Pearson Edexcel

Mark Scheme (Results)

October 2022

Pearson Edexcel International Advanced Level In Chemistry (WCH14)
Paper 01: 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.
- 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.

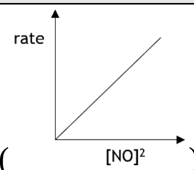
/ means that the responses are alternatives and either answer should receive full credit.
( ) means that a phrase/word is not essential for the award of the mark, but helps the examiner to get the sense of the expected answer.
Phrases/words in **bold** indicate that the <u>meaning</u> of the phrase or 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	**The only correct answer is A** (electrical conductivity) ***B*** *is not correct because none of the reactants or products is coloured* ***C*** *is not correct because there is no change in mass* ***D*** *is not correct because titration is not a continuous monitoring method*	**1**

Question Number	Answer	Mark
2(a)	**The only correct answer is D** (27) ***A*** *is not correct because the reaction is not overall first order* ***B*** *is not correct because the reaction is not overall second order* ***C*** *is not correct because the reaction is second order with respect to NO and first order with respect to* H_2	**1**

Question Number	Answer	Mark
2(b)	**The only correct answer is D (**  **)** ***A*** *is not correct because the reaction is not zero order with respect to* H_2 ***B*** *is not correct because the reaction is not zero order with respect to* H_2 ***C*** *is not correct because the concentration of NO decreases with time*	**1**

Question Number	Answer	Mark
2(c)	**The only correct answer is B** (Step **2**) ***A*** *is not correct because hydrogen is involved in the rate-determining step* ***C*** *is not correct because only 1 mol of hydrogen appears in the rate-determining step* ***D*** *is not correct because enough information has been provided*	1

Question Number	Answer	Mark
3(a)	**The only correct answer is C** (the second ionisation energy of strontium is +1614 kJ mol^{-1}) ***A*** *is not correct because lattice energies are always exothermic* ***B*** *is not correct because –590 is twice the first electron affinity of iodine* ***D*** *is not correct because the standard enthalpy change of atomisation of strontium is +164 kJ* mol^{-1}	1

Question Number	Answer	Mark
3(b)	**The only correct answer is D** (+107) ***A*** *is not correct because the sign of the enthalpy change of atomisation of strontium has not been reversed and the answer has not been divided by two* ***B*** *is not correct because the sign of the enthalpy change of atomisation of strontium has not been reversed* ***C*** *is not correct because +214 is the enthalpy change in producing 2 mol of I(g)*	1

Question Number	Answer	Mark
3(c)	**The only correct answer is B** (–1937) ***A*** *is not correct because this is the standard enthalpy change of formation of strontium iodide* ***C*** *is not correct because this is the experimental lattice energy* ***D*** *is not correct because the theoretical lattice energy is less exothermic than the experimental value*	1

Question Number	Answer	Mark
4	**The only correct answer is A** (the enthalpy change of hydration of an ion is always negative) ***B*** *is not correct because the enthalpy change of solution of an ionic compound can be positive* ***C*** *is not correct because some ionic compounds with an endothermic enthalpy change of solution are soluble* ***D*** *is not correct because enthalpy change of hydration and the entropy change of solution also determine the solubility of an ionic compound*	1

Question Number	Answer	Mark
5	**The only correct answer is C** (Os(s) < Hg(l) < He(g) < O_2(g)) ***A*** *is not correct because solids and liquids have lower entropy than gases* ***B*** *is not correct because these elements are arranged by decreasing standard entropy* ***D*** *is not correct because oxygen has greater entropy than helium*	1

Question Number	Answer	Mark
6(a)	**The only correct answer is D** (low temperature and low pressure) ***A*** *is not correct because the forward reaction is exothermic and there are more moles of gas on the product side* ***B*** *is not correct because the forward reaction is exothermic* ***C*** *is not correct because there are more moles of gas on the product side*	1

Question Number	Answer	Mark
6(b)	**The only correct answer is D** (the reaction is highly exothermic) ***A*** *is not correct because catalysts do not affect the position of equilibrium* ***B*** *is not correct because the reaction needs to provide energy to maintain the temperature* ***C*** *is not correct because the energy requirements do not depend on the thermodynamic feasibility*	1

Question Number	Answer	Mark
6(c)	**The only correct answer is B** (atm) ***A*** *is not correct because this is for the reverse reaction* ***C*** *is not correct because this is for* K_c *for the reverse reaction* ***D*** *is not correct because this is for* K_c	1

Question Number	Answer	Mark
7	**The only correct answer is C** ($NH_3 + H_2O \rightarrow NH_4^+ + OH^-$) ***A*** *is not correct because* H_2O *is acting as a Brønsted-Lowry base* ***B*** *is not correct because* H_2O *is acting as a Brønsted-Lowry base* ***D*** *is not correct because* H_2O *is acting as both a Brønsted-Lowry acid and a Brønsted-Lowry base*	1

Question Number	Answer	Mark
8	**The only correct answer is B** (13.0) ***A*** *is not correct because the concentration of hydroxide ions is not 0.2 mol* dm^{-3} ***C*** *is not correct because the concentration of hydroxide ions is not 0.050 mol* dm^{-3} ***D*** *is not correct because the concentration of hydroxide ions is not 0.025 mol* dm^{-3}	1

Question Number	Answer	Mark
9	**The only correct answer is A** (5.06) ***B*** *is not correct because this is the pH of an equimolar solution of* CH_3COOH *and* CH_3COONa ***C*** *is not correct because this is the pH when the concentrations are reversed* ***D*** *is not correct because this is the pH of a 0.100 mol* dm^{-3} *solution of* CH_3COOH	1

Question Number	Answer	Mark
10	**The only correct answer is B** (bromocresol green (pK_{in} = 4.7)) ***A*** *is not correct because the pH range would not lie within the vertical section of a strong acid weak base titration* ***C*** *is not correct because the pH range would not lie within the vertical section of a strong acid weak base titration* ***D*** *is not correct because the pH range would not lie within the vertical section of a strong acid weak base titration*	1

Question Number	Answer	Mark
11	**The only correct answer is A** (CH_3COOH) ***B*** *is not correct because* CH_3COCH_3 *has a lower boiling temperature than water* ***C*** *is not correct because* $CH_3CH_2CH_2CHO$ *is not completely miscible in water and has a lower boiling temperature than water* ***D*** *is not correct because* $CH_3CH_2COOCH_2CH_3$ *is not completely miscible in water and has a lower boiling temperature than water*	1

Question Number	Answer	Mark
12	**The only correct answer is B** (ethanal) ***A*** *is not correct because methanal does not form a precipitate with iodine in the presence of alkali* ***C*** *is not correct because propanone does not form a precipitate with Benedict's solution* ***D*** *is not correct because butanone does not form a precipitate with Benedict's solution*	1

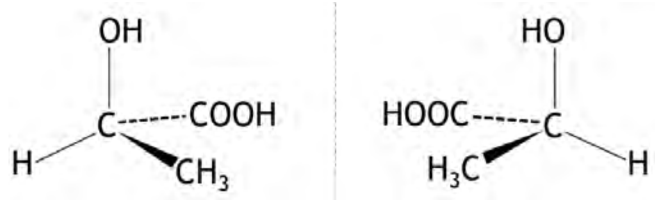
Question Number	Answer	Mark
13	**The only correct answer is C** ($(CH_3)_3CCOC(CH_3)_3$ + $LiAlH_4$) ***A*** *is not correct because one of the products of this reaction is 2-methylpropan-2-ol* ***B*** *is not correct because one of the products of this reaction is 2-methylpropan-2-ol* ***D*** *is not correct because one of the products of this reaction is 2-methylpropan-2-ol*	1

Question Number	Answer	Mark
14	**The only correct answer is B** (increasing the carrier gas flow rate) ***A*** *is not correct because decreasing the column temperature increases retention time* ***C*** *is not correct because the amount of sample does not affect retention time* ***D*** *is not correct because increasing the column length increases retention time*	1

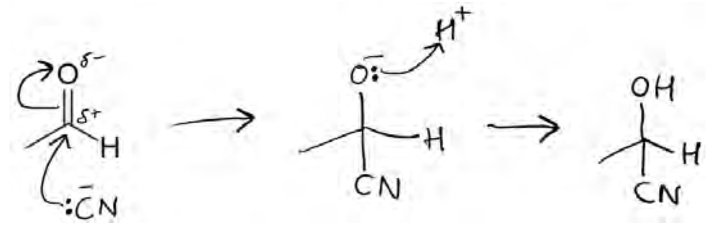
Total for Section A = 20 marks

Section B

Question Number	Answer	Additional Guidance	Mark
15(a)	An answer that makes reference to the following point: • 2-hydroxypropanoic acid	Allow spaces, use of commas and omission of hyphen (eg 2,hydroxy propanoic acid) Allow propan**e**oic for propanoic Allow hydroxyl for hydroxy Do not award hydroxo for hydroxy	**1**

Question Number	Answer	Additional Guidance	Mark
15(b)	An answer that makes reference to the following points: • one enantiomer **(1)** • second enantiomer **(1)**	Example of correct diagram:  Allow groups in any order Allow CO_2H for COOH Ignore all connectivity errors	**2**

Question Number	Answer	Additional Guidance	Mark
15(c)(i)	An answer that makes reference to the following point: • (mixture containing) equal amounts of (both) enantiomers (of lactic acid)	Accept equimolar/50:50 mixture for equal amounts Accept optical isomers / non-superimposable mirror images / + and – / R and S / dextrorotatory/D/d and laevorotatory/L/l for enantiomers Allow stereoisomers for enantiomers Allow isomers / both forms of lactic acid for enantiomers Ignore any reference to lack of optical activity	**1**

Question Number	Answer	Additional Guidance	Mark
15(c)(ii)	An answer that makes reference to the following points: • curly arrow from **lone pair on carbon** of cyanide ion **(1)** • correct C=O bond dipole shown **and** curly arrow from C=O bond to O or just beyond **(1)** • correct intermediate **(1)** • curly arrow from lone pair on O atom of intermediate to H^+ **and** correct product **(1)**	Example of correct mechanism:  Ignore absence of lone pair Do not award omission of negative charge Allow curly arrow from negative charge on O atom Allow curly arrow to H atom of HCN (and ignore second curly arrow and cyanide by-product) Ignore all C–OH connectivity errors in product	**4**

Question Number	Answer	Additional Guidance	Mark
15(c)(iii)	An answer that makes reference to the following points: • H_2O and H^+ reactants **and** NH_4^+ product **(1)** • correct organic species **and** correct balancing **(1)**	Example of correct equation: $CH_3CH(OH)CN + 2H_2O + H^+ \rightarrow CH_3CH(OH)COOH + NH_4^+$ Accept H_3O^+ for H^+ Allow H^+ shown above arrow Allow any strong acid (eg HCl) for H^+ Allow correct ammonium salt (eg NH_4Cl) for NH_4^+ **M2 dependent on M1** Allow any combination of structural, displayed or skeletal formulae and ignore vertical connectivity of OH/CN/COOH Allow omission of brackets around OH Allow any order of groups in structural formulae, eg $CH_3CCN(OH)H$ Allow multiples $CH_3CH(OH)CN + 2H_2O \rightarrow CH_3CH(OH)COOH + NH_3$ scores (1) Ignore state symbols, even if incorrect	**2**

Question Number	Answer	Additional Guidance	Mark
15(c)(iv)	An answer that makes reference to the following points: • cyanide/CN^-/nucleophile attacks from above and below **(1)**	Accept from either side / both sides / front and back / top and bottom for above and below Ignore from both directions / two directions Do not award from any side	**2**
	• (as trigonal) planar around the C(δ+) **(1)**	Allow planar around reaction site / C=O / CHO / carbonyl functional group for C(δ+) Allow flat for planar Ignore ethanal / carbonyl compound is planar Do not award intermediate / carbocation is planar	

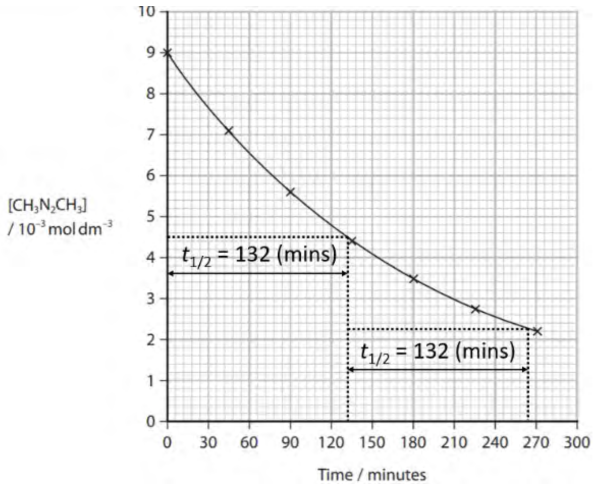
Question Number	Answer	Additional Guidance	Mark
15(d)(i)	An answer that makes reference to the following points: • conversion of pH to $[H^+]$ **and** conversion of pK_a to K_a **(1)**	Example of calculation: $[H^+] = 10^{-3.00} = 1.00 \times 10^{-3}$ / 0.00100 (mol dm^{-3}) Allow 1SF (ie 1×10^{-3} / 0.001) $K_a = 10^{-3.86} = 1.3804 \times 10^{-4}$ / 0.00013804 (mol dm^{-3}) Ignore SF except 1 SF	**4**
	• K_a expression rearranged for [HA] **(1)**	$[HA] = \frac{[H^+]^2}{K_a}$	
	• calculation of equilibrium [HA] **(1)**	$[HA] = \frac{(1 \times 10^{-3})^2}{1.3804 \times 10^{-4}} = 7.2444 \times 10^{-3}$ / 0.0072444 (mol dm^{-3}) Ignore SF except 1 SF TE on K_a from M1 (eg use of 3.86) No TE on incorrect K_a expression	
	• conversion of moles to mass **(1)**	($7.2444 \times 10^{-3} \times 90.0$ =) 0.65199/0.6520/0.652/0.65 (g) Ignore SF except 1 SF Allow units of g dm^{-3} Do not award incorrect units Correct answer with some working scores (4)	

Question Number	Answer	Additional Guidance	Mark
15(d)(ii)	An explanation that makes reference to the following points: • $[HA]_{equilibrium}$ < $[HA]_{initial}$ **(1)** • (so) greater mass (of acid required) **(1)**	Allow any indication that [HA] is underestimated (in the calculation) Allow just [HA] is lower Do not award $[HA]_{initial}$ is lower Accept $[HA]_{initial}$ (= $7.2444 \times 10^{-3} + 1 \times 10^{-3}$) = 8.2444×10^{-3} (mol dm^{-3}) Allow dissociation of the (lactic) acid is not negligible / is significant **M2 dependent on M1** Accept actual mass required is 0.74199 (g) Allow just more (acid required)	**2**

Question Number	Answer	Additional Guidance	Mark
15(d)(iii)	An answer that makes reference to the following point: • (hydroxyl) OH group is electron withdrawing	Accept OH group has negative inductive effect Allow OH group attracts electrons Allow OH group weakens (carboxylic) O–H bond Allow lactic acid anion is more stable (than ethanoate) Ignore any reference to electronegativity Ignore any reference to intermolecular forces Ignore reference to degree of dissociation / pK_a / K_a Do not award lactic acid has two acidic protons	**1**

Total for Question 15 = 19 marks

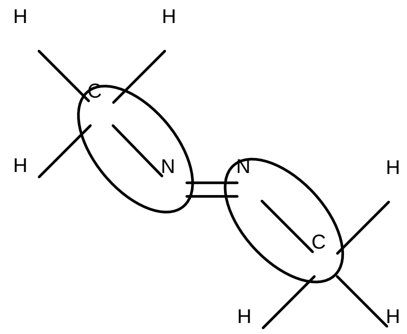
Question Number	Answer	Additional Guidance	Mark
16(a)	An answer that makes reference to the following points: • (rate =) $k[CH_3N_2CH_3]$	Accept rate = k[azomethane] Ignore state symbols even if incorrect Do not award non-square brackets	**1**

Question Number	Answer	Additional Guidance	Mark
16(b)(i)	An answer that makes reference to the following points:	Example of working on graph: 	**2**
	• determination of one half-life (with some working shown on graph) **(1)**	Allow half-life value between 126 and 138 Ignore units even if incorrect	
	• second half-life (with some working shown on graph) **and** constant (half-life shows reaction is first order) **(1)**	Allow half-life value between 126 and 138 Ignore units even if incorrect Allow similar for constant	

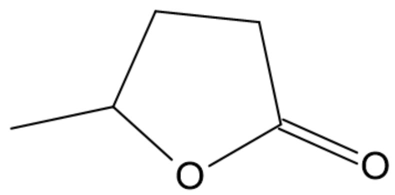
Question Number	Answer	Additional Guidance	Mark
16(b)(ii)	An answer that makes reference to the following points: • $t_{1/2}$ expression rearranged for k **(1)** • calculation of k in s^{-1} **(1)**	Example of calculation: $k = \frac{\ln 2}{t_{1/2}}$ $k = \frac{0.69315}{(132 \times 60)} = 8.7519 \times 10^{-5}$ / 0.000087519 (s^{-1}) TE on (b)(i) Ignore SF except 1SF Do not award 0.0052511 (s^{-1} / min^{-1}) Correct answer with some working scores (2)	**2**

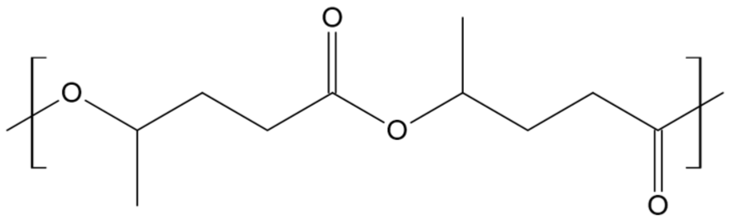
Question Number	Answer	Additional Guidance	Mark
16(c)(i)	An answer that makes reference to the following points: • at a higher temperature more particles/collisions have ($E \geq$) E_a **(1)** • (therefore the) rate (of reaction) is higher **(1)**	Accept reverse arguments in M1 and M2 Ignore reference to successful collisions Ignore just particles/collision have more energy Ignore reference to collision frequency **M2 is standalone mark** Allow (therefore the) half-life decreases	**2**

Question Number	Answer	Additional Guidance	Mark
16(c)(ii)	An answer that makes reference to the following points: • substitution of k and T values into expression **(1)** • calculation of E_a **(1)** • units of J mol^{-1} or kJ mol^{-1} **and** calculated answer to 2SF **(1)**	Example of calculation: $\log\left[\frac{1.1 \times 10^{-6}}{3.5 \times 10^{-3}}\right] = -\frac{E_a}{2.3\,R}\left[\frac{1}{523} - \frac{1}{623}\right]$ **or** $\log\left[\frac{3.5 \times 10^{-3}}{1.1 \times 10^{-6}}\right] = -\frac{E_a}{2.3\,R}\left[\frac{1}{623} - \frac{1}{523}\right]$ E_a = 218 130 (J mol^{-1}) / 218.13 (kJ mol^{-1}) Ignore sign Ignore units Ignore SF except 1SF TE on transposition of k and T values E_a = (+)220 000 J mol^{-1} / (+)220 kJ mol^{-1} Correct answer with some working scores (3)	**3**

Question Number	Answer	Additional Guidance	Mark
16(d)	An answer that makes reference to the following point: • a diagram that shows C–N bond(s) must break	 Only one C–N bond needs to be identified Allow any indication of C–N bond, including unambiguous use of curly arrows	**1**

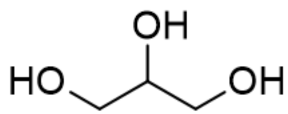
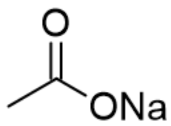
Total for Question 16 = 11 marks

Question Number	Answer	Additional Guidance	Mark
17(a)(i)	An answer that makes reference to the following points: • correct structure of cyclic ester **B**	Example of structure:  Allow displayed or structural formula, or any correct combination of formulae	**1**

Question Number	Answer	Additional Guidance	Mark
17(a)(ii)	An answer that makes reference to the following points: • ester linkage **(1)** • rest of structure **and** two repeat units **(1)**	Example of structure:  Allow displayed or structural formula, or any correct combination of formulae If more than one ester linkage shown all must be correct **M2 dependent on M1** Allow omission of brackets around extension bonds Allow the –O– to be at either end but not both ends Ignore n	**2**

Question Number	Answer	Additional Guidance	Mark
17(a)(iii)	An answer that makes reference to the following points: • (as) one molecule (of reactant) forms two molecules (of product) in reaction 1 **(1)** • (as) no change in the number of molecules in reaction 2 **(1)**	Accept moles for molecules Allow particles for molecules Ignore any reference to physical states Allow number of molecules increases in reaction 1 Do not award no change in number of molecules in reaction 1 Do not award standard entropy of ester B is greater than polymer C Allow number of molecules does not increase in reaction 2 Do not award number of molecules decreases in reaction 2	**2**

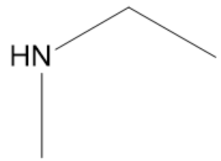
Question Number	Answer	Additional Guidance	Mark
17(b)(i)	An answer that makes reference to the following points: • $C_9H_{14}O_6$	Allow C, H and O in any order Do not award any other answer	**1**

Question Number	Answer	Additional Guidance	Mark
17(b)(ii)	An answer that makes reference to the following points: • correct structure of propane-1,2,3-triol **(1)** • correct structure of sodium ethanoate **(1)** • mole ratio **(1)**	Allow structural, displayed or skeletal formulae, or any combination Do not award molecular formulae  Allow missing H from OH groups in skeletal formula Ignore connectivity, including horizontal C–HO  Accept ionic $–O^{-}Na^{+}$ / CH_3COO^{-} and Na^{+} shown separately Do not award covalent –O–Na 3 mol NaOH **and** 3 mol sodium ethanoate/ethanoate/ethanoic acid **and** 1 mol propane-1,2,3-triol Allow multiples Ignore state symbols, even if incorrect	**3**

Question Number	Answer	Additional Guidance	Mark
17(c)(i)	An answer that makes reference to the following points: • water/H_2O	Ignore state symbols Do not award any other answer	**1**

Question Number	Answer	Additional Guidance	Mark
17(c)(ii)	An answer that makes reference to the following points: • NH_3 reactant **(1)** • NH_4Cl product **and** balanced equation **(1)**	Example of correct equation: $CH_3COCl + 2NH_3 \rightarrow CH_3CONH_2 + NH_4Cl$ Allow structural, displayed, skeletal or molecular formulae Ignore state symbols, even if incorrect **M1 dependent on CH_3COCl / an organic reactant** **M2 dependent on M1** Allow HCl Allow multiples $CH_3COCl + NH_3 \rightarrow CH_3CONH_2 + HCl$ scores (2) $C_2H_3ClO + NH_3 \rightarrow C_2H_5NO + HCl$ scores (2)	**2**

Question Number	Answer	Additional Guidance	Mark
17(c)(iii)	An answer that makes reference to the following point: • CH_3SH	Allow displayed formula Allow skeletal formula provided H attached to S shown Ignore name even if incorrect Do not award CH_4S	**1**

Question Number	Answer	Additional Guidance	Mark
17(c)(iv)	An answer that makes reference to the following point: • skeletal formula of *N*-methylethylamine	Example of correct structure:  Allow displayed N–H bond Allow omission of NH proton Ignore any other type of formula Ignore bond angles and bond lengths	**1**

<table>
<tr><th>Question Number</th><th>Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr>
<td>17(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.

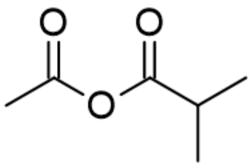
The following table shows how the marks should be awarded for indicative content.
<table>
<tr><th>Number of indicative marking points seen in answer</th><th>Number of marks awarded for indicative marking points</th></tr>
<tr><td>6</td><td>4</td></tr>
<tr><td>5-4</td><td>3</td></tr>
<tr><td>3-2</td><td>2</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.
<table>
<tr><th></th><th>Number of marks awarded for structure and sustained lines of reasoning</th></tr>
<tr><td>Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout.</td><td>2</td></tr>
<tr><td>Answer is partially structured with some linkages and lines of reasoning.</td><td>1</td></tr>
<tr><td>Answer has no linkages between points and is unstructured.</td><td>0</td></tr>
</table>
</td>
<td>
The mark for indicative content should be added to the mark for lines of reasoning. For example, an answer with five indicative marking points that is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning).

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

If there is any incorrect chemistry, deduct mark(s) from the reasoning. If no reasoning mark(s) awarded, do not deduct mark(s).

Comment: Look for the indicative marking points first, then consider the mark for the structure of the answer and sustained line of reasoning.
</td>
<td>6</td>
</tr>
</table>

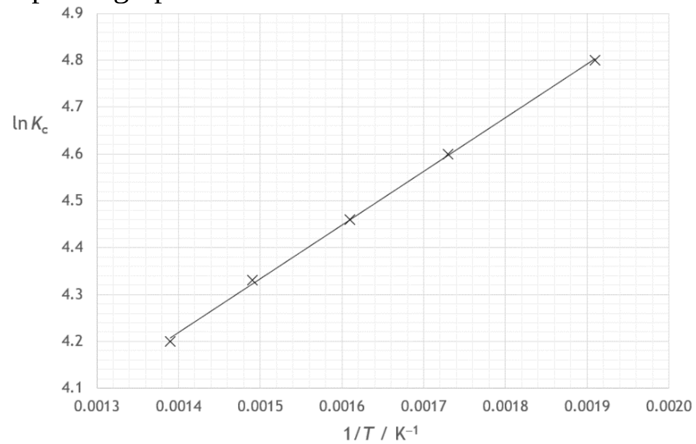
	Indicative points: • **IP1:** confirmation of RMM/molar mass/molecular formula (from molecular ion peak) • **IP2:** interpretation of IR data • **IP3:** interpretation of carbon-13 NMR data • **IP4:** identification of fragment causing singlet proton NMR peak • **IP5:** identification of fragment causing doublet NMR peak **and** septet NMR peak • **IP6:** structure of Z	M_r = 130 / (molar) mass is 130 (g mol^{-1}) **or** molecular formula is $C_6H_{10}O_3$ **C=O** (carboxylic acid, anhydrides as has) peak(s) at 1820 (cm^{-1}) **or** 1754 (cm^{-1}) (five peaks so) five carbon environments singlet / peak at ~2.1 ppm / peak with 3H due to $C\underline{\mathbf{H_3}}CO$ doublet / peak at ~1.1 ppm / peak with 6H due to $(C\underline{\mathbf{H_3}})_2CH$ **and** septet/heptet/multiplet / peak at ~2.5 ppm / peak with 1H due to $(CH_3)_2C\underline{\mathbf{H}}$  Allow any unambiguous structure	

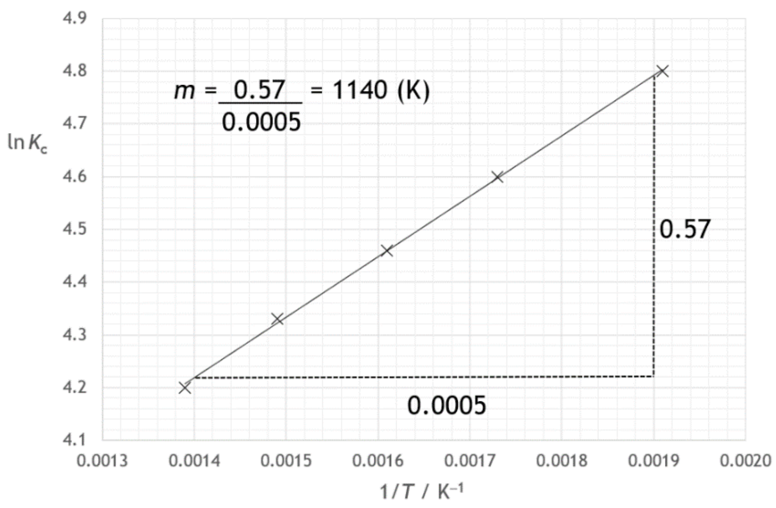
Total for Question 17 = 20 marks

Question Number	Answer	Additional Guidance	Mark
18(a)	An answer that makes reference to the following point: • correct expression	Example of correct expression: $(K_c =) \dfrac{[HI(g)]^2}{[H_2(g)][I_2(g)]}$ Allow omission of state symbols Ignore any reference to units, even if incorrect Do not award non-square brackets	**1**

Question Number	Answer	Additional Guidance	Mark
18(b)	An answer that makes reference to the following points: • moles H_2 and I_2 reacting **(1)** • equilibrium moles H_2 **and** equilibrium moles I_2 **(1)** • calculation of K_c **(1)** • calculated answer to 3SF or 2SF **and** no units **(1)**	Correct answer with some working scores (4) Example of calculation: $\dfrac{9.68 \times 10^{-3}}{2} = 4.84 \times 10^{-3}$ (mol) $n(H_2) = 5.00 \times 10^{-3} - 4.84 \times 10^{-3} = 1.6 \times 10^{-4}$ (mol) $n(I_2) = 1.00 \times 10^{-2} - 4.84 \times 10^{-3} = 5.16 \times 10^{-3}$ (mol) TE on moles reacting provided +ve moles (Because volume is 1 dm^3, mol = concentration) $(K_c =) \dfrac{(9.68 \times 10^{-3})^2}{(1.6 \times 10^{-4} \times 5.16 \times 10^{-3})} = 113.496$ TE on equilibrium moles TE on K_c expression from (a) for inverted expression or use of [HI] for $[HI]^2$ only Do not award –ve K_c value $(K_c =)$ 113 / 110 **and** no units Allow 114 **and** no units if 9.7×10^{-3} moles reacting TE on M3 TE on units from any K_c expression in (a)	**4**

Question Number	Answer		Additional Guidance	Mark
18(c)(i)	An answer that makes reference to the following points:		**Penalise SF once only**	**2**
	• $1/T$ value to 3SF	**(1)**	0.00191 Accept 1.91×10^{-3} Calculator value is 0.001912045889	
	• $\ln K_c$ value to 3SF	**(1)**	4.60 Calculator value is 4.5971138014	

Question Number	Answer		Additional Guidance	Mark
18(c)(ii)	An answer that makes reference to the following points:		Example of graph:  	**3**
	• linear scales	**(1)**	points plotted must cover at least half of grid in each direction	
	• five points correctly plotted	**(1)**	Allow accuracy to ± half a small square	
	• straight line of best fit covering all points	**(1)**	Ignore extrapolations of line of best fit	

Question Number	Answer	Additional Guidance	Mark
18(c)(iii)	An answer that makes reference to the following point: • calculation of gradient (with some working)	Example of working on graph:  gradient = (+)1140 (K) Allow any value between 1060 and 1220 Allow use of data from the table provided points used lie on line of best fit Ignore units even if incorrect Ignore SF except 1 SF	**1**

Question Number	Answer	Additional Guidance	Mark
18(c)(iv)	An answer that makes reference to the following points: • rearrangement of expression for ΔH **(1)** • calculation of ΔH **(1)**	Example of calculation: ΔH = – gradient × R ΔH = –1140 × 8.31 = –9473.4 (J mol^{-1}) Accept –9.4734 kJ mol^{-1} Accept use of 8.314 for R TE on value of gradient from (c)(iii) Ignore SF except 1SF Do not award incorrect units	**2**

Question Number	Answer	Additional Guidance	Mark
18(c)(v)	An answer that makes reference to the following points: • calculation of ΔG **(1)** • units of ΔG **(1)**	Example of calculation: $\Delta G = -RT \ln K_c$ $= -8.31 \times 620 \times 4.46$ $= -22979$ (J mol^{-1})/-22.979 (kJ mol^{-1}) Accept –22980/–22.980 from use of ln(86.5) for 4.46 Accept use of 8.314 for R Ignore SF except 1SF Do not award omission of –ve sign **M2 dependent on use of $R \times T$ in M1** J mol^{-1} (from 8.31 × 620) OR kJ mol^{-1} (from 8.31/1000 × 620) Calculation of ΔG at any other temperature with correct units scores (1)	**2**

Question Number	Answer	Additional Guidance	Mark
18(c)(vi)	An answer that makes reference to the following points: • rearrangement of expression for ΔS_{system} **(1)** • calculation of ΔS_{system} **(1)**	Example of calculation: $\Delta S_{system} = \frac{(\Delta H - \Delta G)}{T}$ $\Delta S_{system} = \frac{(-9473.4 - (-22979))}{620}$ $= (+)21.783$ (J mol^{-1} K^{-1}, units can be in any order) Accept 0.021783 (kJ mol^{-1} K^{-1}, units can be in any order) TE on ΔH from (c)(iv) and ΔG from (c)(v) Ignore SF except 1SF Do not award incorrect units Correct answer scores (2)	**2**

Question Number	Answer	Additional Guidance	Mark
18(d)	An answer that makes reference to the following points: • $\Delta S_{\text{surroundings}}$ is (always) positive **and** (as) ΔH is negative **(1)** • ΔS_{system} is positive **(1)** • (so) ΔS_{total} is (always) positive **(1)**	Allow (as) reaction is exothermic Allow $\Delta S_{\text{surroundings}}$ is (always) negative **and** (as) ΔH is positive / reaction is endothermic as TE on (c)(iv) Allow $T\Delta S$ is positive Allow ΔS_{system} / $T\Delta S$ is negative as TE on (c)(vi) **M3 dependent on positive $\Delta S_{\text{surroundings}}$ and positive ΔS_{system}** Accept (so) $\Delta S_{\text{total}} > 0$	**3**

Total for Question 18 = 20 marks
Total for Section C = 20 marks
Total for Paper = 90 marks

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