
<td>
• calculation of eqm moles (1)

• calculation or expressions for 3 partial pressures (1)

• substitution of values into K_p expression (1)

• calculation of K_p
and
answer to 2 / 3 SF
and
units (1)
</td>
<td>
Example of calculation:
<table>
<tr><td></td><td>SO_2</td><td>O_2</td><td>SO_3</td></tr>
<tr><td>Initial mol</td><td>2.00</td><td>1.00</td><td>-</td></tr>
<tr><td>Eqm mol</td><td>2.00 – 1.60
= 0.40</td><td>1.00 – 0.80
= 0.20</td><td>1.60</td></tr>
<tr><td>Total mol at eqm</td><td colspan="3">0.40 + 0.20 + 1.60 = 2.20</td></tr>
<tr><td>Partial pressure /atm</td><td>$\frac{0.40 \times 5.00}{2.20}$
= 0.90909</td><td>$\frac{0.20 \times 5.00}{2.20}$
= 0.45455</td><td>$\frac{1.60 \times 5.00}{2.20}$
= 3.6364</td></tr>
</table>
TE for partial pressures on eqm moles

$K_p = \frac{3.6364^2}{0.90909^2 \times 0.45455}$

$= 35.2 / 35\ atm^{-1}$
TE on expression for K_p in (a)(iii)

Allow answer from previous correct rounding to 2 or more SF e.g. 0.91, 0.45 and 3.6 gives 34.8
Penalise incorrect rounding once only e.g. 0.909 to 0.9

Allow fractions in working but not in final answer

Allow atm^- for units but do not allow any other units
Allow correct units written in (a)(iii) if not written here

Correct answer to 2 or 3 SF with units and no working scores (4)
</td>
<td>(4)</td>
</tr>
</table>

Question Number	Answer	Additional Guidance	Mark
18(b)(i)	• calculation of mass of H_2SO_4 in 1 dm^3 **(1)** • calculation of concentration of acid **(1)**	Example of calculation: mass of H_2SO_4 in 1 dm^3 concentrated acid = 0.985 x 1800 = 1773 (g) concentration of acid = $\frac{1773}{(2 \times 1.0) + 32.1 + (4 \times 16.0)}$ = 18.073 / 18.07 / 18.1 / 18 (mol dm^{-3}) TE on mass of H_2SO_4 in 1 dm^3 Allow 98 for molar mass of H_2SO_4 giving 18.092 / 18.09 / 18.1 / 18 (mol dm^{-3}) Correct answer to 3 or more SF with no working scores (2) Do not award (2) for 18 unless 0.985 has been used in calculation	**(2)**

Question Number	Answer	Additional Guidance	Mark
18(b)(ii)	• calculation of $[H^+(aq)]$ / $[H_3O^+(aq)]$	Example of calculation: $[H^+(aq)]$ / $[H_3O^+(aq)] = 10^{-0.97}$ $= 0.10715$ / 0.1072 / 0.107 / 0.11 (mol dm^{-3}) Ignore SF except 1 SF Ignore incorrect units Correct answer with no working scores (1) Do not award 0.1 / 0.10 / 0.214	**(1)**

Question Number	Answer	Additional Guidance	Mark
18(b)(iii)	An explanation that makes reference to the following points: **First equilibrium** • the first ionisation of sulfuric acid is complete **or** the equilibrium position of the first equation lies very far to the right **(1)** **Second equilibrium** • so $[H_3O^+(aq)]$ (from the second equilibrium) is very small **(1)**	Allow $[H^+(aq)]$ for $[H_3O^+(aq)]$ Ignore missing state symbols Allow high $[H_3O^+(aq)]$ from first equilibrium Allow acid fully dissociates in first equilibrium Ignore just acid fully dissociates Allow second equilibrium shifts to the left Allow second dissociation is suppressed / further dissociation is prevented	**(2)**

Question Number	Answer	Additional Guidance	Mark
18(c)(i)	• $HSO_4^- + OH^- \rightarrow SO_4^{2-} + H_2O$ **(1)** • $SO_4^{2-} + H^+ \rightarrow HSO_4^-$ **or** $SO_4^{2-} + H_3O^+ \rightarrow HSO_4^- + H_2O$ **(1)**	Allow equations in either order Allow ⇌ provided equations written in directions shown Ignore state symbols even if incorrect Penalise non-ionic equations once only e.g. using HCl and NaOH Allow $HSO_4^- \rightarrow SO_4^{2-} + H^+$ **and** $H^+ + OH^- \rightarrow H_2O$ for M1	**(2)**

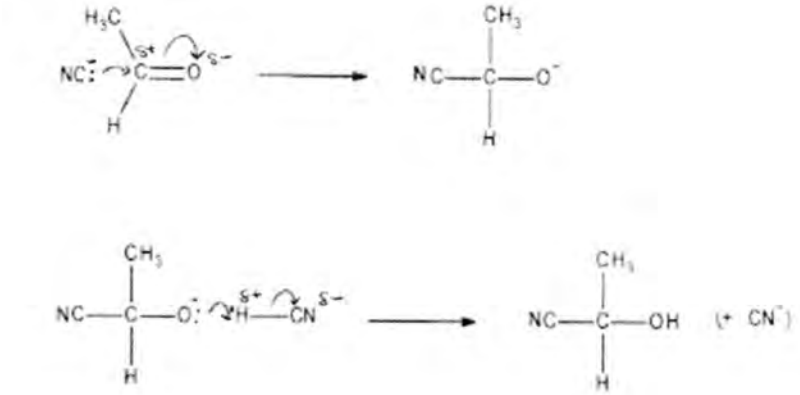
Question Number	Answer	Additional Guidance	Mark
18(c)(ii)	• calculation of the concentration of SO_4^{2-} ions **(1)** • calculation of the concentration of HSO_4^- ions **(1)** • expression for K_a **(1)** • re-arrangement of expression **and** calculation of $[H^+]$ **(1)** • calculation of pH **(1)**	Example of calculation: $[SO_4^{2-}] = \frac{25.0 \times 0.150}{1000} \times \frac{1000}{100}$ $= 0.0375$ (mol dm^{-3}) Allow mol $SO_4^{2-} = 0.00375 / 3.75 \times 10^{-3}$ (mol) $[HSO_4^-] = \frac{75.0 \times 0.100}{1000} \times \frac{1000}{100}$ $= 0.075$ (mol dm^{-3}) Allow mol $HSO_4^- = 0.0075 / 7.5 \times 10^{-3}$ (mol) Do not award this mark if subtraction then done $K_a = \frac{[H^+][SO_4^{2-}]}{[HSO_4^-]} / 0.012 = \frac{[H^+] \times 0.0375}{0.075}$ Allow mol substituted into correct expression $[H^+] = \frac{K_a[HSO_4^-]}{[SO_4^{2-}]} = \frac{0.012 \times 0.075}{0.0375}$ $= 0.024$ (mol dm^{-3}) TE on expression, $[SO_4^{2-}]$ and $[HSO_4^-]$ or mol $pH = -\log[H^+] = -\log 0.024$ $=1.6198 / 1.620 / 1.62 / 1.6$ TE on $[H^+]$ Ignore SF except 1 SF Correct answer without working scores (5) Allow alternative methods	**(5)**

(Total for Question 18 = 20 marks)

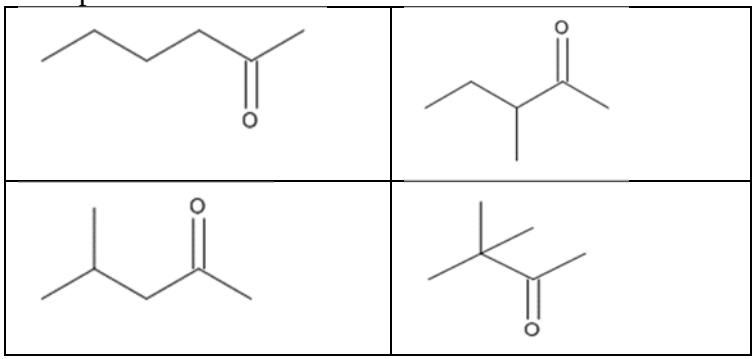
Question Number	Answer	Additional Guidance	Mark
19(a)	• $C_{10}H_{18}O$	Allow symbols in any order i.e. $C_{10}OH_{18}$ / $H_{18}C_{10}O$ / $H_{18}OC_{10}$ / $OC_{10}H_{18}$ / $OH_{18}C_{10}$ Allow large numbers e.g. C10H18O Do not award superscripts e.g. $C^{10}H^{18}O$	**(1)**

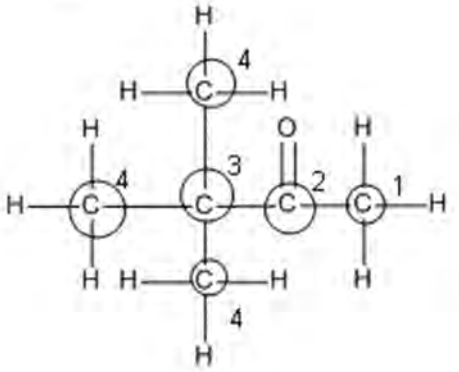
Question Number	Answer	Additional Guidance	Mark
19(b)	An answer that makes reference to the following points: • curly arrow from lone pair on C of CN^- towards C of aldehyde group **(1)** • curly arrow from C=O to, or just beyond, O **and** dipole on C=O **(1)** • intermediate **(1)** • curly arrow from lone pair on O^- to H **and** curly arrow from H-CN bond to anywhere on CN **and** final organic product **(1)**	Penalise an incorrect dipole in M1 and M4 once only Penalise curly arrow not starting from lone pair once only in M1 and M4 Penalise half arrow-heads once only Allow CN^- to attack C=O from any angle Allow CN bond displayed If M1 lost as curly arrow from N of CN^-, allow CN joined to carbon through N Ignore connectivity for vertical CN groups Allow curly arrow from lone pair on O^- to H^+ Ignore missing dipole in HCN	**(4)**

Example of mechanism:



Question Number	Answer	Additional Guidance	Mark
19 (c)(i)	• CH_3CO- / $-COCH_3$ / methyl ketone	Allow any combination of structural / displayed formula or skeletal formula Allow methyl next to ketone / methyl and ketone / methylcarbonyl Allow CH_3COR / $RCOCH_3$ Ignore missing continuation bond from structures Do not award ethanal / methyl secondary alcohol / a specific compound	**(1)**

Question Number	Answer	Additional Guidance	Mark
19(c)(ii)	• any 2 skeletal formulae **(1)** • remaining 2 skeletal formulae **(1)**	Examples of skeletal formulae:  Ignore bond lengths and bond angles Allow (1) for 4 correct displayed / structural formulae	**(2)**

Question Number	Answer	Additional Guidance	Mark
19(c)(iii)	• displayed formula of **F** **(1)** • carbon atoms labelled **(1)**	Example of displayed formula:  Allow CH_3 Allow other unambiguous labels for the carbon atoms Allow M2 for labels on structural / skeletal formulae, including labels on formulae in (c)(ii) Ignore reference to singlet / splitting patterns	**(2)**

<table>
<tr><th>Question Number</th><th>Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr>
<td>19(d)*</td>
<td>This question assesses a student’s ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning.

Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.

The following table shows how the marks should be awarded for indicative content.

<table>
<tr><th>Number of indicative marking points seen in answer</th><th>Number of marks awarded for indicative marking points</th></tr>
<tr><td>6</td><td>4</td></tr>
<tr><td>5–4</td><td>3</td></tr>
<tr><td>3–2</td><td>2</td></tr>
<tr><td>1</td><td>1</td></tr>
<tr><td>0</td><td>0</td></tr>
</table>

The following table shows how the marks should be awarded for structure and lines of reasoning.</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, an answer with five indicative marking points that is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning).
If there are no linkages between points, the same five indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages).</td>
<td>(6)</td>
</tr>
</table>

	Number of marks awarded for structure of answer and sustained line of reasoning	
Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout.	2	
Answer is partially structured with some linkages and lines of reasoning.	1	
Answer has no linkages between points and is unstructured.	0	

Comment:
Look for the indicative marking points first, then consider the mark for structure of answer and sustained line of reasoning

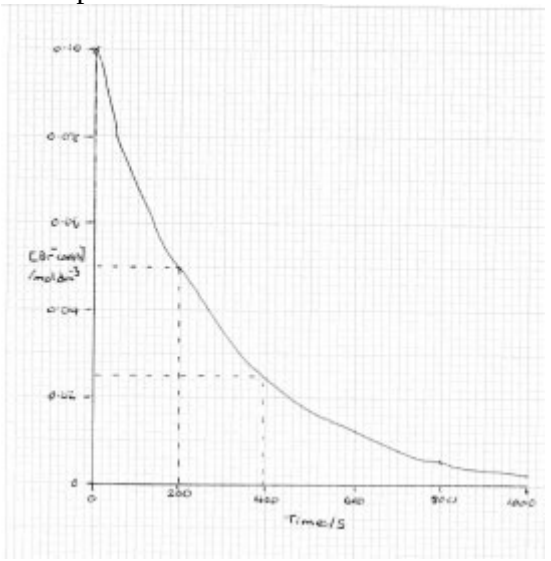
In general it would be expected that 5 or 6 indicative points would get 2 reasoning marks, and 3 or 4 indicative points would get 1 mark for reasoning, and 0, 1 or 2 indicative points would score zero marks for reasoning.

Additional incorrect chemistry loses a structure and lines of reasoning mark (if 1 or 2 have been awarded).

	Indicative content • **IP1 London forces** Pentane (only) has London forces / all have London forces • **IP2 Butanal** Butanal (also) has (permanent) dipole-dipole interactions • **IP3 Propanoic acid** Propanoic acid (also) has (dipole-dipole and) hydrogen bonding • **IP4 Intermolecular forces** The London forces have about the same strength as they have a similar number of electrons / pentane has 42, butanal has 40 (and propanoic acid has 40 electrons) **or** butanal has dipole-dipole interactions because it is polar / has a dipole on C=O **or** propanoic acid has hydrogen bonding because it contains OH / COOH group • **IP5 Butanal and pentane** Dipole-dipole interactions are stronger than London forces **or** more energy is needed to overcome the dipole-dipole interactions than London forces • **IP6 Butanal and propanoic acid** Hydrogen bonding is stronger than dipole-dipole interactions **or** more energy is needed to overcome hydrogen bonding than dipole-dipole interactions	Allow dispersion forces / van der Waals' forces / forces between an instantaneous dipole and an induced dipole for London forces throughout answer Do not award IP1 if any other forces mentioned Allow dipole-dipole forces / attractions / bonds Do not award IP2 if hydrogen bonding included Allow similar relative molecular masses (butanal 72, pentane 72, propanoic acid 74) Do not award incorrect numbers of electrons / relative molecular masses Allow dipole-dipole interactions linked to C=O Allow diagram of hydrogen bond between two molecules Ignore formation of dimer Allow London forces are the weakest (intermolecular force) Do not award if covalent bonds broken or explanation is about intermolecular forces with water Allow hydrogen bonding is the strongest (intermolecular force) Do not award if covalent bonds broken or explanation is about intermolecular forces with water	**(6)**

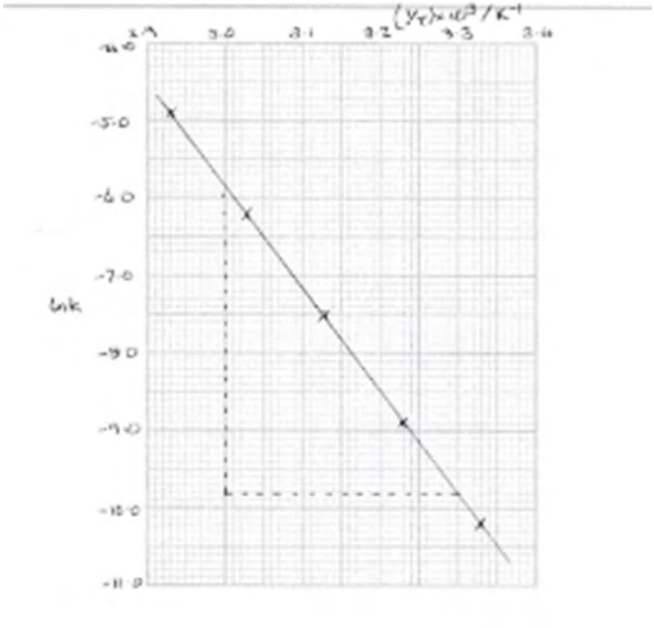
(Total for Question 19 = 16 marks)

Question Number	Answer	Additional Guidance	Mark
20(a)	• substitution of values into expression for ΔS_{system} **(1)** • calculation of ΔS_{system} **(1)** • substitution of values into expression for $\Delta S_{surroundings}$ **(1)** • calculation of $\Delta S_{surroundings}$ **(1)** • calculation of ΔS_{total} **(1)**	Example of calculation: ΔS_{system} = (2 x 95.9) + (3 x 205.0) – (2 x 149.2) Allow 191.8 + 615.0 – 298.4 / 806.8 – 298.4 ΔS_{system} = (+)508.4 (J K^{-1} mol^{-1}) $\Delta S_{surroundings} = -\frac{(-67.2)}{298}$ $\Delta S_{surroundings}$ = (+)0.2255 (kJ K^{-1} mol^{-1}) or (+)225.5 (J K^{-1} mol^{-1}) ΔS_{total} = 508.4 + 225.5 = (+)733.9 (J K^{-1} mol^{-1}) or (+)0.7339 (kJ K^{-1} mol^{-1}) TE on calculated values for ΔS_{system} and $\Delta S_{surroundings}$ Do not award ΔS_{system} added to $\Delta S_{surroundings}$ in different units e.g. 508.4 + 0.2255 = 508.6255 Ignore SF except 1 SF Units are not needed. Units in any order e.g. J mol^{-1} K^{-1} Penalise incorrect / incomplete units in ΔS_{total} but allow: e.g. J / mol/ K or J/mol.K mol^{-} and K^{-} in otherwise correct units Correct answer with no working scores (5)	**(5)**

Question Number	Answer	Additional Guidance	Mark
20(b)(i)	• working for at least one half-life shown on graph **(1)** • values of two half-lives **(1)** • first order **and** because the half-lives are constant / the same / similar **(1)**	Example of half-lives:  half-lives may be written or clearly shown on graph first half-life = 200 s **and** second half-life = 200 s ± 20 s Allow 2nd half-life = 400 – 200 = 200 s Stand alone mark Do not award zero order / second order	**(3)**

Question Number	Answer	Additional Guidance	Mark
20(b)(ii)	An explanation that makes reference to the following points: • first order with respect to BrO_3^- ions **and** because in runs 1 and 2 as $[BrO_3^-]$ doubles (and $[H^+]$ is constant) the rate doubles **(1)** • in runs 1 and 3, as $[BrO_3^-]$ triples rate should triple (to 1.08×10^{-2}) and $[H^+]$ also doubles and rate increases by a factor of 4 **(1)** • so reaction is second order with respect to H^+ ions **(1)**	In M1 and M2, the working may be shown in the table Allow implied runs e.g. as $[BrO_3^-]$ doubles (and $[H^+]$ is constant), the rate doubles Allow correct alternative explanations using runs 2 and 3 and others e.g. $[BrO_3^-]$ triples, $[H^+]$ doubles and rate x 12 Do not award just $[H^+]$ doubles and rate x 4 with no mention of bromate ions Stand alone mark	**(3)**

Question Number	Answer	Additional Guidance	Mark
20(b)(iii)	• rate equation **(1)** • units of k **(1)**	rate = $k[Br^-(aq)][BrO_3^-(aq)][H^+(aq)]^2$ TE on orders in (a)(i) and (ii) Allow species in any order / R for rate / K for k Ignore missing state symbols If no order given in (a)(i), allow rate equation with Br^- included or omitted $dm^9\ mol^{-3}\ s^{-1}$ Allow these in any order Allow $dm^9\ mol^{-3}\ s^-$ TE on rate equation	**(2)**

Question Number	Answer	Additional Guidance	Mark
20(c)		Example of graph:  Example of gradient: $\frac{-9.8 - (-5.85)}{3.3 \times 10^{-3} - 3.0 \times 10^{-3}} = -13167$ K	**(7)**

Question Number	Answer		Additional Guidance	Mark
20(c)	• axes correct way around **and** suitable scale	**(1)**	Points / line must cover at least half the grid in both directions ln *k* values must become more negative down the axis with negative signs shown Allow horizontal axis shown at bottom of graph	
	• both axes labelled **and** units for x axis	**(1)**	y axis: ln k with no units on y axis **and** x axis: 0.0033 etc with (1/T) / K^{-1} **or** 3.3 etc with (1/T) / 10^{-3} K^{-1} **or** 3.3 x 10^{-3} etc with (1/T) / K^{-1} **or** 3.3 etc with (1/T) x 10^{3} / K^{-1} Brackets are not needed around 1/T	
	• all points plotted correctly **and** best-fit straight line	**(1)**	Allow ± ½ square Allow line covering points provided it is straight Ignore extrapolation in either direction	
	• calculation of gradient	**(1)**	This may be shown on the graph Allow gradient in the range (−)12800 to (−)13800 Allow gradient calculated from data in the table If gradient not evaluated, allow correct working	
	• sign and units of gradient	**(1)**	Negative sign **and** units K Allow 1/K^{-1} for units Allow −12.8 to −13.8 kK for M4 and M5	
	• calculation of activation energy	**(1)**	E_a = 13167 x 8.31 / 1000 = 109.418 Expected range 106 to 115 **or** 13167 x 8.31 = 109418 TE on gradient	
	• sign and corresponding units of activation energy	**(1)**	+ 109.418 kJ mol^{-1} or +109418 J mol^{-1} Allow kJ mol^{-} or J mol^{-} Ignore missing + but do not award − sign Penalise 1 SF for gradient and E_a value once only	

(Total for Question 20 = 20 marks)

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