



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 meaning of the phrase or the actual word is **essential** to the answer.

ecf/TE/cq (error carried forward) means that a wrong answer given in an earlier part of a question is used correctly in answer to a later part of the same question.

Candidates must make their meaning clear to the examiner to gain the mark. Make sure that the answer makes sense. Do not give credit for correct words/phrases which are put together in a meaningless manner. Answers must be in the correct context.

Quality of Written Communication

Questions which involve the writing of continuous prose will expect candidates to:

- write legibly, with accurate use of spelling, grammar and punctuation in order to make the meaning clear
- select and use a form and style of writing appropriate to purpose and to complex subject matter
- organise information clearly and coherently, using specialist vocabulary when appropriate.

Full marks will be awarded if the candidate has demonstrated the above abilities.

Questions where QWC is likely to be particularly important are indicated (QWC) in the mark scheme, but this does not preclude others.

Section A (multiple choice)

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

| Question Number | Answer | Mark |
|-----------------|---|------|
| 2 | <p>The only correct answer is B (0 2)</p> <p><i>A is incorrect because experiments 1 and 2 show the order for Z is 2</i></p> <p><i>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.</i></p> <p><i>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.</i></p> | (1) |

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

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

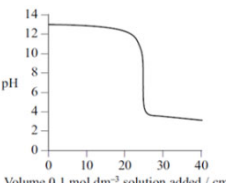
| Question Number | Answer | Mark |
|-----------------|--|------|
| 4 (b) | <p>The only correct answer is D (the rate is unchanged when the hydrogen ion concentration is doubled)</p> <p><i>A is incorrect because the rate of reaction does increase with temperature</i></p> <p><i>B is incorrect because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

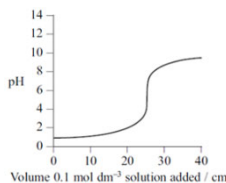
| Question Number | Answer | Mark |
|-----------------|---|------|
| 5 | <p>The only correct answer is D (2-bromo-2-methylpropane)</p> <p><i>A is incorrect because this is a primary bromoalkane and RBr is most likely to be tertiary</i></p> <p><i>B is incorrect because this is a secondary bromoalkane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

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

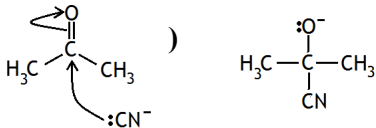
| Question Number | Answer | Mark |
|-----------------|---|------|
| 7 | <p>The only correct answer is A ($K_c = (K_c')^2$)</p> <p><i>B is incorrect because this is not true as K_c' must be squared</i></p> <p><i>C is incorrect because this is not true as K_c' must be squared not multiplied by 2</i></p>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

| Question Number | Answer | Mark |
|-----------------|---|------|
| 8 | <p>The only correct answer is B (4.47)</p> <p><i>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)</i></p> <p><i>C is incorrect because this answer is $-\log K_a$ so does not consider the concentrations</i></p> <p><i>D is incorrect because this answer is $-\log(2xK_a)$ which has the concentrations upside down</i></p> | (1) |

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

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

| Question Number | Answer | Mark |
|-----------------|--|------|
| 9 (c) | <p>The only correct answer is A</p> <p><i>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</i></p> <p><i>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</i></p> <p><i>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</i></p> | (1) |

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

| Question Number | Answer | Mark |
|-----------------|--|------|
| 11 | <p>The only correct answer is B (CHI_3)</p> <p><i>A is incorrect because there should be 3I not 3H attached to the C</i></p> <p><i>C is incorrect because this is the product of the reaction between iodine and propanone in acidic conditions</i></p> <p><i>D is incorrect because this is an intermediate during the reaction between iodine and propanone</i></p> | (1) |
| 12 | <p>The only correct answer is C (CH_3CONH_2)</p> <p><i>A is incorrect because this is formed by the initial reaction between the two</i></p> <p><i>B is incorrect because this is formed by the reaction between HCl and methylamine</i></p> <p><i>D is incorrect because this is the organic product of the reaction between the two</i></p> | (1) |
| 13 | <p>The only correct answer is C (Ethyl ethanoate, $\text{CH}_3\text{COOCH}_2\text{CH}_3$)</p> <p><i>A is incorrect because this has a percentage of 40%</i></p> <p><i>B is incorrect because this is isomeric to D so cannot be the answer</i></p> <p><i>D is incorrect because this is isomeric to B so cannot be the answer</i></p> | (1) |

| Question Number | Answer | Mark |
|-----------------|--|------|
| 14 | <p>The only correct answer is B (a carboxylic acid)</p> <p><i>A is incorrect because this will not react with magnesium</i></p> <p><i>C is incorrect because this will not react with magnesium</i></p> <p><i>D is incorrect because this will not react with lithium tetrahydridoaluminate(III) or magnesium</i></p> | (1) |
| 15 (a) | <p>The only correct answer is C (add 2,4-dinitrophenylhydrazine (Brady's reagent) to each compound)</p> <p><i>A is incorrect because neither would react</i></p> <p><i>B is incorrect because neither would react</i></p> <p><i>D is incorrect because neither would react</i></p> | (1) |
| 15 (b) | <p>The only correct answer is B (warm each compound with acidified potassium dichromate(VI) solution)</p> <p><i>A is incorrect because neither would react</i></p> <p><i>C is incorrect because neither would react</i></p> <p><i>D is incorrect because neither would react</i></p> | (1) |

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

(Total for Section A = 20 marks)

Section B

| Question Number | Answer | Additional guidance | Mark |
|-----------------|---|--|---|
| | <ul style="list-style-type: none"> <li data-bbox="398 523 539 549">• Top line <li data-bbox="398 628 577 654">• Bottom line <li data-bbox="398 766 607 791">• Middle 2 lines | <p data-bbox="1106 319 1771 485">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</p> <p data-bbox="1039 520 1429 552">(1) $\text{Ca}^{2+}(\text{g}) + 2\text{Cl}(\text{g}) + 2\text{e}^{-}$</p> <p data-bbox="1039 628 1182 654">(1) Either</p> <p data-bbox="1106 692 1697 724">$\text{Ca}(\text{s}) + 2\text{Cl}(\text{g})$ or $\text{Ca}(\text{g}) + \text{Cl}_2(\text{g})$</p> <p data-bbox="1039 762 1240 788">(2) any two of</p> <p data-bbox="1106 826 1720 858">$\text{Ca}^{+}(\text{g}) + 2\text{Cl}(\text{g}) + \text{e}^{-}$ or $\text{Ca}(\text{g}) + 2\text{Cl}(\text{g})$</p> <p data-bbox="1106 896 1854 928">or $\text{Ca}^{+}(\text{g}) + \text{Cl}_2(\text{g}) + \text{e}^{-}$ or $\text{Ca}^{2+}(\text{g}) + \text{Cl}_2(\text{g}) + 2\text{e}^{-}$</p> <p data-bbox="1106 967 1868 1024">Allow TE from one line to the next, so penalising any error once only.</p> | <p data-bbox="1921 319 1973 344">(4)</p> |

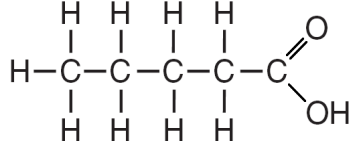
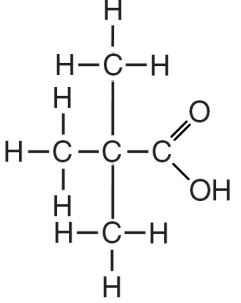
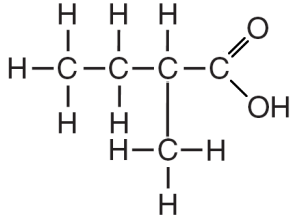
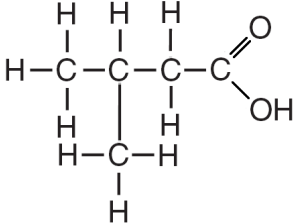
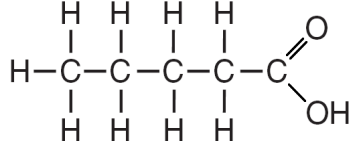
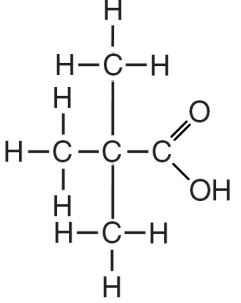
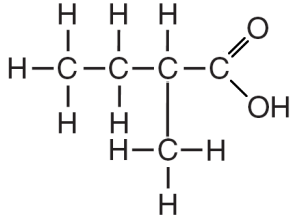
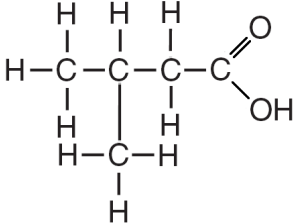
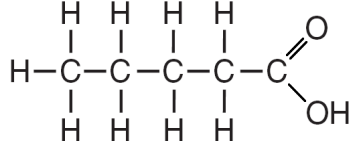
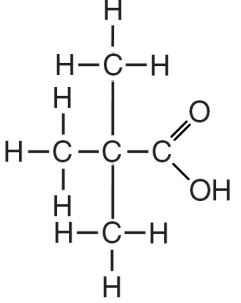
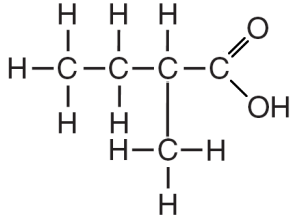
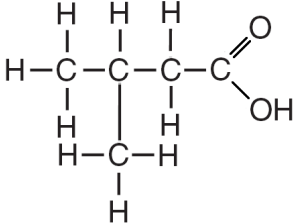
| Question Number | Answer | Additional guidance | Mark |
|-----------------|--|---|------|
| 16(a)(ii) | <ul style="list-style-type: none"> <li data-bbox="398 284 943 347">• An equation linking enthalpy changes with correct signs and / or values (1) <li data-bbox="398 592 943 715">• Multiplies atomisation of chlorine OR electron affinity of chlorine by 2 (1) <li data-bbox="398 754 943 818">• Calculates final value of second ionisation energy of calcium with sign (1) | <p>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 $\Delta H_5 = -590.0 - 178.2 - ((2 \times) 121.7) + -795.8 - -2258 - ((2 \times) -348.8)$ Similar numerical expressions of the other equations also score</p> <p>2 x 121.7 / 243.4 / 243 OR 2 x -348.8 / -697.6 / -698</p> <p>(+) 1148.2 / (+) 1148 / (+) 1150 (kJ mol⁻¹)</p> <p>ALLOW TE on all stages of calculation for max 2. Correct answer with no working scores (3) Ignore SF except 1 SF</p> <p>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)</p> | (3) |

| Question Number | Answer | Additional guidance | Mark |
|-----------------|--|---|------|
| 16(b) | <p>An explanation that makes reference to the following points:</p> <p>EITHER</p> <ul style="list-style-type: none"> • Bonding is partially covalent / not purely ionic / has covalent character (1) • Ca²⁺ ion is small (and highly charged) (1) • Leading to polarisation / distortion in the electron cloud of the chloride / Cl⁻ (ion) / anion (1) <p>OR</p> <ul style="list-style-type: none"> • Bonding is almost purely ionic / slightly covalent (1) • Ca²⁺ 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) | <p>Penalise the use of calcium and / or chlorine (atom) once only Ignore descriptions of possible macroscopic features of covalent character such as structures etc.</p> <p>Allow calcium ion is small and highly charged / has a high charge density</p> <p>Do not award chlorine Do not award distortion by calcium / calcium atom</p> <p>Allow virtually 100% ionic Do not award purely ionic / 100 % ionic</p> <p>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</p> <p>Allow chloride (ion) is not very polarised / is not very polarisable</p> <p>Do not award chlorine Do not award chloride is not polarised / polarisable</p> | (3) |

| Question Number | Answer | Additional guidance | Mark |
|-----------------|---|--|------|
| 16(c) | <p>An explanation that makes reference to the following points:</p> <ul style="list-style-type: none"> • (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) | <p>Penalise mention specifically of atoms instead of ions once only</p> <p>Penalise mention specifically of molecules once only</p> <p>Award reverse arguments if clearly referring to ascending the group</p> <p>Ignore discussion of polarising power</p> <p>Allow less negative / less energy is released</p> <p>Ignore increases / decreases</p> <p>Allow “size” instead of “radius”</p> <p>Ignore atomic radius increases</p> <p>Allow correct formulae of cations</p> <p>Do not award just “charge density decreases” without explanation</p> <p>Allow less attraction to chloride ion</p> <p>Do not award just “weaker bonds” or “weaker bonding”</p> | (3) |

| Question Number | Answer | Additional guidance | Mark |
|-----------------|--|--|------|
| 16(d) | <ul style="list-style-type: none">An expression linking enthalpy of solution, lattice enthalpy and hydration enthalpies (1)Value of $\Delta_{\text{sol}}H$ (1) | <p>Example of calculation $\Delta_{\text{sol}}H = -\Delta_{\text{latt}}H + (\Sigma)\Delta_{\text{hyd}}H$ OR $\Delta_{\text{sol}}H = -(-2258) + (-1650) + (2 \times -364)$</p> <p>-120 (kJ mol⁻¹)</p> <p>Correct answer with no working scores (2)</p> <p>(+)120 / (+)244 / -4636 (kJ mol⁻¹) scores (1)</p> | (2) |

(Total for Question 16 = 15 marks)

| Question Number | Answer | Additional guidance | Mark | | | | | | | | |
|---|--|--|------|---|--|---|---|---|---|--|-----|
| 17(a) | <ul style="list-style-type: none"> • Structure A (1) • Structure B (1) • Structure C (1) • Structure D (1) | <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 50%; text-align: center;">A</th> <th style="width: 50%; text-align: center;">B</th> </tr> </thead> <tbody> <tr> <td style="text-align: center; vertical-align: middle;">  </td> <td style="text-align: center; vertical-align: middle;">  </td> </tr> <tr> <th style="text-align: center;">C</th> <th style="text-align: center;">D</th> </tr> <tr> <td style="text-align: center; vertical-align: middle;">  </td> <td style="text-align: center; vertical-align: middle;">  </td> </tr> </tbody> </table> <p>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 CH₃ groups. Penalise incorrect names also given once only</p> | A | B |  |  | C | D |  |  | (4) |
| A | B | | | | | | | | | | |
|  |  | | | | | | | | | | |
| C | D | | | | | | | | | | |
|  |  | | | | | | | | | | |

| Question Number | Answer | Additional guidance | Mark | | | | | | | | | | | | |
|-----------------|--|--|------|---|---|---|---|---|-----------|-----------|-----------|---------|---------|---------|-----|
| 17(b)(i) | <ul style="list-style-type: none"> • 3, 4 or 5 correct boxes (1) • 6, 7 or 8 correct boxes (2) • Nine correct boxes (3) | <table border="1" style="margin-left: auto; margin-right: auto;"> <thead> <tr> <th>b</th> <th>c</th> <th>d</th> </tr> </thead> <tbody> <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> </tbody> </table> <p>Allow a value or range within the range</p> <p>Allow triple / single 3lines / 1 line</p> | b | c | d | 2 | 2 | 3 | 2.7 – 4.2 | 1.5 – 2.9 | 1.5 – 2.9 | triplet | triplet | singlet | (3) |
| b | c | d | | | | | | | | | | | | | |
| 2 | 2 | 3 | | | | | | | | | | | | | |
| 2.7 – 4.2 | 1.5 – 2.9 | 1.5 – 2.9 | | | | | | | | | | | | | |
| triplet | triplet | singlet | | | | | | | | | | | | | |

| Question Number | Answer | Additional guidance | Mark |
|-----------------|--|---------------------|------|
| 17(b)(ii) | <ul style="list-style-type: none"> • Five / 5 (peaks) | | (1) |

| Question Number | Answer | Additional guidance | Mark |
|-----------------|---|--|------|
| 17(c)(i) | <ul style="list-style-type: none"> <li data-bbox="477 331 1178 368">• Identifies isomer F (1) <li data-bbox="477 501 1178 537">• Identifies compound V and compound W (1) <li data-bbox="477 708 1178 772">• Two points of justification for identification of isomer F, compound V and compound W (2) | <p data-bbox="1200 260 1727 296">Penalise use of C₃H₇ for formulae once only</p> <p data-bbox="1200 328 1850 461">F is propyl ethanoate / CH₃COOCH₂CH₂CH₃ Allow TE on incorrect alcohol or carboxylic acid for V and W If name and formula is given both must be correct</p> <p data-bbox="1200 501 1760 633">Compound V is ethanoic acid / CH₃COOH and Compound W is propan-1-ol / CH₃CH₂CH₂OH Ignore just 'propanol'</p> <p data-bbox="1200 708 1850 868">Any two from: Compound V is a carboxylic acid justified by infra-red Award for correct identification of the bond responsible for either peak?</p> <p data-bbox="1200 908 1816 1007">Compound W is propan-1-ol / an alcohol / propanol justified by reduction of propanal Allow propanol here but not in M2</p> <p data-bbox="1200 1046 1850 1110">Compound V or W justified by reaction with the other to form an ester</p> <p data-bbox="1200 1150 1805 1214">Compound F is an ester justified by smell / neutral compound</p> | (4) |

| Question Number | Answer | Additional guidance | Mark |
|-----------------|--|--|------|
| 17(c)(ii) | <ul style="list-style-type: none">(Lithium tetrahydridoaluminate(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) | <ul style="list-style-type: none">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) | <p>An explanation that makes reference to the following points:</p> <ul style="list-style-type: none">• 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) | <p>In general ignore reference to other intermolecular forces (but see below)</p> <p>Allow it forms hydrogen bonds Ignore it forms hydrogen bonds with other compounds/substances Ignore comments about straight chain so stronger London forces</p> <p>Allow hydrogen bonding is stronger than London forces and/or permanent dipoles Allow just 'forms strong hydrogen bonds'</p> | (3) |

Total for Question 17 = 17 marks)

| Question Number | Answer | Additional guidance | Mark |
|-----------------|---|---|------|
| 18(a)(i) | <ul style="list-style-type: none">• Calculation of hydrogen ion concentration • Calculation of hydroxide ion concentration | <p>Example of calculation</p> <p>(1) $[H^+] = 10^{-pH}$</p> <p>$[H^+] = 0.074989 / 0.075 / 7.4989 \times 10^{-2} \text{ (mol dm}^{-3}\text{)}$</p> <p>Do not award just $[H^+] = 10^{-1.125}$</p> <p>(1) $[OH^-] = 1.0 \times 10^{-14} \div 0.074989$</p> <p>$[OH^-] = 1.3335 \times 10^{-13} \text{ (mol dm}^{-3}\text{)}$</p> <p>Allow = $1 \times 10^{-12.875}$</p> <p>Allow 1 mark for correct unidentified concentrations whatever order they are given</p> <p>Ignore SF except 1 SF</p> | (2) |

| Question Number | Answer | Additional guidance | Mark |
|-----------------|--|--|------|
| 18(a)(ii) | <ul style="list-style-type: none"> • 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) <p>OR</p> <ul style="list-style-type: none"> • 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) | <p>Example of calculation</p> <p>$= 0.074989 \times 25 \div 1000 = 0.0018747 / 1.8747 \times 10^{-3} \text{ (mol)}$</p> <p>$[\text{H}^+] = 10^{-1.5} / 0.031623 / 3.1623 \times 10^{-2} \text{ (mol dm}^{-3}\text{)}$</p> <p>$0.0018747 \div 0.031623 = 0.059284 \text{ (dm}^3\text{)}$</p> <p>$59.284 - 25.000 = 34.29284 \text{ (cm}^3\text{)}$ $= 34.3 / 34 \text{ (cm}^3\text{)}$</p> <p>$= 1.5 - 1.125 = 0.375$</p> <p>$[\text{H}^+] = 10^{-0.375} / 0.42170 / 4.2170 \times 10^{-1} \text{ (mol dm}^{-3}\text{)}$</p> <p>$= 25 \div 0.42170 = 59.284 \text{ (cm}^3\text{)}$</p> <p>$59.284 - 25.000 = 34.29284 \text{ (cm}^3\text{)} = 34.3 / 34 \text{ (cm}^3\text{)}$</p> <p>Allow 0.034 / 0.0343 dm³</p> <p>Allow TE throughout including from (a)(i)</p> <p>Correct answer with no working scores (4)</p> <p>Ignore SF except 1 SF until final answer</p> | (4) |

| Question Number | Answer | Additional guidance | Mark |
|-----------------|--|--|------|
| 18(b)(i) | <ul style="list-style-type: none"> • Any two correct acid or base (1) • All four correct acid and base plus indication of pairings (1) | <p>e.g.</p> $\text{H}_2\text{PO}_4^-(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{HPO}_4^{2-}(\text{aq}) + \text{H}_3\text{O}^+(\text{aq})$ <p style="text-align: center;"> Acid Base Conjugate Base Conjugate Acid </p> <p>OR</p> <p style="text-align: center;"> acid base base acid </p> <p style="text-align: center;"> </p> <p>linked in some way to show pairs (eg as shown) scores (2)</p> <p>Just</p> <p style="text-align: center;"> acid base base acid </p> <p style="text-align: right;">scores (1)</p> | (2) |

| Question Number | Answer | Additional guidance | Mark |
|-----------------|--|--|------|
| 18(b)(ii) | An explanation that makes reference to the following points: <ul style="list-style-type: none">• 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) | <ul style="list-style-type: none">• Correct expression for K_{a1} | $K_{a1} = \frac{[\text{H}_2\text{PO}_4^-(\text{aq})][\text{H}_3\text{O}^+(\text{aq})]}{[\text{H}_3\text{PO}_4(\text{aq})]}$ <p>Allow use of H^+ instead of H_3O^+</p> <p>Do not award the charge outside of the square bracket</p> | (1) |

| Question Number | Answer | Additional guidance | Mark |
|-----------------|--|--|------|
| 18(c)(ii) | <ul style="list-style-type: none"> <li data-bbox="392 316 1025 347">• Calculate hydrogen ion concentration (1) <li data-bbox="392 523 1025 587">• States $[H_2PO_4^-(aq)] = [H_3O^+(aq)]$ or shown in the expression for K_{a1} (1) <li data-bbox="392 1066 1025 1098">• Calculates K_{a1} (1) <li data-bbox="392 1169 1025 1201">• Units (1) | <p data-bbox="1050 244 1335 276">Example of calculation:</p> $= 10^{-pH} / 10^{-1.2} / 0.063096 / 6.3096 \times 10^{-2} / 0.0631 / 6.31 \times 10^{-2}$ <p data-bbox="1050 379 1868 411">Do not award 0.0630 but TE can be awarded for the remaining marks</p> <p data-bbox="1050 451 1576 483">Allow TE for an incorrect expression for K_{a1}</p> $K_{a1} = \frac{[H_3O^+(aq)]^2}{[H_3PO_4(aq)]}$ $K_{a1} = \frac{(0.063096)^2}{0.500 - 0.063096} = \frac{0.0039811}{0.43690}$ $= 0.0091121 / 9.1121 \times 10^{-3} / 0.00911 / 9.11 \times 10^{-3}$ <p data-bbox="1050 842 1160 874">ALLOW</p> <p data-bbox="1050 914 1518 946">Use of assumption $[H_3PO_4(aq)] = 0.500$</p> $= 0.0079621 / 7.9621 \times 10^{-3} / 0.00796 / 7.96 \times 10^{-3}$ <p data-bbox="1050 1082 1536 1114">Correct value with no working scores (3)</p> <p data-bbox="1050 1185 1160 1217">mol dm^{-3}</p> <p data-bbox="1050 1257 1756 1321">Correct answer with no working and correct units scores (4) Ignore SF except 1 SF but allow 0.5 for concentration</p> | (4) |

| Question Number | Answer | Additional guidance | Mark |
|-----------------|--|---|------|
| 18(d) | <p>An explanation that makes reference to the following points:</p> <ul style="list-style-type: none"> 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) <p>Either</p> <ul style="list-style-type: none"> Added OH^- combines with H^+ to form water / $\text{H}^+ + \text{OH}^- \rightarrow \text{H}_2\text{O}$ <p>AND</p> <p>Dihydrogen phosphate ion / H_2PO_4^- dissociates to form more H^+ / $\text{H}_2\text{PO}_4^- \rightleftharpoons \text{HPO}_4^{2-} + \text{H}^+$</p> <p>Or</p> <p>Added OH^- reacts with dihydrogen phosphate ion (to form water) / $\text{OH}^- + \text{H}_2\text{PO}_4^- \rightleftharpoons \text{HPO}_4^{2-} + \text{H}_2\text{O}$ (1)</p> <ul style="list-style-type: none"> (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) | <p>Allow large amount / abundance</p> <p>For this mark to be scored at least one ionic equation is required</p> <p>If the equilibrium is given allow ‘added OH^- causes the equilibrium to move to the right’</p> <p>Allow pH is unchanged Allow ratio changes a little / changes slightly Ignore there is no change in concentrations / the ratio is unchanged</p> | (3) |

(Total for Question 18 = 18 marks)

(Total for Section B = 50 marks)

Section C

| Question Number | Answer | Additional guidance | Mark |
|-----------------|---|---|------|
| 19(a)(i) | <ul style="list-style-type: none"> <li data-bbox="483 384 1178 416">• Gives expression for $\Delta S^\ominus_{\text{system}}$ (1) <li data-bbox="483 488 1178 520">• Calculation of value of $\Delta S^\ominus_{\text{system}}$ (1) | <p data-bbox="1200 317 1480 349">Example of calculation</p> $\Delta S^\ominus_{\text{system}} = (2 \times 192.3) - 191.6 - (3 \times 130.6)$ $= -198.8 / -199 \text{ (J K}^{-1} \text{ mol}^{-1}\text{)}$ <p data-bbox="1200 555 1738 587">Ignore SF except 1 SF but award -200 (2 SF)</p> <p data-bbox="1200 622 1861 718">Award -0.198.8 / -0.199 / -0.20 kJ K⁻¹ mol⁻¹ but units must be given Allow kJ mol⁻¹ K⁻¹</p> <p data-bbox="1200 753 1536 785">Do not award incorrect units</p> <p data-bbox="1200 820 1704 852">Correct answer with no working scores (2)</p> <p data-bbox="1200 887 1839 919">A positive version of the acceptable answer scores (1)</p> <p data-bbox="1200 954 1525 986">-0.2 kJ K⁻¹ mol⁻¹ scores (1)</p> <p data-bbox="1200 1021 1895 1085">Allow TE on an incorrect expression which contains either (2 x 192.3) or (3 x 130.6)</p> | (2) |

| Question Number | Answer | Additional guidance | Mark |
|-----------------|--|---|------|
| 19(a)(ii) | <p>An explanation that makes reference to the following points:</p> <p>(Yes because....)</p> <ul style="list-style-type: none">• Disorder / number of ways of distributing energy quanta decreases (1)• As number of molecules / moles / particles (of gas) decreases (1) | <p>Allow just “entropy decreases” Do not award just ‘ΔS_{system} is negative’</p> <p>Allow 4 moles gives 2 moles / 4 molecules gives 2 molecules</p> <p>Do not award 2 molecules gives 1 molecule</p> <p>Allow TE on positive result in (a)(i), but must state answer is unexpected.</p> <p>Ignore no changes of states</p> <p>If (a)(i) is positive and no statement about expectation is made max (1)</p> <p>Positive answer expected scores (0)</p> | (2) |

| Question Number | Answer | Additional guidance | Mark |
|-----------------|---|--|------|
| 19(a)(iii) | <ul style="list-style-type: none"><li data-bbox="398 316 1167 347">• Use of $\Delta S_{\text{surroundings}} = -\Delta H/T$ (1)<li data-bbox="398 419 1167 451">• Calculates $\Delta S_{\text{surroundings}}$ (1) | <p data-bbox="1200 244 1485 276">Example of calculation:</p> <p data-bbox="1200 316 1637 347">$\Delta S_{\text{surroundings}} = -(-110.2 \times 1000) \div 700$</p> <p data-bbox="1200 411 1559 443">= (+) 157.4 / 157 (J K⁻¹ mol⁻¹)</p> <p data-bbox="1200 483 1249 515">OR</p> <p data-bbox="1200 547 1585 579">= (+) 0.1574 / 0.157 kJ K⁻¹ mol⁻¹</p> <p data-bbox="1200 619 1865 715">Allow TE on incorrect equation with recognisable error, e.g. transfer error of value for ΔH or use of incorrect temperature.</p> <p data-bbox="1200 754 1541 786">Do not award incorrect units</p> <p data-bbox="1200 826 1469 858">Ignore SF except 1 SF</p> <p data-bbox="1200 898 1709 930">Correct answer with no working scores (2)</p> <p data-bbox="1200 962 1709 994">Correct value with negative sign scores (1)</p> | (2) |

| Question Number | Answer | Additional guidance | Mark |
|-----------------|---|---|------|
| 19(a)(iv) | <ul style="list-style-type: none">Finds ΔS_{system} | <p>Example of calculation</p> $(\Delta S_{\text{system}} = \Delta S_{\text{total}} - \Delta S_{\text{surroundings}})$ $= (-78.7 - 157.4)$ $= -236.1 / -236 \text{ (J K}^{-1} \text{ mol}^{-1}\text{)}$ <p>OR</p> $= -0.2361 / -0.236 \text{ (kJ K}^{-1} \text{ mol}^{-1}\text{)}$ <p>Allow -235.7 if $\Delta S_{\text{surroundings}} = 157 \text{ J K}^{-1} \text{ mol}^{-1}$ -238.7 if $\Delta S_{\text{surroundings}} = 160 \text{ J K}^{-1} \text{ mol}^{-1}$</p> <p>TE from (a)(iii)</p> <p>Ignore SF except 1 SF</p> | (1) |

| Question Number | Answer | Additional guidance | Mark | | | | | | | | | | | | |
|--|---|--|---|---|---|-----|---|-----|---|---|---|---|---|--|-----|
| 19(a)(v) | <p>This question assesses a student’s ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning.</p> <p>Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.</p> <p>The following table shows how the marks should be awarded for indicative content.</p> <table border="1" data-bbox="376 547 891 860"> <thead> <tr> <th data-bbox="376 547 624 683">Number of indicative marking points seen in answer</th> <th data-bbox="624 547 891 683">Number of marks awarded for indicative marking points</th> </tr> </thead> <tbody> <tr> <td data-bbox="376 683 624 719">6</td> <td data-bbox="624 683 891 719">4</td> </tr> <tr> <td data-bbox="376 719 624 756">5–4</td> <td data-bbox="624 719 891 756">3</td> </tr> <tr> <td data-bbox="376 756 624 793">3–2</td> <td data-bbox="624 756 891 793">2</td> </tr> <tr> <td data-bbox="376 793 624 829">1</td> <td data-bbox="624 793 891 829">1</td> </tr> <tr> <td data-bbox="376 829 624 860">0</td> <td data-bbox="624 829 891 860">0</td> </tr> </tbody> </table> <p>The following table shows how the marks should be awarded for structure and lines of reasoning.</p> | Number of indicative marking points seen in answer | Number of marks awarded for indicative marking points | 6 | 4 | 5–4 | 3 | 3–2 | 2 | 1 | 1 | 0 | 0 | <p>Guidance on how the mark scheme should be applied:</p> <p>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).</p> <p>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).</p> <p>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.</p> | (6) |
| Number of indicative marking points seen in answer | Number of marks awarded for indicative marking points | | | | | | | | | | | | | | |
| 6 | 4 | | | | | | | | | | | | | | |
| 5–4 | 3 | | | | | | | | | | | | | | |
| 3–2 | 2 | | | | | | | | | | | | | | |
| 1 | 1 | | | | | | | | | | | | | | |
| 0 | 0 | | | | | | | | | | | | | | |

| | Number of marks awarded for structure of answer and sustained line of reasoning | <p>If there is any incorrect Chemistry, deduct mark(s) from the reasoning. If no reasoning mark(s) awarded, do not deduct mark(s).</p> <p>Ignore comments about ΔS_{system}</p> <p>ALLOW reaches equilibrium faster Higher energy cost as an alternative but not just higher cost without justification.</p> <p>ALLOW $-\Delta H/T$ for ΔS_{surr}</p> <p>Ignore decreases / smaller</p> <p>ALLOW K_c or K</p> | | |
|--|---|--|--|--|
| Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout. | 2 | | | |
| Answer is partially structured with some linkages and lines of reasoning. | 1 | | | |
| Answer has no linkages between points and is unstructured. | 0 | | | |
| <p>Indicative content</p> <ul style="list-style-type: none"> • 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 | | | | |

| Question Number | Answer | Additional guidance | Mark |
|-----------------|---|--|------|
| 19(b)(i) | <ul style="list-style-type: none"> Correct expression for K_p | $K_p = \frac{pp(\text{NH}_3)^2}{pp(\text{N}_2) pp(\text{H}_2)^3}$ <p>Other formats are acceptable but must have a p or pp. Accept capital P</p> <p>Do not award use of square brackets, e.g. [N₂]</p> | (1) |

| Question Number | Answer | Additional guidance | Mark |
|-----------------|--|--|------|
| 19(b)(ii) | <ul style="list-style-type: none"> Calculates partial pressure of ammonia Calculates value of K_p States units | <p>Example of calculation</p> <p>(1) $pp\text{NH}_3 = (255 - 25 - 150) = 80 \text{ (atm)}$</p> <p>(1) $K_p = \frac{(80)^2}{(25)(150)^3} = (7.5851852 \times 10^{-5})$ $= 7.5852 \times 10^{-5}$ Ignore SF except 1 SF</p> <p>TE on incorrect $pp\text{NH}_3$ and on equation in (i)</p> <p>(1) atm^{-2}</p> <p>TE for units on incorrect equation in (i)</p> | (3) |

| Question Number | Answer | Additional guidance | Mark |
|-----------------|--|--|------|
| 19(b)(iii) | <p>An explanation that makes reference to the following points:</p> <ul style="list-style-type: none">• (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) | <p>Allow partial pressures of denominator / N_2 and H_2 increases more than the numerator / NH_3 Ignore use of Le Chatelier's Principle</p> <p>Must be linked to Q_p returning to the value of K_p not as a result of Le Chatelier's Principle</p> <p>Allow produces more ammonia (so K_p is constant / returns to original value)</p> | (3) |

(Total for Question 19 = 20 marks)

(Total for Section C = 20 marks)

Total for Paper = 90 marks

