Mark Scheme (Results)

October 2020

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 <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.

Quality of Written Communication
Questions which involve the writing of continuous prose will expect candidates to:
- write legibly, with accurate use of spelling, grammar and punctuation in order to make the meaning clear
- select and use a form and style of writing appropriate to purpose and to complex subject matter
- organise information clearly and coherently, using specialist vocabulary when appropriate.

Full marks will be awarded if the candidate has demonstrated the above abilities.
Questions where QWC is likely to be particularly important are indicated (QWC) in the mark scheme, but this does not preclude others.

Section A (multiple choice)

Question Number	Answer	Mark
1	**The only correct answer is C** (quenching and titrating with acid) ***A*** *is incorrect because bromine is coloured* ***B*** *is incorrect because ions are produced during the reaction* ***D*** *is incorrect because carbon dioxide is a gas produced in the reaction*	(1)

Question Number	Answer	Mark
2	**The only correct answer is B** (0 2) ***A*** *is incorrect because experiments 1 and 2 show the order for Z is 2* ***C*** *is incorrect because in experiments 3 and 2 doubling the concentration of Y results in no change in the rate, so Y is order 0.* ***D*** *is incorrect because in experiments 1 and 3 doubling the concentration of Z results in 4x the rate, so halving the concentration of Y makes no difference to rate so is order 0.*	(1)

Question Number	Answer	Mark
3	**The only correct answer is B** (460 mins) ***A*** *is incorrect because this value would be misreading the scale of the graph* ***C*** *is incorrect because this is the time to get half way to the final concentration on the graph* ***D*** *is incorrect because this is half the time of the reaction on the graph*	(1)

Question Number	Answer	Mark
4 (a)	**The only correct answer is A** (the units for the rate constant are $dm^3\ mol^{-1}\ s^{-1}$) ***B*** *is incorrect because the reaction is second order overall* ***C*** *is not correct because the units of rate are always mol* $dm^{-3}\ s^{-1}$ ***D*** *is not correct because the rate would double as iodine is zero order*	(1)

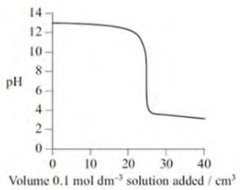
Question Number	Answer	Mark
4 (b)	**The only correct answer is D** (the rate is unchanged when the hydrogen ion concentration is doubled) ***A*** *is incorrect because the rate of reaction does increase with temperature* ***B*** *is incorrect because the rate constant depends on the temperature and increases as temperature rises* ***C*** *is not correct because sodium hydroxide would neutralise some of the* $[H^+]$ *catalyst so change rate*	(1)

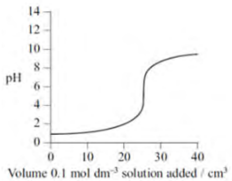
Question Number	Answer	Mark
5	**The only correct answer is D** (2-bromo-2-methylpropane) ***A*** *is incorrect because this is a primary bromoalkane and RBr is most likely to be tertiary* ***B*** *is incorrect because this is a secondary bromoalkane and RBr is most likely to be tertiary* ***C*** *is incorrect because this is a primary bromoalkane and RBr is most likely to be tertiary*	(1)

Question Number	Answer	Mark
6	**The only correct answer is B** ($\Delta S_{surroundings}$ is positive) ***A*** *is incorrect because ΔH is negative for an exothermic reaction* ***C*** *is incorrect because ΔS_{system} is positive as a gas is being formed* ***D*** *is incorrect because as both ΔS_{system} and $\Delta S_{surroundings}$ are positive so ΔS_{total} will be positive*	(1)

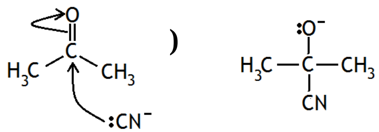
Question Number	Answer	Mark
7	**The only correct answer is A (** $K_c = (K_c')^2$) ***B*** *is incorrect because this is not true as K_c' must be squared* ***C*** *is incorrect because this is not true as K_c' must be squared not multiplied by 2* ***D*** *is incorrect because this is not true as K_c' must be squared not square rooted*	(1)

Question Number	Answer	Mark
8	**The only correct answer is B** (4.47) ***A*** *is incorrect because this answer assumes the concentration of ethanoate ion = concentration of hydrogen ion (as it would be in a weak acid calculation)* ***C*** *is incorrect because this answer is $-\log K_a$ so does not consider the concentrations* ***D*** *is incorrect because this answer is $-\log(2xK_a)$ which has the concentrations upside down*	(1)

Question Number	Answer	Mark
9 (a)	**The only correct answer is D**  ***A*** *is incorrect because, if the graph starts or finishes at a pH of about 1, a strong acid is present* ***B*** *is incorrect because, if the graph starts or finishes at a pH of about 1, a strong acid is present* ***C*** *is incorrect because, if the graph starts or finishes at a pH of about 1, a strong acid is present*	(1)

Question Number	Answer	Mark
9 (b)	**The only correct answer is C**  ***A*** *is incorrect because the mid-point of the vertical portion of the graph is at pH = 7* ***B*** *is incorrect because the mid-point of the vertical portion of the graph is at pH = 7* ***D*** *is incorrect because the mid-point of the vertical portion of the graph is at pH > 7*	(1)

Question Number	Answer	Mark
9 (c)	**The only correct answer is A** ***B*** *is incorrect because the range of colour change for bromothymol blue (6.0 – 7.6) is not within the vertical portion of the graph* ***C*** *is incorrect because the range of colour change for phenol red (6.8 – 8.4) is not within the vertical portion of the graph* ***D*** *is incorrect because the range of colour change for thymol blue (acid) (1.2 – 2.8) is not within the vertical portion of the graph*	(1)

Question Number	Answer	Mark
10	**The only correct answer is A (**  ***B*** *is incorrect because the arrow from the C=O should go to O not C* ***C*** *is incorrect because the dipole for the C=O has been reversed* ***D*** *is incorrect because the arrow should go from :CN⁻ not to it*	(1)

Question Number	Answer	Mark
11	**The only correct answer is B** (CHI_3) ***A*** *is incorrect because there should be 3I not 3H attached to the C* ***C*** *is incorrect because this is the product of the reaction between iodine and propanone in acidic conditions* ***D*** *is incorrect because this is an intermediate during the reaction between iodine and propanone*	(1)

Question Number	Answer	Mark
12	**The only correct answer is C** (CH_3CONH_2) ***A*** *is incorrect because this is formed by the initial reaction between the two* ***B*** *is incorrect because this is formed by the reaction between HCl and methylamine* ***D*** *is incorrect because this is the organic product of the reaction between the two*	(1)

Question Number	Answer	Mark
13	**The only correct answer is C** (Ethyl ethanoate, $CH_3COOCH_2CH_3$) ***A*** *is incorrect because this has a percentage of 40%* ***B*** *is incorrect because this is isomeric to D so cannot be the answer* ***D*** *is incorrect because this is isomeric to B so cannot be the answer*	(1)

Question Number	Answer	Mark
14	**The only correct answer is B** (a carboxylic acid) ***A*** *is incorrect because this will not react with magnesium* ***C*** *is incorrect because this will not react with magnesium* ***D*** *is incorrect because this will not react with lithium tetrahydridoaluminate(III) or magnesium*	(1)

Question Number	Answer	Mark
15 (a)	**The only correct answer is C** (add 2,4-dinitrophenylhydrazine (Brady's reagent) to each compound) ***A*** *is incorrect because neither would react* ***B*** *is incorrect because neither would react* ***D*** *is incorrect because neither would react*	(1)

Question Number	Answer	Mark
15 (b)	**The only correct answer is B** (warm each compound with acidified potassium dichromate(VI) solution) ***A*** *is incorrect because neither would react* ***C*** *is incorrect because neither would react* ***D*** *is incorrect because neither would react*	(1)

Question Number	Answer	Mark
15 (c)	**The only correct answer is D** (add a few drops of each compound, drop by drop, to water) ***A*** *is incorrect because as butanal would react but 2-methylpropan-2-ol would not* ***B*** *is incorrect because as butanal would react but 2-methylpropan-2-ol would not* ***C*** *is incorrect because as butanal would react but 2-methylpropan-2-ol would not*	(1)

(Total for Section A = 20 marks)

Section B

Question Number	**Answer**	**Additional guidance**	**Mark**
	• Top line **(1)** • Bottom line **(1)** • Middle 2 lines **(2)**	Penalise missing or incorrect state symbol once only Penalise lack of electrons or too few electrons once only Penalise the writing of the change for each step e.g. Ca(s) ⟶ Ca(g) once only. Assume that the other substance is unchanged $Ca^{2+}(g) + 2Cl(g) + 2e^{(-)}$ Either $Ca(s) + 2Cl(g)$ or $Ca(g) + Cl_2(g)$ any two of $Ca^{+}(g) + 2Cl(g) + e^{(-)}$ or $Ca(g) + 2Cl(g)$ or $Ca^{+}(g) + Cl_2(g) + e^{(-)}$ or $Ca^{2+}(g) + Cl_2(g) + 2e^{(-)}$ Allow TE from one line to the next, so penalising any error once only.	**(4)**

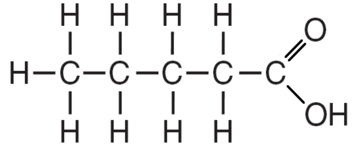
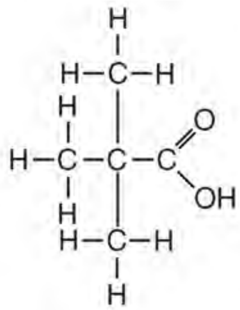
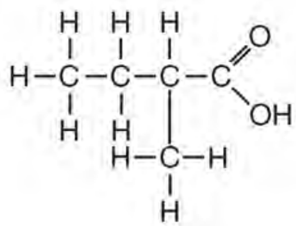
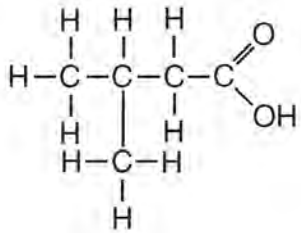
Question Number	Answer	Additional guidance	Mark
16(a)(ii)	• An equation linking enthalpy changes with correct signs and / or values **(1)** • Multiplies atomisation of chlorine OR electron affinity of chlorine by 2 **(1)** • Calculates final value of second ionisation energy of calcium with sign **(1)**	Example of calculation: $\Delta H_1 = \Delta H_2 + \Delta H_3 + \Delta H_4 + \Delta H_5 + \Delta H_6 + \Delta H_7$ OR $\Delta H_6 + \Delta H_7 = \Delta H_1 - \Delta H_2 - \Delta H_3 - \Delta H_4 - \Delta H_5$ OR $\Delta H_5 = -\Delta H_4 - \Delta H_3 - \Delta H_2 + \Delta H_1 - \Delta H_7 - \Delta H_6$ OR $\Delta H_5 = -590.0 - 178.2 - ((2\text{ x})\ 121.7) + -795.8 - -2258 - ((2\text{ x}) - 348.8)$ Similar numerical expressions of the other equations also score 2 x 121.7 / 243.4 / 243 OR 2 x – 348.8 / – 697.6 / – 698 (+) 1148.2 / (+) 1148 / (+) 1150 (kJ mol^{-1}) ALLOW TE on all stages of calculation for max 2. Correct answer with no working scores (3) Ignore SF except 1 SF Common incorrect answers include: – 1148.2 / – 1148 / – 1150 (kJ mol^{-1}) scores (2) (+)799.4 / (+)799 / (+)780 (kJ mol^{-1}) (1 x 348.8) scores (2) (+)1269.9 / (+)1270 (kJ mol^{-1}) (1 x 121.7) scores (2) (+)921.1 / (+)921 / (+) 920 (kJ mol^{-1}) (1 x 348.8 and 121.7) scores (1) (+)2512.7 (Changing sign of $\Delta H_6 + \Delta H_7$ and no 2 x) scores (0)	**(3)**

Question Number	Answer	Additional guidance	Mark
16(b)	An explanation that makes reference to the following points: **EITHER** • Bonding is partially covalent / not purely ionic / has covalent character **(1)** • Ca^{2+} ion is small (and highly charged) **(1)** • Leading to polarisation / distortion in the electron cloud of the chloride / Cl^{-} (ion) / anion **(1)** **OR** • Bonding is almost purely ionic / slightly covalent **(1)** • Ca^{2+} is not sufficiently small (and highly charged) **(1)** • To polarise the chloride / Cl^{-} (ion) very much / to distort the electron cloud of the chloride / Cl^{-} (ion) **(1)**	Penalise the use of calcium and / or chlorine (atom) once only Ignore descriptions of possible macroscopic features of covalent character such as structures etc. Allow calcium ion is small and highly charged / has a high charge density Do not award chlorine Do not award distortion by calcium / calcium atom Allow virtually 100% ionic Do not award purely ionic / 100 % ionic calcium ion is not sufficiently small and highly charged / has too small a charge density Do not award calcium / calcium atom is not sufficiently small / charged Allow chloride (ion) is not very polarised / is not very polarisable Do not award chlorine Do not award chloride is not polarised / polarisable	**(3)**

Question Number	Answer	Additional guidance	Mark
16(c)	An explanation that makes reference to the following points: • (on descending the group) lattice enthalpy becomes less exothermic **(1)** • as the radius of metal ion / M^{2+} ion / cation increases (and charge on ions remains the same / 2+) **(1)** • (down group) weaker forces of **attraction** between **ions** **(1)**	Penalise mention **specifically** of atoms instead of ions once only Penalise mention **specifically** of molecules once only Award reverse arguments if clearly referring to ascending the group Ignore discussion of polarising power Allow less negative / less energy is released Ignore increases / decreases Allow "size" instead of "radius" Ignore atomic radius increases Allow correct formulae of cation**s** Do not award just "charge density decreases" without explanation Allow less attraction to chloride ion Do not award just "weaker bonds" or "weaker bonding"	**(3)**

Question Number	Answer	Additional guidance	Mark
16(d)	• An expression linking enthalpy of solution, lattice enthalpy and hydration enthalpies **(1)** • Value of $\Delta_{sol}H$ **(1)**	Example of calculation $\Delta_{sol}H = -\Delta_{latt}H + (\Sigma)\Delta_{hyd}H$ OR $\Delta_{sol}H = -(-2258) + (-1650) + (2 \times -364)$ −120 (kJ mol^{-1}) Correct answer with no working scores (2) (+)120 / (+)244 / -4636 (kJ mol^{-1}) scores (1)	**(2)**

(Total for Question 16 = 15 marks)

Question Number	**Answer**	**Additional guidance**	**Mark**
17(a)	• Structure A **(1)** • Structure B **(1)** • Structure C **(1)** • Structure D **(1)**	A  B  C  D  Allow condensed or skeletal formulae If Structure B has not been scored allow this structure as a correct answer for Structure D Penalise OH−C connectivity once only to horizontal bonds Ignore connectivity on vertical bonds to OH and all bonds to CH_3 groups. Penalise incorrect names also given once only	**(4)**

Question Number	Answer	Additional guidance	Mark
17(b)(i)	• 3, 4 or 5 correct boxes **(1)** • 6, 7 or 8 correct boxes **(2)** • Nine correct boxes **(3)**	<table><tr><th>b</th><th>c</th><th>d</th></tr><tr><td>2</td><td>2</td><td>3</td></tr><tr><td>2.7 – 4.2</td><td>1.5 – 2.9</td><td>1.5 – 2.9</td></tr><tr><td>triplet</td><td>triplet</td><td>singlet</td></tr></table> Allow a value or range within the range Allow triple / single 3lines / 1 line	**(3)**

Question Number	Answer	Additional guidance	Mark
17(b)(ii)	• Five / 5 (peaks)		**(1)**

Question Number	Answer	Additional guidance	Mark
17(c)(i)		Penalise use of C_3H_7 for formulae once only	**(4)**
	• Identifies isomer **F** **(1)**	**F** is propyl ethanoate / $CH_3COOCH_2CH_2CH_3$ Allow TE on incorrect alcohol or carboxylic acid for V and W If name and formula is given both must be correct	
	• Identifies compound **V** and compound **W** **(1)**	Compound **V** is ethanoic acid / CH_3COOH and Compound **W** is propan-1-ol / $CH_3CH_2CH_2OH$ Ignore just 'propanol'	
	• Two points of justification for identification of isomer **F**, compound **V** and compound **W** **(2)**	Any two from: Compound **V** is a carboxylic acid justified by infra-red Award for correct identification of the bond responsible for either peak? Compound **W** is propan-1-ol / an alcohol / propanol justified by reduction of propanal Allow propanol here but not in M2 Compound **V** or **W** justified by reaction with the other to form an ester Compound **F** is an ester justified by smell / neutral compound	

Question Number	Answer	Additional guidance	Mark
17(c)(ii)	• (Lithium tetrahydridoalumate(III) / lithium aluminium hydride) / $LiAlH_4$ **AND** in dry ether / diethyl ether / ethoxyethane (solvent)	ALLOW Lithal ALLOW Sodium tetrahydridoborate / sodium borohydride AND Water / ethanol solvent	**(1)**

Question Number	Answer	Additional guidance	Mark
17(c)(iii)	• Catalyst	Ignore mention of acid / homogeneous / proton donor Ignore additional words Do not award just ‘proton donor’ or donates hydrogen ions	**(1)**

Question Number	Answer	Additional guidance	Mark
17(d)	An explanation that makes reference to the following points: • Isomer A (has the highest boiling temperature) **(1)** • (Isomer A has the) **only** molecules held together by hydrogen bonding / Isomer A forms hydrogen bonds but E and F do not **(1)** • Hydrogen bonds are the strongest intermolecular forces **(1)**	In general ignore reference to other intermolecular forces (but see below) Allow it forms hydrogen bonds Ignore it forms hydrogen bonds with other compounds/substances Ignore comments about straight chain so stronger London forces Allow hydrogen bonding is stronger than London forces and/or permanent dipoles Allow just ‘forms strong hydrogen bonds’	**(3)**

Total for Question 17 = 17 marks)

Question Number	**Answer**	**Additional guidance**	**Mark**
18(a)(i)	• Calculation of hydrogen ion concentration **(1)** • Calculation of hydroxide ion concentration **(1)**	Example of calculation ($[H^+] = 10^{-pH}$) $[H^+] = 0.074989$ / 0.075 / 7.4989×10^{-2} ($mol\ dm^{-3}$) Do not award just $[H^+] = 10^{-1.125}$ ($[OH^-] = 1.0 \times 10^{-14} \div 0.074989$) $[OH^-] = 1.3335 \times 10^{-13}$ ($mol\ dm^{-3}$) Allow $= 1 \times 10^{-12.875}$ Allow 1 mark for correct unidentified concentrations whatever order they are given Ignore SF except 1 SF	**(2)**

Question Number	Answer	Additional guidance	Mark
18(a)(ii)	• Calculation of moles of H^+ in original solution **(1)** • Calculation of concentration of H^+ in new solution **(1)** • Calculation of volume of new solution **(1)** • Calculation of volume of water needed to add giving answer to 2 or 3 SF **(1)** OR • Calculation of change in pH **(1)** • Concentration of change of concentration of H^+ **(1)** • Calculation of volume of new solution **(1)** • Calculation of volume of water needed to add giving answer to 2 or 3 SF **(1)**	Example of calculation = 0.074989 x 25 ÷ 1000 = 0.0018747 / 1.8747 x 10^{-3} (mol) $[H^+]$ = $10^{-1.5}$ / 0.031623 / 3.1623 x 10^{-2} (mol dm^{-3}) 0.0018747 ÷ 0.031623 = 0.059284 (dm^3) 59.284 – 25.000 = 34.29284 (cm^3) = 34.3 / 34 (cm^3) = 1.5 – 1.125 = 0.375 $[H^+]$ = $10^{-0.375}$ / 0.42170 / 4.2170 x 10^{-1} (mol dm^{-3}) = 25 ÷ 0.42170 = 59.284 (cm^3) 59.284 – 25.000 = 34.29284 (cm^3) = 34.3 / 34 (cm^3) Allow 0.034 / 0.0343 dm^3 Allow TE throughout including from (a)(i) Correct answer with no working scores (4) Ignore SF except 1 SF until final answer	**(4)**

Question Number	Answer	Additional guidance	Mark
18(b)(i)	• Any two correct acid or base **(1)** • All four correct acid and base plus indication of pairings **(1)**	e.g. $H_2PO_4^-(aq) + H_2O(l) \rightleftharpoons HPO_4^{2-}(aq) + H_3O^+(aq)$ Acid ……… Base ……… Conjugate Base ……… Conjugate Acid ……… OR acid ……… base ……… base ……… acid ……… linked in some way to show pairs (eg as shown) scores (2) Just acid ……… base ……… base ……… acid ……… scores (1)	**(2)**

Question Number	Answer	Additional guidance	Mark
18(b)(ii)	An explanation that makes reference to the following points: • oxonium / H_3O^+ ion produced in first dissociation **(1)** • (prevents further dissociation by) pushing second equilibrium to the left. **(1)**	Allow hydronium / hydroxonium ion / H^+	**(2)**

Question Number	Answer	Additional guidance	Mark
18(c)(i)	• Correct expression for K_{a1}	$K_{a1} = \frac{[H_2PO_4^-((aq))][H_3O^+((aq))]}{[H_3PO_4((aq))]}$ Allow use of H^+ instead of H_3O^+ Do not award the charge outside of the square bracket	**(1)**

Question Number	Answer	Additional guidance	Mark
18(c)(ii)	• Calculate hydrogen ion concentration **(1)** • States $[H_2PO_4^-((aq))] = [H_3O^+((aq))]$ or shown in the expression for K_{a1} **(1)** • Calculates K_{a1} **(1)** • Units **(1)**	Example of calculation: $= 10^{-pH}$ / $10^{-1.2}$ / 0.063096 / 6.3096 x 10^{-2} / 0.0631 / 6.31 x 10^{-2} Do not award 0.0630 but TE can be awarded for the remaining marks Allow TE for an incorrect expression for K_{a1} $K_{a1} = \frac{[H_3O^+((aq))]^2}{[H_3PO_4((aq))]}$ $K_{a1} = \frac{(0.063096)^2}{0.500 - 0.063096} = \frac{0.0039811}{0.43690}$ = 0.0091121 / 9.1121 x 10^{-3} / 0.00911 / 9.11 x 10^{-3} ALLOW Use of assumption $[H_3PO_4(aq)] = 0.500$ = 0.0079621 / 7.9621 x 10^{-3} / 0.00796 / 7.96 x 10^{-3} Correct value with no working scores (3) mol dm^{-3} Correct answer with no working and correct units scores (4) Ignore SF except 1 SF but allow 0.5 for concentration	**(4)**

Question Number	Answer	Additional guidance	Mark
18(d)	An explanation that makes reference to the following points: • The mixture contains a (large) reservoir / high concentration of **both** phosphate ions / of hydrogen phosphate and dihydrogen phosphate ions / of $H_2PO_4^-$ and HPO_4^{2-} **(1)** **Either** • Added OH^- combines with H^+ to form water / $H^+ + OH^- \rightarrow H_2O$ **AND** Dihydrogen phosphate ion / $H_2PO_4^-$ dissociates to form more H^+ / $H_2PO_4^- \rightleftharpoons HPO_4^{2-} + H^+$ **Or** Added OH^- reacts with dihydrogen phosphate ion (to form water) / $OH^- + H_2PO_4^- \rightleftharpoons HPO_4^{2-} + H_2O$ **(1)** • (pH changes very little because added OH^- is removed) and change in concentration of $H_2PO_4^-$ **and** HPO_4^{2-} is small / ratio [salt]/[acid] hardly changes **(1)**	Allow large amount / abundance For this mark to be scored at least one ionic equation is required If the equilibrium is given allow 'added OH^- causes the equilibrium to move to the right' Allow pH is unchanged Allow ratio changes a little / changes slightly Ignore there is no change in concentrations / the ratio is unchanged	(3)

(Total for Question 18 = 18 marks)
(Total for Section B = 50 marks)

Section C

Question Number	Answer	Additional guidance	Mark
19(a)(i)	• Gives expression for $\Delta S^{\ominus}_{system}$ **(1)** • Calculation of value of $\Delta S^{\ominus}_{system}$ **(1)**	Example of calculation $\Delta S^{\ominus}_{system}$ = (2 x 192.3) – 191.6 – (3 x 130.6) = **–198.8 / –199** (J K^{-1} mol^{-1}) Ignore SF except 1 SF but award –200 (2 SF) Award –0.198.8 / –0.199 / –0.20 kJ K^{-1} mol^{-1} but units **must** be given Allow kJ mol^{-1} K^{-1} Do not award incorrect units Correct answer with no working scores (2) A positive version of the acceptable answer scores (1) –0.2 kJ K^{-1} mol^{-1} scores (1) Allow TE on an incorrect expression which contains either (2 x 192.3) or (3 x 130.6)	**(2)**

Question Number	Answer	Additional guidance	Mark
19(a)(ii)	An explanation that makes reference to the following points: (Yes because….) • Disorder / number of ways of distributing energy quanta decreases **(1)** • As number of molecules / moles / particles (of gas) decreases **(1)**	Allow just "entropy decreases" Do not award just '$\Delta S^\ominus_{system}$ is negative' Allow 4 moles gives 2 moles / 4 molecules gives 2 molecules Do not award 2 molecules gives 1 molecule Allow TE on positive result in (a)(i), but must state **answer is unexpected**. Ignore no changes of states If (a)(i) is positive and no statement about expectation is made max (1) Positive answer expected scores (0)	**(2)**

Question Number	Answer	Additional guidance	Mark
19(a)(iii)	• Use of $\Delta S_{surroundings} = -\Delta H/T$ **(1)** • Calculates $\Delta S_{surroundings}$ **(1)**	Example of calculation: $\Delta S_{surroundings} = -(-110.2 \times 1000) \div 700$ = (+) 157.4 / 157 (J K^{-1} mol^{-1}) OR = (+) 0.1574 / 0.157 kJ K^{-1} mol^{-1} Allow TE on incorrect equation with recognisable error, e.g. transfer error of value for ΔH or use of incorrect temperature. Do not award incorrect units Ignore SF except 1 SF Correct answer with no working scores (2) Correct value with negative sign scores (1)	**(2)**

Question Number	Answer	Additional guidance	Mark
19(a)(iv)	• Finds ΔS_{system}	Example of calculation ($\Delta S_{system} = \Delta S_{total} - \Delta S_{surroundings}$) = (-78.7 - 157.4)) = -236.1 / -236 (J K^{-1} mol^{-1}) OR = -0.2361 / -0.236 (kJ K^{-1} mol^{-1}) Allow -235.7 if $\Delta S_{surroundings}$ = 157 J K^{-1} mol^{-1} -238.7 if $\Delta S_{surroundings}$ = 160 J K^{-1} mol^{-1} TE from (a)(iii) Ignore SF except 1 SF	**(1)**

<table>
<tr><th>Question Number</th><th>Answer</th><th>Additional guidance</th><th>Mark</th></tr>
<tr><td>19(a)(v)</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).

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.</td><td>(6)</td></tr>
</table>

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<tr><td></td><td>Number of marks awarded for structure of answer and sustained line of reasoning</td></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>

Indicative content

• Rate of reaction is higher / faster
• More ammonia produced in a given time
• At higher temperature ΔS_{surr} is less positive / decreases / smaller
• ΔS_{total} more negative / less positive
• K_p decreases
• equilibrium position moves further left / in the endothermic direction / in reverse direction / gives lower yield of ammonia / makes reaction less feasible
</td>
<td>
If there is any incorrect Chemistry, deduct mark(s) from the reasoning.
If no reasoning mark(s) awarded, do not deduct mark(s).

Ignore comments about ΔS_{system}

ALLOW reaches equilibrium faster
Higher energy cost as an alternative but not just higher cost without justification.

ALLOW $-\Delta H/T$ for ΔS_{surr}

Ignore decreases / smaller

ALLOW K_c or K
</td>
<td></td>
</tr>
</table>

Question Number	Answer	Additional guidance	Mark
19(b)(i)	• Correct expression for K_p	$K_p = \dfrac{pp(NH_3)^2}{pp(N_2)\ pp(H_2)^3}$ Other formats are acceptable but must have a p or pp. Accept capital P Do not award use of square brackets, e.g. $[N_2]$	**(1)**

Question Number	Answer	Additional guidance	Mark
19(b)(ii)	• Calculates partial pressure of ammonia **(1)** • Calculates value of K_p **(1)** • States units **(1)**	Example of calculation $ppNH_3$ = (255 –25 –150) = 80 (atm) K_p =((80)^2/ (25) (150)^3) = (7.5851852 x 10^{-5}) =7.5852 x 10^{-5} Ignore SF except 1 SF TE on incorrect $ppNH_3$ and on equation in (i) atm^{-2} TE for units on incorrect equation in (i)	**(3)**

Question Number	Answer	Additional guidance	Mark
19(b)(iii)	An explanation that makes reference to the following points: • (K_p) remains the same **(1)** • Fraction / quotient / Q / Q_p / apparent value of K_p decreases in value (when pressure increases) **(1)** • so equilibrium shifts to right hand side (to return K_p to its original value / to keep K_p constant) **(1)**	Allow partial pressures of denominator / N_2 and H_2 increases more than the numerator / NH_3 Ignore use of Le Chatelier's Principle Must be linked to Q_p returning to the value of K_p not as a result of Le Chatelier's Principle Allow produces more ammonia (so K_p is constant / returns to original value)	**(3)**

(Total for Question 19 = 20 marks)

(Total for Section C = 20 marks)

Total for Paper = 90 marks

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