Mark Scheme (Results)

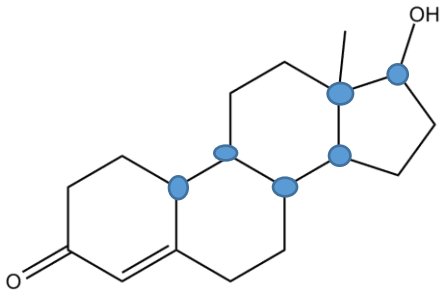
October 2024

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

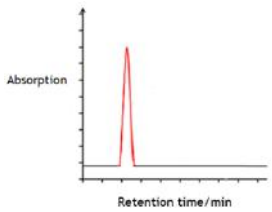
Section A

Question Number	Answer	Mark
1	**The only correct answer is B** (butanoyl chloride and propan-1-ol) ***A*** *is incorrect because it would produce 1-methylethyl butanoate* ***C*** *is incorrect because it would produce butyl propanoate* ***D*** *is incorrect because it would produce 1-methylpropyl propanoate*	**(1)**

Question Number	Answer	Mark
2	**The only correct answer is D** (CH_3CH_2COOH) ***A*** *is incorrect because* $CH_3CH_2CH_2CH_2CH_3$ *has a similar number of electrons but no hydrogen bonds* ***B*** *is incorrect because* $CH_3CH_2CH_2CHO$ *has a similar number of electrons but no hydrogen bonds* ***C*** *is incorrect because* $CH_3COCH_2CH_3$ *has a similar number of electrons but no hydrogen bonds*	**(1)**

Question Number	Answer	Mark
3(a)	**The only correct answer is A** (six) ***B*** *is incorrect because there are six chiral centres as shown* ***C*** *is incorrect because there are six chiral centres as shown* ***D*** *is incorrect because there are six chiral centres as shown* 	**(1)**

Question Number	Answer	Mark
3(b)	**The only correct answer is B** (reduction, addition) ***A*** *is incorrect because the conversion of C=C to C-C is an addition reaction* ***C*** *is incorrect because the conversion of C=O to C-OH is a reduction and the conversion of C=C to C-C is an addition reaction* ***D*** *is incorrect because the conversion of C=O to C-OH is a reduction*	**(1)**

Question Number	Answer	Mark
3(c)	**The only correct answer is D** () ***A*** *is incorrect because the area under the curve is unchanged and the retention time has doubled* ***B*** *is incorrect because the retention time has doubled* ***C*** *is incorrect because the area under the curve is unchanged*	**(1)**

Question Number	Answer	Mark
4	**The only correct answer is C** (H_2X) ***A*** *is incorrect because there is more than one equivalence point on the curve* ***B*** *is incorrect because hydrogen can only form one bond per atom in a molecule* ***D*** *is incorrect because the equivalence points are not the three horizontal sections on the curve*	**(1)**

Question Number	Answer	Mark
5	**The only correct answer is C** (CH_3COOH, $CH_3CO_2^-$) ***A** is incorrect because HSO_3^- is a base in the forward reaction and SO_3^{2-} is not formed* ***B** is incorrect because HSO_3^- is a base in the forward reaction* ***D** is incorrect because $CH_3COOH_2^+$ is not formed*	**(1)**

Question Number	Answer	Mark
6	**The only correct answer is D** (methyl orange) ***A** is incorrect because the colour change at the end-point is too gradual* ***B** is incorrect because the pH range of the indicator is outside the change in pH at equivalence* ***C** is incorrect because the pH range of the indicator is outside the change in pH at equivalence*	**(1)**

Question Number	Answer	Mark
7	**The only correct answer is D** (donates hydrogen ions and becomes an anion) ***A*** *is incorrect because the very weak acid does not accept hydroxide ions, and does not become a cation under these conditions* ***B*** *is incorrect because the very weak acid does not accept hydroxide ions, under these conditions* ***C*** *is incorrect because the very weak acid does not become a cation, under these conditions*	**(1)**

Question Number	Answer	Mark
8	**The only correct answer is C** (6.8) ***A*** *is incorrect because the increase in T moves the equilibrium to the right, increasing the concentration of* H^+ *ions, hence lowering the pH from 7 (at 298 K)* ***B*** *is incorrect because this is the pH at 298 K and the increase in T moves the equilibrium to the right, increasing the concentration of* H^+ *ions, hence lowering the pH* ***D*** *is incorrect as it would require an increase in* K_w *of approximately 250 times*	**(1)**

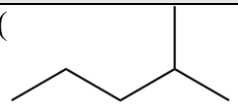
Question Number	Answer	Mark
9	**The only correct answer is A** ($K_p = p(NO_2)^2\ p(O_2)^{½}$) ***B*** *is incorrect because the stoichiometric coefficients to balance the equation have been doubled in the equilibrium expression* ***C*** *is incorrect because solid species have been included in the equilibrium expression* ***D*** *is incorrect because the stoichiometric coefficients to balance the equation have been doubled and solid species have been included in the equilibrium expression*	**(1)**

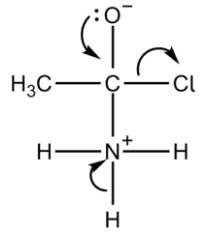
Question Number	Answer	Mark
10(a)	**The only correct answer is B** (add sodium carbonate solution to each compound) ***A*** *is incorrect because neither compound will react with Tollens' reagent* ***C*** *is incorrect because neither compound will react with iodine under alkaline conditions* ***D*** *is incorrect because both compounds will react with phosphorus(V) chloride*	**(1)**

Question Number	Answer	Mark
10(b)	**The only correct answer is C** (warm each compound with iodine under alkaline conditions) ***A*** *is incorrect because neither compound will react with Tollens' reagent* ***B*** *is incorrect because neither compound will react with sodium carbonate solution* ***D*** *is incorrect because both compounds will react with phosphorus(V) chloride*	**(1)**

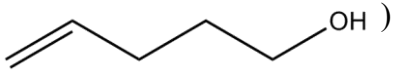
Question Number	Answer	Mark
10(c)	**The only correct answer is A** (warm each compound with Tollens' reagent) ***B*** *is incorrect because neither compound will react with sodium carbonate solution* ***C*** *is incorrect because neither compound will react with iodine under alkaline conditions* ***D*** *is incorrect because neither compound will react with phosphorus(V) chloride*	**(1)**

Question Number	Answer	Mark
11	**The only correct answer is B** (W and X only) ***A*** *is incorrect because reaction X and W will give a positive value for* ΔS_{total} ***C*** *is incorrect because reaction Y will give a negative value for* ΔS_{total} ***D*** *is incorrect because reaction Z will give a negative value for* ΔS_{total}	**(1)**

Question Number	Answer	Mark
12	**The only correct answer is C** () ***A*** *is incorrect because the isomer has only 2 peaks its* ^{13}C *NMR spectrum* ***B*** *is incorrect because the isomer has only 4 peaks its* ^{13}C *NMR spectrum* ***D*** *is incorrect because the isomer has only 3 peaks its* ^{13}C *NMR spectrum*	**(1)**

Question Number	Answer	Mark
13	**The only correct answer is A** () ***B*** *is incorrect because a bond pair of electrons is moving away from an electronegative Cl atom* ***C*** *is incorrect because the positive nitrogen does not have an electron pair that could move to the N-H bond* ***D*** *is incorrect because a bond pair of electrons is moving towards a lone pair of electrons*	**(1)**

Question Number	Answer	Mark
14(a)	**The only correct answer is B** (ether) ***A*** *is incorrect because $LiAlH_4$ will accept a proton from ethanol* ***C*** *is incorrect because $LiAlH_4$ will react with ethyl ethanoate* ***D*** *is incorrect because $LiAlH_4$ will accept a proton from water*	**(1)**

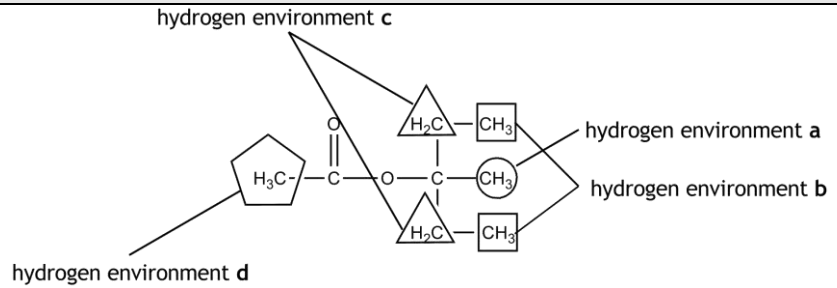
Question Number	Answer	Mark
14(b)	**The only correct answer is D** () ***A*** *is incorrect because the carboxyl group will be reduced to a primary alcohol by* $LiAlH_4$ ***B*** *is incorrect because the C=C will not be reduced to an alkane by* $LiAlH_4$ ***C*** *is incorrect because the carboxyl group will be reduced to a primary alcohol by* $LiAlH_4$ *and the C=C will not be reduced to an alkane by* $LiAlH_4$	**(1)**

Question Number	Answer	Mark
15	**The only correct answer is B** ($HO(CH_2)_4COCl$) ***A*** *is incorrect because both functional groups at either end of the monomer are the same* ***C*** *is incorrect because an addition polymer would form* ***D*** *is incorrect because the alcohol on one monomer will not react with the halogenoalkane on a second monomer*	**(1)**

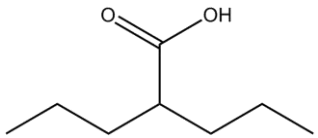
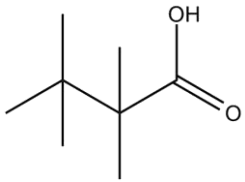
TOTAL FOR SECTION A = 20 MARKS

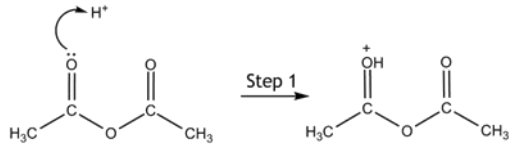
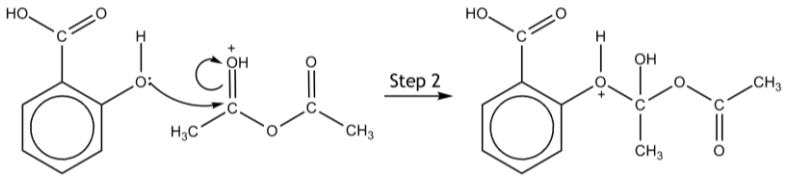
Section B

Question Number	Answer	Additional Guidance	Mark
16(a)	An answer that makes reference to the following point: • 3-methylpentan-3-ol	Allow 3-methyl-3-pentanol / 3-methyl pent-3-ol / 3-methyl penta-3-ol 3-hydroxy-3-methylpentane / 3-methylpentane-3-ol Ignore punctuation errors e.g. additional commas, spaces, missing hyphens etc.	**(1)**

Question Number	Answer	Additional Guidance	Mark
16(b)(i)	An answer that makes reference to the following points: • 3 environments correctly labelled/circled scores **(2)** • 2 environments correctly labelled / circled scores **(1)** • 1 or 0 environments correctly labelled/circled scores **(0)**	 If additional labelling of carbon atoms not attached to hydrogen atoms, apply list principle.	**(2)**

Question Number	Answer	Additional Guidance	Mark
16(b)(ii)	An explanation that makes reference to three of the following points • the chemical shift for the CH_3CO methyl group will be at 1.6 – 3.0 ppm OR CH_3CH_2 groups will be at 0 – 1.8 ppm **(1)** • the peak for CH_3CO will be a singlet (as the adjacent carbon has no hydrogen atoms attached) **and** the peak for the methyl groups attached to CH_2 groups will be a triplet (as adjacent carbons have 2 hydrogen atoms attached) **(1)** • the (relative) **area** (under the peak) for methyl groups attached to CH_2 group will be twice the area (under the peak) for CH_3CO **(1)**	Ignore comments related to peaks / areas / splitting due to CH_2 groups Allow any single value or range within the ranges If values are given for both methyl groups, do not award 2 single values that are the same or if one of the values is out of range Ignore references to CH_2 splitting pattern Allow the (relative) **area** (under the peak) for methyl groups attached to CH_2 group will be 6, the (relative) **area** (under the peak) for CH_3CO will be 3 Ignore heights (of the peaks) If no marks awarded for specific comments as per the MS, allow 1 mark max for any **two** generic comments (for any proton environments) from • (chemical) shifts / different peak positions • **area** (under peak) • splitting (pattern)	**(3)**

Question Number	Answer	Additional Guidance	Mark
16(c)	An answer that makes reference to the following point:  **or**  	Allow correct displayed, structural or hybrid formulae Ignore incorrect connectivity of OH group	**(1)**

Question Number	Answer	Additional Guidance	Mark
16(d)(i)	An answer that makes reference to the following points: • arrow from lone pair of carbonyl oxygen to H^+ ion **(1)** • arrow from lone pair of hydroxyl oxygen to carbon attached to protonated oxygen in intermediate **(1)**	Ignore correct partial charges on carbonyl bond Do not award incorrect dipoles on carbonyl, but penalise only once in both marking points Do not award full negative charge on oxygen, but penalise only once in both marking points Penalise use of half-arrows once only Do not award additional incorrect arrows in either step Do not award δ+ added to hydrogen ion  	**(2)**

Question Number	Answer	Additional Guidance	Mark
16(d)(ii)	An answer that makes reference to the following point: • catalyst	Allow to speed up reaction (without being used up) / reduces activation energy Ignore electrophile / acid / electron acceptor / proton donor Do not award nucleophile	**(1)**

(Total for Question 16 = 10 marks)

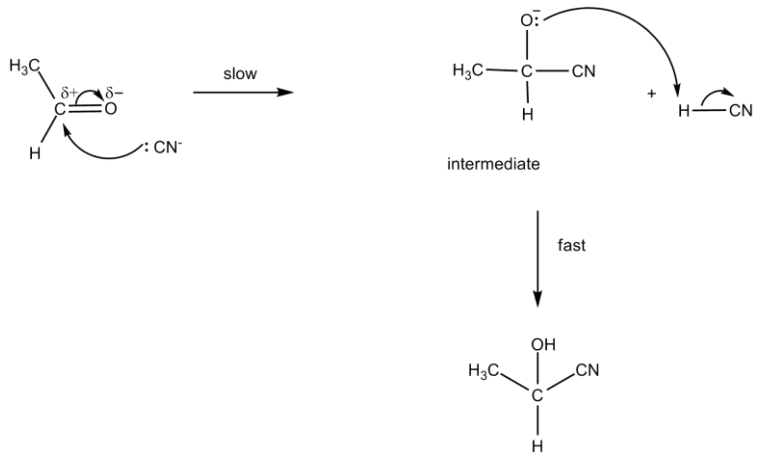
Question Number	Answer	Additional Guidance	Mark
17(a)	An answer that makes reference to the following points: • calculation of moles of hydroxide ions **(1)** • calculation of moles of hydrogen ions **(1)** OR calculation of moles of sulfuric acid • calculation of excess moles of hydroxide ions **(1)** • calculation of concentration of excess hydroxide ions **(1)** • calculation of concentration of hydrogen ions **(1)** • calculation of pH to 1dp **(1)** Alternative method for M5 and M6 • M5 calculation of pOH / calculation of log[OH^-] • M6 calculation of pH to 1dp	<u>Example of calculation</u> $(80.0 \div 1000) \times 0.240 = 0.0192$ (mol) $(20.0 \div 1000) \times 0.072 \times 2 = 2.88 \times 10^{-3}$ (mol) $(20.0 \div 1000) \times 0.072 = 1.44 \times 10^{-3}$ (mol) $0.0192 - 2.88 \times 10^{-3} = 0.01632$ (mol) No subtraction loses M3 **and** M4 $(0.01632) \div (100 \div 1000) = 0.1632$ (mol dm^{-3}) $(1.00 \times 10^{-14}) \div 0.1632 = 6.1275 \times 10^{-14}$ (mol dm^{-3}) $-\log (6.1275 \times 10^{-14}) = 13.2$ Allow TE throughout M1 to M5 TE for M6 must give a value greater than 7 and less than 14 Comment Take care to check as use of 1.44×10^{-3} in the subtraction as this gives an answer very close to the true answer but would not score M3 $-\log (0.1632) = 0.78728$ / $\log(0.1632) = -0.78728$ $14 - 0.78728 = 13.2$ / $14 - (-0.78728) = 13.2$	**(6)**

Question Number	Answer	Additional Guidance	Mark
17(b)(i)	An answer that makes reference to the following point: • (an acid solution) that contains a significant proportion / amount of undissociated acid	Allow an acid that hardly dissociates / an acid that is (only) partially dissociated / an acid that doesn't dissociate completely / dissociation is low / dissociation is small / equilibrium lies to the left / K_a is small / pK_a is large Ignore comments about concentration or number of H^+ ions	**(1)**

Question Number	Answer	Additional Guidance	Mark
17(b)(ii)	A description that makes reference to two of the following points: • a solution whose pH barely changes / resists changes in pH **(1)** • when **small** amounts of **acid** are added **(1)** **and** when **small** amounts of **base / alkali** are added	Allow a solution whose pH remains (almost) constant Allow prevents pH (of solution) from changing (significantly) Allow H^+ for acid Allow OH^- for base Ignore any comments regarding composition of buffer even if incorrect	**(2)**

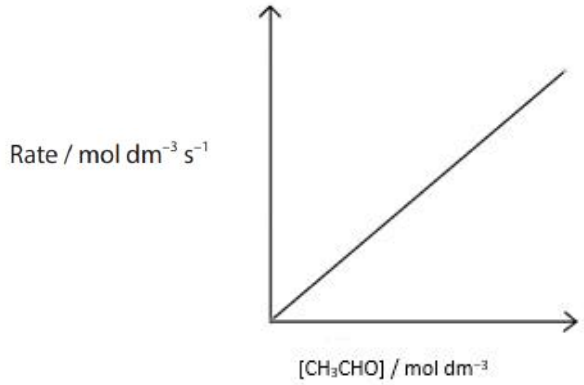
Question Number	Answer	Additional Guidance	Mark
17(b)(iii)	An answer that makes reference to the following points: • calculation of concentration of hydrogen ions **(1)** • rearrangement of K_a expression **(1)** • calculation of concentration of sodium hydrogensulfite **(1)** • calculation of moles of sodium hydrogensulfite **(1)** • calculation of mass of sodium hydrogensulfite **(1)** Alternative M1, M2 and M3 via Henderson-Hasselbalch • calculation of pK_a **(1)** • rearrangement of Henderson-Hasselbalch expression **(1)** • calculation of concentration of sodium hydrogensulfite **(1)** Comment allow use of moles instead of concentration in Henderson-Hasselbach expression.	Example of calculation $10^{-2.18}$ / 6.6069×10^{-3} (mol dm^{-3}) $1.54 \times 10^{-2} = \frac{6.6069 \times 10^{-3} \times [NaHSO_3]}{0.048}$ $[NaHSO_3] = \frac{1.54 \times 10^{-2} \times 0.048}{6.6069 \times 10^{-3}}$ 0.11188 (mol dm^{-3}) $(0.11188) \times (50.0 \div 1000) = 5.5941 \times 10^{-3}$ (mol) $5.5941 \times 10^{-3} \times 104.1 = 0.58235$ (g) Ignore SF except 1 SF Allow TE throughout $-\log(1.54 \times 10^{-2}) = 1.8125$ $pH = pK_a + \log\frac{[NaHSO_3]}{0.048}$ $2.18 = 1.8125 + \log[NaHSO_3] - \log(0.048)$ $\log[NaHSO_3] = 2.18 - 1.8125 - 1.3188 = -0.9513$ $[NaHSO_3] = 10^{-0.9513} = 0.11188$ (mol dm^{-3})	**(5)**

(Total for Question 17 = 14 marks)

Question Number	Answer	Additional Guidance	Mark
18(a)(i)	An answer that makes reference to the following points: • structure of the intermediate carbanion including full negative charge anywhere on the ion or outside a bracket around the ion **(1)** step 1 mechanism • dipole on C=O • curly arrow from C=O bond to O(δ–) • lone pair on C of CN^- • arrow from lone pair on C of CN^- to C in C=O step 2 mechanism • lone pair on O of intermediate • arrow from lone pair on oxygen of intermediate to H (of H-CN) • curly arrow from H-C bond to C (of CN)	 do not award :$CN^{\delta-}$ Ignore correct dipole on HCN Penalise use of half-arrows once only All 7 points scores 3 marks 4, 5 or 6 points scores 2 marks 2 or 3 points score 1 mark Note – if lone pair missing in M4 do not penalise again in M5 If lone pair missing in M6, do not penalise again in M7 If both lone pairs shown but neither arrow comes from the lone pairs, penalise once only	**(4)** **Expert**

Question Number	Answer	Additional Guidance	Mark
18(a)(ii)	An explanation that makes reference to the following points: • to move the dissociation equilibrium of HCN to the right **(1)** • to increase the concentration of cyanide ions / CN^- **(1)**	OH^- reacts with HCN to produce CN^- Allow to produce **more** cyanide ions / CN^- Ignore 'speeds up the reaction' Do not award acts as a catalyst	**(2)**

Question Number	Answer	Additional Guidance	Mark
18(b)	An answer that makes reference to the following point: • rate = $k[CH_3CHO][CN^-]$	Accept reagents in either order Allow upper case *K* Do not award rate = $k[CH_3CHO][HCN]$	**(1)**

Question Number	Answer	Additional Guidance	Mark
18(c)	An answer that makes reference to the following point: • straight line upwards beginning at the origin	Allow TE from (b)  Do not award vertical or horizontal lines Comment Mark consequentially on (b), so if 2nd order wrt CH_3CHO candidate should show 2nd order line If no answer given in (b) allow first order line only	**(1)**

<table>
<tr><th>Question Number</th><th>Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr>
<td>*18(d)</td>
<td>This question assesses the student's ability to show a coherent and logically structured answer with linkages and fully sustained reasoning.

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

The following table shows how the marks should be awarded for indicative content.
<table>
<tr><td>Number of indicative marking points seen in answer</td><td>Number of marks awarded for indicative marking points</td></tr>
<tr><td>6</td><td>4</td></tr>
<tr><td>5-4</td><td>3</td></tr>
<tr><td>3-2</td><td>2</td></tr>
<tr><td>1</td><td>1</td></tr>
<tr><td>0</td><td>0</td></tr>
</table>

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

The mark for indicative content should be added to the mark for lines of reasoning. For example, a response with five indicative marking points that is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning).

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

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

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)

Expert</td>
</tr>
</table>

	Indicative points		
	IP1 formation of orange precipitate / solid / crystals	Allow yellow / orange-yellow / red	
	IP2 (precipitate) separated by (Buchner) filtration	Allow use a filter funnel to separate Allow IP2 as part of post-recrystallisation process Ignore hot filtration (to remove insoluble impurities)	
	IP3 dissolve impure solid in (minimum volume) of hot / boiling solvent **and** cool (to form crystals)	Allow any identified solvent e.g. water	
	IP4 (filter then) rinse with (ice) cold solvent **and** to remove (remaining) dissolved impurities / minimise loss of crystals / minimise dissolving of crystals	If neither IP3 or IP4 are awarded, then allow an IP for '**re**crystallise the precipitate/ solid/ crystals'	
	IP5 dry between filter papers / in (warm) oven (to remove excess solvent) / in a dessicator	Allow dry with paper towel	
	IP6 identify melting temperature **and** compare to data book / (chemical) literature / known values / database / (reputable) internet (source)	Do not award identify boiling temperature	

(Total for Question 18 = 14 marks)

Question Number	Answer	Additional Guidance	Mark
19(a)(i)	An answer that makes reference to the following point: • (isomers that have the same structural formula but) a different spatial arrangement of **atoms**	Allow different 3D arrangement of **atoms** Allow 'non-superimposable mirror images' Ignore 'different structure' Ignore any references to geometric isomerism Ignore any references to chiral centres	**(1)**

Question Number	Answer	Additional Guidance	Mark
19(a)(ii)	An explanation that makes reference to the following points: • (when concentration of) 2-bromobutane doubles (from 0.15 to 0.30) rate doubles, so 1st order wrt 2-bromobutane / 0.3 ÷ 0.15 = 2 **and** 0.054 ÷ 0.027 = 2 so 1st order wrt 2-bromobutane **(1)** • (when concentration of) 2-bromobutane triples (from 0.15 to 0.45) overall rate increases by a factor of 6 / 0.45 ÷ 0.15 = 3 **and** 0.162 ÷ 0.027 = 6 **(1)** • (change in concentration of) 2-bromobutane must have tripled rate, so effect of doubling the concentration of hydroxide ions (from 0.15 to 0.30) must have doubled rate so 1st order wrt hydroxide ions (so S_N2) / 6 ÷ 3 = 2 so 1st order wrt hydroxide ions (so S_N2) **(1)**	Allow when (concentration of) 2-bromobutane goes up by a factor of 1.5 (from 0.30 to 0.45) overall rate increases by a factor of 3 / 0.45 ÷ 0.3 = 1.5 **and** 0.162 ÷ 0.054 = 3 Allow (change in concentration) of 2-bromobutane must have increased rate by × 1.5, so effect of doubling the concentration of hydroxide ions (from 0.15 to 0.30) must have doubled rate so first order wrt hydroxide ions (so S_N2) / 3 ÷ 1.5 = 2 so 1st order wrt hydroxide ions (so S_N2) If no marks awarded allow 1 rescue mark for linking the most relevant experiments to the deduction of orders i.e. experiments 1 and 2 show reaction is first order with respect to 2-bromobutane **and** experiments 1 and 3 show reaction is first order with respect to hydroxide ions	**(3)**

Question Number	Answer	Additional Guidance	Mark
19(a)(iii)	An explanation that makes reference to the following points: • product is optically active **(1)** • stereochemistry is inverted / structure inverted / product rotates (plane-polarised) light in opposite direction **(1)** • as the bromine (atom) is large, attack from the same side (by hydroxide ion) cannot occur OR attack on the (δ+) carbon (the hydroxide (ion)) is only possible on the opposite side to the bromine (atom) / leaving group **(1)**	Allow product is (also) a stereoisomer Do not award racemic mixture Allow the product formed is the mirror image (of the reactant molecule) Allow the product has opposite optical activity (to the reactant) Ignore references to magnitude of rotation Allow hydroxide (ion) is repelled by (δ–) bromine (atom) / attack (by hydroxide (ion)) can only occur from one direction Allow so that the most stable transition state is formed Allow (there is space for) hydroxide (ion) to attack the (δ+) carbon on the opposite side (than Br)	**(3)**

Question Number	Answer		Additional Guidance	Mark
19(b)	An explanation that makes reference to the following points:			**(3)**
	• two activation energies (on the profile) imply 2 steps (in the reaction) / implies intermediate forms	**(1)**	Accept the trough shows the formation of intermediate / shows two steps Allow '2 bumps means 2 steps' / '2 peaks means an intermediate forms'	
	• first activation energy is large(r) / high(er)	**(1)**	Allow reverse arguments for M2 and M3	
	• so first step (of mechanism) is slow(er) (so S_N1)	**(1)**	Allow first step is the rate determining step / RDS (of the mechanism)	

(Total for Question 19 = 10 marks)
TOTAL FOR SECTION B = 48 MARK

Section C

Question Number	Answer	Additional Guidance	Mark
20(a)(i)	• expression for calculation of $\Delta S^{\theta}_{\text{system}}$ **(1)** • calculation of $\Delta S^{\theta}_{\text{system}}$ **(1)**	<u>Example of calculation</u> (70.4 + 213.6) − 112.1 = (+)171.9 (J K^{-1} mol^{-1}) Accept (+)172 (J K^{-1} mol^{-1}) Accept (+) 0.1719 kJ K^{-1} mol^{-1} If units are given for M2, they must be correct Allow 1 mark for final answer of − 171.9 (J K^{-1} mol^{-1}) Ignore SF except 1 SF Correct answer with no working scores (2) The only TE allowed from M1 to M2 is a transcription error in copying the data from the table	**(2)**

Question Number	Answer	Additional Guidance	Mark
20(a)(ii)	• recognition that at the minimum temperature for decomposition $\Delta S^{\theta}_{surr} = -\Delta S^{\theta}_{\text{system}}$ **(1)** • conversion of temperature to Kelvin **(1)** • calculation of ΔH **and** answer to **2 or 3 SF** **(1)** Alternative for M1 • recognition that at the minimum temperature for decomposition $\Delta G^{\theta} = 0$ OR T = $\Delta H \div \Delta$S	<u>Example of calculation</u> Allow TE from (a)(i) ΔS^{θ}_{surr} = –171.9 (J K^{-1} mol^{-1}) M1 can be subsumed within award of M3 712 + 273 = 985 (K) ΔH = – (985 × – 0.1719) = (+) 169.3 = (+) 169 / 170 (kJ mol^{-1}) Allow ΔH = – (985 × – 171.9) = (+) 169300 = 169000 / 170000 J mol^{-1} Allow TE from M1 to M3 Correct answer with no working scores 3	**(3)**

Question Number	Answer		Additional Guidance	Mark
20(b)	• calculation of energy released	**(1)**	<u>Example of calculation</u> Allow TE throughout $4.18 \times 200 \times 6.8 = 5684.8$ (J) Ignore any signs in M1 Do not award use of mass = 204.26	**(3)**
	• calculation of moles of anhydrous magnesium chloride	**(1)**	$4.26 \div 95.3 = 0.044701$ (mol)	
	• calculation of $\Delta_{sol}H$, including sign and unit	**(1)**	$5684.8 \div 0.044701 = 127170$ J mol^{-1} so $\Delta_{sol}H$ = **–** 127 kJ mol^{-1} / **–** 127170 J mol^{-1} Correct answer with no working scores 3 Ignore SF except 1 SF	

Question Number	Answer	Additional Guidance	Mark
20(c)(i)	An answer that makes reference to the following points: • correct formulae and state symbols in left hand box **and** correct formula and state symbol in right hand box	 $Mg^{2+}(g) + 2Cl^{-}(g)$ $MgCl_2(s)$	**(1)**

Question Number	Answer	Additional Guidance	Mark
20(c)(ii)	• expression for standard enthalpy of hydration **(1)** • calculation of enthalpy of hydration of chloride ions **(1)** • calculation of standard enthalpy of hydration of chloride ions **(1)**	Example of calculation $-2526 + (-127) = -1920 + 2\Delta_{hyd}H[Cl^-(g)]$ $2\Delta_{hyd}H[Cl^-(g)] = [-2526 + (-127)] + 1920$ $= -733$ (kJ mol^{-1}) $-733 \div 2 = -366.5 / -367$ (kJ mol^{-1}) OR $-2526 + (-155) = -1920 + 2\Delta_{hyd}H[Cl^-(g)]$ $2\Delta_{hyd}H[Cl^-(g)] = [-2526 + (-155)] + 1920$ $= -761$ (kJ mol^{-1}) $(= -761 \div 2) = -380.5 / -381$ (kJ mol^{-1}) Allow TE from b for M1 No TE from M1 into M2 for incorrect expression, apart from transcription error from b, or value carried though from (b) with incorrect units Allow TE from M2 to M3 Correct answer with no/some working scores (3) Ignore SF except 1 SF Allow use of – 155 even if an answer is evaluated in (b)	**(3)**

Question Number	Answer	Additional Guidance	Mark
20(d)(i)	An answer that makes reference to two of the following points: • the bonding is 100% ionic / the bonding is **only** ionic **(1)** • the ions are in contact with each other **(1)** • the ions are perfect spheres **(1)** • the charges are point charges **(1)**	 Allow no covalent character Allow 'it is 100% ionic' Allow no distortion of electron cloud of Cl^- / chloride ion Allow no polarisation of Cl^- / chloride ion Ignore polarisation of chlor**ine** Allow the charge is distributed evenly across the ions	**(2)**

Question Number	Answer	Additional Guidance	Mark
20(d)(ii)	An explanation that makes reference to the following points: • experimental value is more exothermic **(1)** • (because the) chloride ion is polarised (by the magnesium ion) **(1)** • giving (the bonding in) magnesium chloride some covalent character (so the bonding is stronger) **(1)**	Allow reverse argument for M1 and M3 Allow more negative Allow greater in magnitude Ignore experimental value is larger / smaller	**(3)**

Question Number	Answer		Additional Guidance	Mark
20(e)(i)	• calculation of moles of $BaCO_3$ **and** HCl	**(1)**	<u>Example of calculation</u> 5.00 ÷ 197.3 = 0.025342 (mol) **and** (120 ÷ 1000) × 0.5 = 0.06 (mol) Both correct answers with no working scores (1) Allow use of 137 for A_r of Ba	**(2)**
	• show that number of moles of $BaCO_3$ is less than that required to react with moles of HCl	**(1)**	0.02534 < (0.06 ÷ 2) / 0.02534 < 0.03 Allow reverse argument i.e. HCl (0.06) is > 2 × $BaCO_3$ (0.05068) Allow TE from M1 only if it shows HCl in excess	

Question Number	Answer		Additional Guidance	Mark
20(e)(ii)	• calculation of moles of $BaCO_3$ (= moles of $BaCl_2$) **and** calculation of relative formula mass of $BaCl_2 \cdot nH_2O$	**(1)**	Example of calculation (5.00 ÷ 197.3 =) 0.02534 (mol) 6.19 ÷ 0.02534 = 244.26 (g mol^{-1})	**(3)**
	• calculation of formula mass due to nH_2O	**(1)**	244.26 **–** (137.3 + 71) = 35.96	
	• calculation of n to nearest whole number	**(1)**	(35.96 ÷ 18 = 1.9978) = 2 Correct final answer with no working scores M3 only	
	Alternative method • deduction of moles of anhydrous $BaCl_2$ **and** calculation of mass of anhydrous $BaCl_2$	**(1)**	0.02534 × (137.3 + 71) = 5.2788 (g)	
	• calculation of mass of water of crystallisation	**(1)**	6.19 **–** 5.2788 = 0.9112 (g)	
	• calculation of mole of water of crystallisation **and** n to nearest whole number	**(1)**	0.9122 ÷ 18 = 0.05062 0.05062 ÷ 0.02534 = 1.9977 = 2	

(Total for Question 20 = 22 marks)
TOTAL FOR SECTION C = 22 MARKS
TOTAL FOR PAPER = 90 MARKS