

# Mark Scheme (Results)

January 2016

Pearson Edexcel International  
Advanced Level in Chemistry  
(WCH04) Paper 01 – General  
Principles of Chemistry I

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## General Marking Guidance

- All candidates must receive the same treatment. Examiners must mark the first candidate in exactly the same way as they mark the last.
- Mark schemes should be applied positively. Candidates must be rewarded for what they have shown they can do rather than penalised for omissions.
- Examiners should mark according to the mark scheme not according to their perception of where the grade boundaries may lie.
- There is no ceiling on achievement. All marks on the mark scheme should be used appropriately.
- All the marks on the mark scheme are designed to be awarded. Examiners should always award full marks if deserved, i.e. if the answer matches the mark scheme. Examiners should also be prepared to award zero marks if the candidate's response is not worthy of credit according to the mark scheme.
- Where some judgement is required, mark schemes will provide the principles by which marks will be awarded and exemplification may be limited.
- When examiners are in doubt regarding the application of the mark scheme to a candidate's response, the team leader must be consulted.
- Crossed out work should be marked UNLESS the candidate has replaced it with an alternative response.
- Mark schemes will indicate within the table where, and which strands of QWC, are being assessed. The strands are as follows:
  - i) ensure that text is legible and that spelling, punctuation and grammar are accurate so that meaning is clear
  - ii) select and use a form and style of writing appropriate to purpose and to complex subject matter
  - iii) organise information clearly and coherently, using specialist vocabulary when appropriate

## Using the Mark Scheme

Examiners should look for qualities to reward rather than faults to penalise. This does NOT mean giving credit for incorrect or inadequate answers, but it does mean allowing candidates to be rewarded for answers showing correct application of principles and knowledge. Examiners should therefore read carefully and consider every response: even if it is not what is expected it may be worthy of credit.

The mark scheme gives examiners:

- an idea of the types of response expected
- how individual marks are to be awarded
- the total mark for each question
- examples of responses that should NOT receive credit.

/ means that the responses are alternatives and either answer should receive full credit.

( ) means that a phrase/word is not essential for the award of the mark, but helps the examiner to get the sense of the expected answer.

Phrases/words in **bold** indicate that the meaning of the phrase or the actual word is **essential** to the answer.

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

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

### Quality of Written Communication

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

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

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

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

## Section A

| Question Number | Correct Answer | Reject | Mark |
|-----------------|----------------|--------|------|
| <b>1</b>        | D              |        | 1    |

| Question Number | Correct Answer | Reject | Mark |
|-----------------|----------------|--------|------|
| <b>2</b>        | D              |        | 1    |

| Question Number | Correct Answer | Reject | Mark |
|-----------------|----------------|--------|------|
| <b>3</b>        | A              |        | 1    |

| Question Number | Correct Answer | Reject | Mark |
|-----------------|----------------|--------|------|
| <b>4</b>        | C              |        | 1    |

| Question Number | Correct Answer | Reject | Mark |
|-----------------|----------------|--------|------|
| <b>5a</b>       | C              |        | 1    |

| Question Number | Correct Answer | Reject | Mark |
|-----------------|----------------|--------|------|
| <b>5b</b>       | B              |        | 1    |

| Question Number | Correct Answer | Reject | Mark |
|-----------------|----------------|--------|------|
| <b>5c</b>       | C              |        | 1    |

| Question Number | Correct Answer | Reject | Mark |
|-----------------|----------------|--------|------|
| <b>6</b>        | A              |        | 1    |

| Question Number | Correct Answer | Reject | Mark |
|-----------------|----------------|--------|------|
| <b>7</b>        | D              |        | 1    |

| Question Number | Correct Answer | Reject | Mark |
|-----------------|----------------|--------|------|
| <b>8</b>        | B              |        | 1    |

| Question Number | Correct Answer | Reject | Mark |
|-----------------|----------------|--------|------|
| <b>9a</b>       | A              |        | 1    |

| Question Number | Correct Answer | Reject | Mark |
|-----------------|----------------|--------|------|
| <b>9b</b>       | B              |        | 1    |

| Question Number | Correct Answer | Reject | Mark |
|-----------------|----------------|--------|------|
| <b>10</b>       | B              |        | 1    |

| Question Number | Correct Answer | Reject | Mark |
|-----------------|----------------|--------|------|
| <b>11</b>       | B              |        | 1    |

| Question Number | Correct Answer | Reject | Mark |
|-----------------|----------------|--------|------|
| <b>12</b>       | D              |        | 1    |

| Question Number | Correct Answer | Reject | Mark |
|-----------------|----------------|--------|------|
| <b>13a</b>      | C              |        | 1    |

| Question Number | Correct Answer | Reject | Mark |
|-----------------|----------------|--------|------|
| <b>13b</b>      | C              |        | 1    |

| Question Number | Correct Answer | Reject | Mark |
|-----------------|----------------|--------|------|
| <b>13c</b>      | D              |        | 1    |

| Question Number | Correct Answer | Reject | Mark |
|-----------------|----------------|--------|------|
| <b>14</b>       | D              |        | 1    |

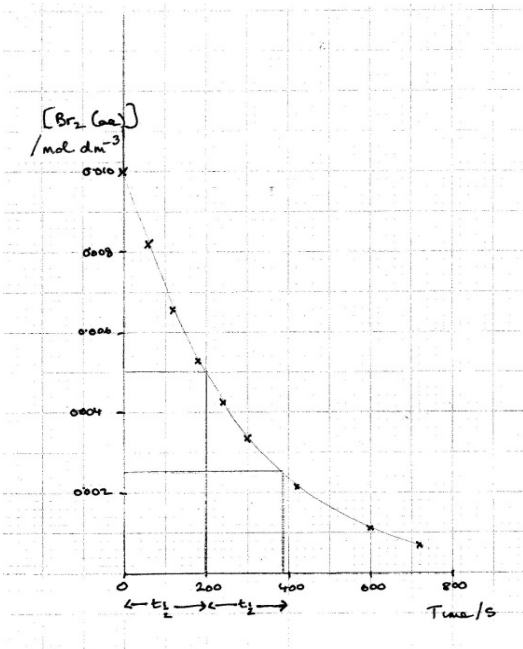
| Question Number | Correct Answer | Reject | Mark |
|-----------------|----------------|--------|------|
| <b>15</b>       | A              |        | 1    |

**TOTAL FOR SECTION A = 20 Marks**

## Section B

| Question Number | Acceptable Answers                                                                                                                                                                                                                                                                                                                                                                                           | Reject                                                                                                                                                                                                       | Mark |
|-----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| <b>16a</b>      | <p>TWO of</p> <p>Bromine / Br<sub>2</sub><br/>by colorimetry <b>(1)</b></p> <p>Carbon dioxide / CO<sub>2</sub><br/>by (measurement of) gas <b>volume</b> / <b>mass</b> change <b>(1)</b></p> <p>ALLOW<br/>Hydrogen ions / H<sup>+</sup> and / or bromide ions / Br<sup>-</sup><br/>By electrical conductivity <b>(1)</b></p> <p>ALLOW<br/>Hydrogen ions / H<sup>+</sup><br/>by pH measurement <b>(1)</b></p> | <p>Dilatometry<br/>Sampling methods</p> <p>Br / Br<sup>-</sup><br/>Calorimetry</p> <p>Just<br/>'gas syringe'<br/>'measure amount of gas'<br/>'use balance'</p> <p>Br<sub>2</sub> or bromine</p> <p>HCOOH</p> | 2    |

| Question Number | Acceptable Answers                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Reject                                                                                                                    | Mark |
|-----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------|------|
| <b>16b(i)</b>   | <p>Suitable scale so the points cover more than half of grid in both directions <b>and</b> axes labelled</p> <p>Horizontal axis labelled time /s<br/>ALLOW<br/>(s)</p> <p>Vertical axis labelled [Br<sub>2</sub>] / mol dm<sup>-3</sup><br/>ALLOW<br/>mol / dm<sup>3</sup><br/>[Br<sub>2</sub>] x 10<sup>-3</sup> /mol dm<sup>-3</sup> <b>(1)</b></p> <p>Correct plotting of <b>all</b> points with smooth curve through all points<br/>ALLOW<br/>Minor wobbles <b>(1)</b></p> | <p>Non uniform<br/>scale scores 0</p> <p>Br<sub>2</sub> for [Br<sub>2</sub>]</p> <p>Straight lines<br/>between points</p> | 2    |

| Question Number | Acceptable Answers                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Reject         | Mark |
|-----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------|------|
| 16b(ii)         |  <p>Any two half lives <b>shown on graph</b><br/> <b>IGNORE</b><br/> Third half life even if not <math>195 \pm 15</math> s (1)</p> <p>Each half life <math>195 \pm 15</math> s must<br/> approximately match values from graph<br/> This may be shown on the graph (1)</p> <p>Third mark is stand alone:<br/> Half life is (approximately) constant (so<br/> first order) (1)</p> <p>ALLOW<br/> Lines showing tangents at two different<br/> concentrations (1)</p> <p>Values of gradients of both tangents (1)</p> <p>Gradient (rate) is directly proportional to<br/> concentration (1)</p> | 200 and<br>400 | 3    |

| Question Number | Acceptable Answers                                                                                                                                        | Reject                                                              | Mark |
|-----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------|------|
| <b>16b(iii)</b> | <b>Concentration</b> of methanoic acid does not change (significantly) during course of reaction (as it is so much greater than concentration of bromine) | Methanoic acid is not involved in the rds<br>Just 'it is in excess' | 1    |

| Question Number | Acceptable Answers                                                                                                         | Reject                                                                | Mark |
|-----------------|----------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------|------|
| <b>16b(iv)</b>  | Rate/ r/ R = $k[\text{Br}_2]^{(1)}[\text{HCOOH}]^{(1)}$<br><br>Formulae must be correct<br><br>ALLOW<br>Upper case K for k | Omission of Rate/ r/ R<br>Br / CHOOH /HCOH<br>Lack of square brackets | 1    |

| Question Number | Acceptable Answers                                                                                                                                                                                                                                                                                                                                         | Reject | Mark |
|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------|------|
| <b>16b(v)</b>   | $k = \frac{4.54 \times 10^{-5}}{0.01 \times 0.5}$<br><br>$= 9.08 \times 10^{-3} / 0.00908$ <b>(1)</b><br><br>Mark units independently but must match rate equation in 16(b)(iv)<br><br>$\text{dm}^3 \text{mol}^{-1} \text{s}^{-1}$ (in any order) <b>(1)</b><br><br>TE on rate equation<br>IGNORE SF<br>NOTE If first order then units are $\text{s}^{-1}$ |        | 2    |

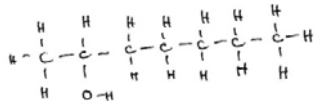
**(Total for Question 16 = 11 marks)**

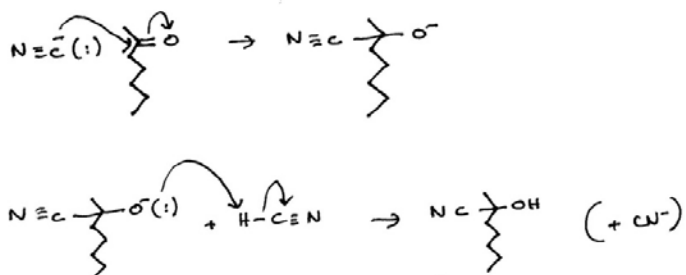
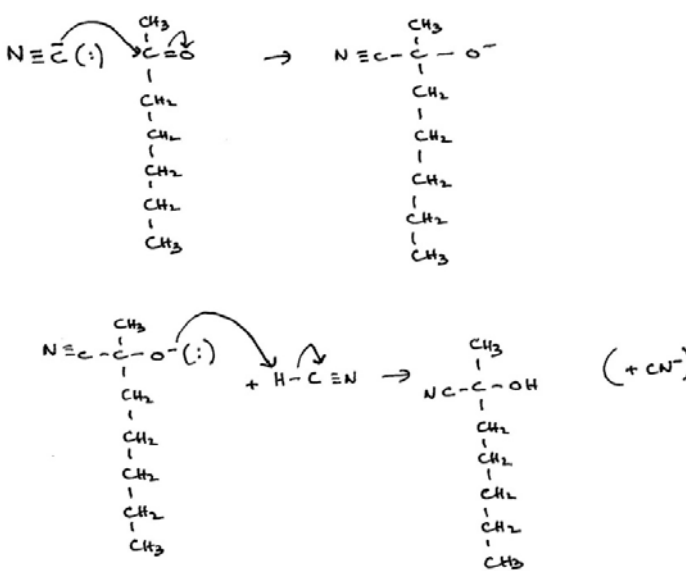
| Question Number | Acceptable Answers                                                                     | Reject    | Mark |
|-----------------|----------------------------------------------------------------------------------------|-----------|------|
| <b>17a</b>      | Heptan-2-one<br><br>ALLOW<br>Hept-2-one<br>Hepta-2-one<br>Heptane-2-one<br>2-heptanone | Heptanone | 1    |

| Question Number | Acceptable Answers                                                                                                                                                                                                                                                                                                                                                                            | Reject                                                                                                 | Mark |
|-----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------|------|
| <b>17b</b>      | (Warm with) iodine and sodium hydroxide/ iodine in the presence of alkali <b>(1)</b><br><br>EITHER<br>Yellow <b>and</b> precipitate with <b>A only</b><br><br>OR<br>Yellow <b>and</b> precipitate with <b>A</b> , no change with <b>B</b><br><br>ALLOW<br>Antiseptic smell with <b>A only</b><br><br>ALLOW<br>Correct result following use of just 'iodoform test' for second mark <b>(1)</b> | Just 'iodoform test'<br><br><br><br><br><br><br><br><br><br>Measure the melting point of the hydrazone | 2    |

| Question Number | Acceptable Answers                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Reject | Mark |
|-----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------|------|
| <b>17c</b>      | <p>Test 2 may be given before test 1<br/>Allow a correct result with a nearly correct test eg no acid in dichromate test scores 0 for test but scores 1 for the result remains orange</p> <p>Test 1: (Warm with) Brady's reagent / (2,4-)dinitrophenylhydrazine / (2,4)DNP(H)<br/><b>(1)</b></p> <p>Yellow/ orange/ red<br/><b>and</b> precipitate/ solid/ crystals<br/><b>and</b> confirms C=O/ carbonyl/ aldehyde or ketone<br/><b>(1)</b></p> <p>Test 2: Any one from<br/>(Warm/boil with) Fehling's solution/ Benedict's solution<br/><b>(1)</b></p> <p>No red-brown/ brown/ orange ppt / stays blue, confirms not an aldehyde<br/>ALLOW<br/>No reaction confirms not an aldehyde/ so it is a ketone<br/><b>(1)</b></p> <p>OR<br/>Test 2: (Warm with) Tollens' reagent/ ammoniacal silver nitrate<br/><b>(1)</b></p> <p>No silver mirror/ grey black or silver ppt confirms not an aldehyde<br/>ALLOW<br/>No reaction confirms not an aldehyde/ so it is a ketone<br/><b>(1)</b></p> <p>OR<br/>(Warm with) potassium/sodium dichromate((VI)) <b>and</b> sulfuric acid/ <math>\text{Cr}_2\text{O}_7^{2-}</math> <b>and</b> <math>\text{H}^+</math><br/>ALLOW<br/>(Warm with) acidified (potassium/ sodium) dichromate((VI))<br/><b>(1)</b></p> <p>remains orange / does not go green confirms not an aldehyde<br/>ALLOW<br/>No reaction confirms not an aldehyde/ so it is a ketone<br/><b>(1)</b></p> |        | 4    |

|  |                                                                                                                                                                          |  |  |
|--|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--|--|
|  | <b>Additional Comments</b><br>READ (b) and (c) TOGETHER<br>DNPH test in (b) scores 0 but if DNPH test is given correctly in (b) allow up to 2 marks for this test in (c) |  |  |
|--|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--|--|

| Question Number | Acceptable Answers                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Reject                                                              | Mark |
|-----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------|------|
| <b>17d</b>      |  <p>OR</p> <p>CH<sub>3</sub>CH(OH)(CH<sub>2</sub>)<sub>4</sub>CH<sub>3</sub> /<br/>         CH<sub>3</sub>CH(OH)CH<sub>2</sub>CH<sub>2</sub>CH<sub>2</sub>CH<sub>2</sub>CH<sub>3</sub>      <b>(1)</b></p> <p>Lithium tetrahydridoaluminate((III))/<br/>         lithium aluminium hydride /<br/>         LiAlH<sub>4</sub> (in dry ether)</p> <p>ALLOW</p> <p>NaBH<sub>4</sub> / sodium borohydride<br/>         H<sub>2</sub> + Ni/Pt/ Pd catalyst      <b>(1)</b></p> | <p>Skeletal formula<br/>         Lack of<br/>         hydrogens</p> | 2    |

| Question Number | Acceptable Answers                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Reject                     | Mark |
|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------|------|
| 17e(i)          |  <p>ALLOW</p>  <p>Arrow from any part of <math>\text{CN}^-</math> (including a lone pair on either the carbon or nitrogen) to <b>carbon</b> of <math>\text{C}=\text{O}</math><br/> <b>and</b><br/>         Arrow from part of <math>\text{C}=\text{O}</math> double bond to oxygen<br/>         ALLOW<br/> <math>\text{CN}^-</math> can approach from LHS or RHS of A<br/>         Two steps via charged canonical form (1)<br/>         Negatively charged intermediate with C-CN bond (1)<br/>         Arrow from resulting <math>\text{O}^-</math> to hydrogen of <math>\text{HCN}/\text{H}^+/\text{H}_2\text{O}</math><br/>         Do not penalise incorrect or absent arrow between H and CN (1)<br/>         IGNORE<br/>         Dipoles on <math>\text{C}=\text{O}</math></p> | CN without negative charge | 3    |

C-N-C  
 Penalise once only

| Question Number | Acceptable Answers                                                                                                                                                                                                                                                                                                                                                       | Reject                                                                                                 | Mark |
|-----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------|------|
| <b>17e(ii)</b>  | <p>Forms a racemic mixture / racemate <b>(1)</b></p> <p>Cyanide can attack (equally) from either side/ above or below <b>(1)</b></p> <p>Because bonds round C=O are (trigonal) planar /<br/> \ C=O is planar<br/> /</p> <p>OR</p> <p>Carbonyl group / C=O <b>group</b> / reaction site is planar</p> <p>OR</p> <p>Bonds around carbonyl carbon are planar <b>(1)</b></p> | <p>Ketone/ the molecule is planar</p> <p>C=O is planar</p> <p>carbocation / intermediate is planar</p> | 3    |

**(Total for Question 17 = 15 marks)**

| Question Number | Acceptable Answers                                                                                                                                                                          | Reject                                                                               | Mark |
|-----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|------|
| <b>18a</b>      | $K_p = \frac{p(\text{CH}_3\text{OH})}{p(\text{CO}) (x) p(\text{H}_2)^2}$<br><br>ALLOW<br>Lower or upper case p/ pp<br>Expression without brackets<br>$p^2\text{H}_2$<br>$p_{\text{CO}}$ etc | Square brackets<br>Expressions<br>without p/ pp/<br>P/PP to show<br>partial pressure | 1    |

| Question Number                                               | Acceptable Answers                                                                                     |            |                |                    |               | Reject | Mark |
|---------------------------------------------------------------|--------------------------------------------------------------------------------------------------------|------------|----------------|--------------------|---------------|--------|------|
| <b>18b</b>                                                    |                                                                                                        | CO         | H <sub>2</sub> | CH <sub>3</sub> OH | total         |        | 1    |
|                                                               | Mol at start                                                                                           | 39.5       | 77.5           | 0                  |               |        |      |
|                                                               | Mol at eqm                                                                                             | <b>1.0</b> | <b>0.5</b>     | 38.5               | <b>40(.0)</b> |        |      |
|                                                               | Mol H <sub>2</sub> (1)                                                                                 |            |                |                    |               |        |      |
|                                                               | Mol CO <b>and</b> total mol                                                                            |            |                |                    |               |        |      |
|                                                               | ALLOW                                                                                                  |            |                |                    |               |        |      |
|                                                               | Total mol shown in working below (1)                                                                   |            |                |                    |               |        |      |
|                                                               | ALLOW                                                                                                  |            |                |                    |               |        |      |
|                                                               | TE on mols of hydrogen                                                                                 |            |                |                    |               |        |      |
|                                                               |                                                                                                        | CO         | H <sub>2</sub> | CH <sub>3</sub> OH |               |        |      |
|                                                               | Mole fraction                                                                                          | 0.025      | 0.0125         | 0.9625             |               |        |      |
|                                                               | pp                                                                                                     | 1.25       | 0.625          | 48.125             |               |        |      |
|                                                               | $K_p = ((48.125)/ (1.25) \times (0.625)^2$<br>$= 98.56 \text{ atm}^{-2})$<br>$= 98.6 \text{ atm}^{-2}$ |            |                |                    |               |        |      |
| All three partial pressures (1)                               |                                                                                                        |            |                |                    |               |        |      |
| Correct value for $K_p$ to 3SF                                |                                                                                                        |            |                |                    |               |        |      |
| TE on partial pressures and expression for $K_p$ in table (1) |                                                                                                        |            |                |                    |               |        |      |
| Units                                                         |                                                                                                        |            |                |                    |               |        |      |
| TE on expression in table (1)                                 |                                                                                                        |            |                |                    |               |        |      |
| Correct answer with no working scores last 3 marks            |                                                                                                        |            |                |                    |               |        |      |

If candidate incorrectly use the ratio 1 CO to 1 H<sub>2</sub> then first mark is lost but the remaining four can be achieved as shown below

|              | CO         | H <sub>2</sub> | CH <sub>3</sub> OH | total                 |
|--------------|------------|----------------|--------------------|-----------------------|
| Mol at start | 39.5       | 77.5           | 0                  | <del>          </del> |
| Mol at eqm   | <b>1.0</b> | <b>39(.0)</b>  | 38.5               | <b>78.5</b>           |

Mol H<sub>2</sub> **(0)**  
Mol CO **and** total mol **(1)**

ALLOW  
TE on mols of hydrogen

|               | CO     | H <sub>2</sub> | CH <sub>3</sub> OH |
|---------------|--------|----------------|--------------------|
| Mole fraction | 0.0127 | 0.497          | 0.490              |
| pp            | 0.637  | 24.8           | 24.5               |

$$K_p = ((24.5)/ (0.637) \times (24.8)^2 \\ = 0.06259 \text{ atm}^{-2} \\ = 0.0626 \text{ atm}^{-2}$$

If candidate does not approximate to 3 SF during the calculation allow 0.0623 to 0.0625

All three partial pressures **(1)**

Correct value for  $K_p$  to 3 SF  
TE on partial pressures and expression for  $K_p$  in 18(a) **(1)**

Units  
TE on expression in 18(a) **(1)**

Correct answer with no working scores last 3 marks

| Question Number | Acceptable Answers                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Reject                                                                      | Mark |
|-----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------|------|
| <b>18c</b>      | <p>(<math>K_p</math> is smaller so reaction does not go as far to right) reaction is exothermic/ <math>\Delta H</math> is negative <b>(1)</b></p> <p><math>\Delta S_{\text{surroundings}} = -\Delta H/T</math> so is positive<br/> ALLOW<br/> If in explaining <math>\Delta S_{\text{surroundings}}</math> is +ve, the expression <math>\Delta S_{\text{surroundings}} = -\Delta H/T</math> is quoted, then the mark can be awarded <b>(1)</b></p> <p>IGNORE<br/> References to <math>\Delta S_{\text{total}} = R \ln K</math></p> <p>Endothermic reaction scores 0</p> | <p>Absence of <math>\Delta S_{\text{surroundings}} = -\Delta H/T</math></p> | 2    |

| Question Number | Acceptable Answers                                                                                                                                                                                                                                                                                                                                                                                 | Reject | Mark |
|-----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------|------|
| <b>18d</b>      | <p> <math>\begin{array}{c} \text{CH}_2\text{OH} \\   \\ \text{CHOH} \\   \\ \text{CH}_2\text{OH} \end{array}</math> <b>(1)</b> </p> <p>+ <b>3</b> <math>\text{C}_{15}\text{H}_{31}\text{COOCH}_3</math> / <math>\text{CH}_3\text{OOC C}_{15}\text{H}_{31}</math> / <math>\text{CH}_3\text{OCOC}_{15}\text{H}_{31}</math> <b>(1)</b></p> <p>ALLOW<br/> partially displayed or skeletal formulae</p> |        | 2    |

**(Total for Question 18 = 10 marks)**

| Question Number | Acceptable Answers           | Reject | Mark |
|-----------------|------------------------------|--------|------|
| <b>19a</b>      | Proton/ H <sup>+</sup> donor |        | 1    |

| Question Number | Acceptable Answers                                                                                                          | Reject             | Mark |
|-----------------|-----------------------------------------------------------------------------------------------------------------------------|--------------------|------|
| <b>19b</b>      | <p>pH of HCl = 1<br/> <b>and</b><br/> pH of weak acid is greater /higher than 1</p> <p>Allow any number &gt;1 and &lt;7</p> | Different (from 1) | 1    |

| Question Number | Acceptable Answers                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Reject | Mark  |        |                |                      |     |                |                      |       |  |   |
|-----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------|-------|--------|----------------|----------------------|-----|----------------|----------------------|-------|--|---|
| <b>19c(i)</b>   | <p>HCOOH/ methanoic acid is stronger <b>because</b> its <math>K_a</math> is bigger/higher<br/>OR its <math>pK_a</math> is smaller / lower</p> <p>(The data:</p> <table><tr><td></td><td><math>K_a</math></td><td><math>pK_a</math></td></tr><tr><td>Methanoic acid</td><td><math>1.6 \times 10^{-4}</math></td><td>3.8</td></tr><tr><td>Propanoic acid</td><td><math>1.3 \times 10^{-5}</math></td><td>4.9 )</td></tr></table> <p>IGNORE<br/>Discussion of inductive effect</p> |        | $K_a$ | $pK_a$ | Methanoic acid | $1.6 \times 10^{-4}$ | 3.8 | Propanoic acid | $1.3 \times 10^{-5}$ | 4.9 ) |  | 1 |
|                 | $K_a$                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | $pK_a$ |       |        |                |                      |     |                |                      |       |  |   |
| Methanoic acid  | $1.6 \times 10^{-4}$                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 3.8    |       |        |                |                      |     |                |                      |       |  |   |
| Propanoic acid  | $1.3 \times 10^{-5}$                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 4.9 )  |       |        |                |                      |     |                |                      |       |  |   |

| Question Number | Acceptable Answers                                                                                                                                                                                                                                                                                                                       | Reject                                                 | Mark |
|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------|------|
| <b>19c(ii)</b>  | <p><math>(\text{HCOOH} + \text{C}_2\text{H}_5\text{COOH}) \rightleftharpoons \text{HCOO}^- + \text{C}_2\text{H}_5\text{COOH}_2^+</math></p> <p>ALLOW<br/> TE for equation with propanoic acid as proton donor giving <math>\text{HCOOH}_2^+</math> and <math>\text{C}_2\text{H}_5\text{COO}^-</math> if HCOOH is stated to be weaker</p> | $\text{COOH}^-$<br>$\text{C}_2\text{H}_6\text{COOH}^+$ | 1    |

| Question Number | Acceptable Answers                                                                                                                                                                                                                                                                                                                                   | Reject                                                                       | Mark |
|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------|------|
| <b>19d</b>      | $[H^+] = (1 \times 10^{-14} / [OH^-])$<br>$= 2 \times 10^{-13} \text{ (mol dm}^{-3}\text{)}$ <b>(1)</b><br><br>pH = 12.7 <b>(1)</b><br><br>OR<br><br>pOH / -log 0.05 = 1.3 <b>(1)</b><br><br>pH = (14 - 1.3 =) 12.7 <b>(1)</b><br><br>Correct answer with no working scores 2<br>provided at least 3 SF<br>Allow TE on first mark provided answer >7 | <br><br><br><br><br><br><br><br><br>13<br><br><br><br><br><br><br><br><br>13 | 2    |

| Question Number | Acceptable Answers                                                                                                                                                                                                             | Reject | Mark |
|-----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------|------|
| <b>19e(i)</b>   | $C_2H_5COOH + NaOH \rightarrow C_2H_5COO^{(-)} Na^{(+)} + H_2O$<br><br>ALLOW<br>$\rightleftharpoons$ for $\rightarrow$<br>$C_2H_5COO^- + Na^+$ for $C_2H_5COO^{(-)} Na^{(+)}$<br><br>IGNORE<br>State symbols even if incorrect |        | 1    |

| Question Number | Acceptable Answers                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Reject | Mark |
|-----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------|------|
| <b>19e(ii)</b>  | <p>Allow salt/ C<sub>2</sub>H<sub>5</sub>COONa/ propanoate ion/ C<sub>2</sub>H<sub>5</sub>COO<sup>-</sup>/ base for A<sup>-</sup></p> <p>Allow propanoic acid/ C<sub>2</sub>H<sub>5</sub>COOH for HA</p> <p><b>First mark</b></p> $K_a = \frac{[H^+][A^-]}{[HA]}$ <p>OR</p> $\log K_a = \log[H^+] + \log [A^-]/[HA]$ <p>OR</p> $pH = pK_a - \log [HA]/[A^-]$ <p>ALLOW<br/>any of these equations re-arranged or used correctly <b>(1)</b></p> <p><b>Next four marks</b></p> <p>Mol NaOH before mixing =<br/>(20 x 0.05/1000) = 0.001<br/><b>and</b> mol propanoic acid before mixing =<br/>(20 x 0.25/1000) = 0.005 <b>(1)</b></p> <p>Mol propanoate in mixture = 0.001<br/>OR [propanoate] = (0.001/40 x 1000)<br/>= 0.025 (mol dm<sup>-3</sup>) <b>(1)</b></p> <p>Mol propanoic acid in mixture = 0.004<br/>OR [propanoic acid] = (0.004/40 x 1000)<br/>= 0.1 (mol dm<sup>-3</sup>) <b>(1)</b></p> $[H^+] = \frac{(1.3 \times 10^{-5})(0.1)}{0.025}$ <p>pH = 4.28/ 4.3 <b>(1)</b></p> <p>Correct pH with no working scores last 4 marks</p> <p>ALLOW</p> <p>Other methods leading to 4.28 e.g. based on equal volumes being mixed so mol propanoate are in double the volume and so concentration is 0.025 mol dm<sup>-3</sup></p> |        | 5    |

| Question Number | Acceptable Answers                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Reject | Mark |
|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------|------|
| <b>19e(iii)</b> | <p><b>First mark</b><br/> The mixture contains a large amount/<br/> reservoir of a (weak) acid/propanoic<br/> acid <b>and</b> its conjugate base/<br/> propanoate ions /salt <b>(1)</b></p> <p><b>Second mark</b><br/> Only awarded if at least one equation<br/> given</p> <p>Added <math>\text{OH}^-</math> combines with <math>\text{H}^+</math><br/> <math>(\text{H}^+ + \text{OH}^- \rightarrow \text{H}_2\text{O})</math> from propanoic<br/> acid<br/> followed by dissociation of more<br/> propanoic acid</p> <p><math>\text{C}_2\text{H}_5\text{COOH} \rightleftharpoons \text{C}_2\text{H}_5\text{COO}^- + \text{H}^+</math></p> <p>OR<br/> Added <math>\text{OH}^-</math> combines with propanoic<br/> acid<br/> <math>\text{OH}^- + \text{C}_2\text{H}_5\text{COOH} \rightarrow \text{C}_2\text{H}_5\text{COO}^- +</math><br/> <math>\text{H}_2\text{O}</math> <b>(1)</b></p> <p><b>Third mark</b><br/> (pH is unchanged because added <math>\text{OH}^-</math><br/> is removed) change in concentration<br/> of <math>\text{C}_2\text{H}_5\text{COO}^-</math> <b>and</b> <math>\text{C}_2\text{H}_5\text{COOH}</math> is<br/> small / ratio [salt]/[acid] hardly<br/> changes <b>(1)</b></p> |        | 3    |

**(Total for Question 19 = 15 marks)**

## Section C

| Question Number | Acceptable Answers                                                                                                                                                                                                                                                                                                           | Reject | Mark |
|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------|------|
| <b>20a(i)</b>   | $\Delta S_{\text{system}} = 240.0 - 102.5 - 210.7$<br>$= -73.2 \text{ J mol}^{-1} \text{ K}^{-1} / -0.0732 \text{ kJ mol}^{-1} \text{ K}^{-1}$<br><br>ALLOW $-73 \text{ J mol}^{-1} \text{ K}^{-1}$<br><br>Correct data <b>(1)</b><br><br>Final answer with sign and units (in any order)<br>TE on incorrect data <b>(1)</b> |        | 2    |

| Question Number | Acceptable Answers                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Reject | Mark |
|-----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------|------|
| <b>20a(ii)</b>  | <b>First check final answer</b><br>$+118.1 \text{ J mol}^{-1} \text{ K}^{-1} / +0.1181 \text{ kJ mol}^{-1} \text{ K}^{-1}$<br><br>ALLOW<br>$+120 \text{ J mol}^{-1} \text{ K}^{-1}$ <b>(2)</b><br><br>OR<br>$\Delta S_{\text{surroundings}} = -(-57 \times 1000 / 298)$<br>$= (+)191.3 \text{ (J mol}^{-1} \text{ K}^{-1})$<br><br>ALLOW<br>$(+)191 \text{ (J mol}^{-1} \text{ K}^{-1})$ <b>(1)</b><br><br>$\Delta S_{\text{total}} = (-73.2 + 191.3) = +118.1 \text{ J mol}^{-1} \text{ K}^{-1}$<br><br>Use of $-73 + 191$ gives <b>+118</b> <b>(1)</b> |        | 2    |

| Question Number | Acceptable Answers                                                                                                                                                                                                                                                                                                         | Reject                     | Mark |
|-----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------|------|
| <b>20a(iii)</b> | (it ceases when) $\Delta S_{\text{total}} = 0$ <b>(1)</b><br><br>(this is when $T\Delta S_{\text{system}} = \Delta H$ )<br><br>$T = \frac{\Delta H}{\Delta S_{\text{system}}} = \frac{57 \times 1000}{73.2}$<br><br>$= 778.69 / 778.7 / 779 / 780 \text{ (K)}$<br><br>Use of 73 gives $780.1 / 780 \text{ (K)}$ <b>(1)</b> | 778<br><br><br>-780.1 -780 | 2    |

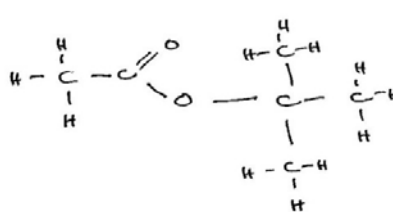
| Question Number | Acceptable Answers                                                                                                                                   | Reject                                                                                                                                                                | Mark |
|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| <b>20b</b>      | (Even though thermodynamically feasible)<br>(The reaction is very slow because) the activation energy is high/ there is an activation energy barrier | Reaction is not spontaneous<br><br>Makes reaction faster<br><br>Catalyst lowers activation energy<br><br>Provides an alternative route with a lower activation energy | 1    |

**(Total for Question 20 = 7 marks)**

| Question Number | Acceptable Answers                                                                                                                                                    | Reject                                                 | Mark |
|-----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------|------|
| <b>21a</b>      | <p>Q: C=O (1750-1735 ester saturated)<br/> <b>and</b><br/> R: C—O (1250-1230 ethanoate)<br/> <b>(1)</b></p> <p>Functional group: ester/ ethanoate<br/> <b>(1)</b></p> | <p>C=O aldehyde</p> <p>Just<br/> O<br/>  <br/> C=O</p> | 2    |

| Question Number | Acceptable Answers                                                                                                                                                                                                                                            | Reject                            | Mark |
|-----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------|------|
| <b>21b(i)</b>   | <p>(Y reacts with sodium carbonate to give CO<sub>2</sub>) so is a (carboxylic) acid<br/> <b>(1)</b></p> <p>M<sub>r</sub> = 60 from mass spectrum<br/> <b>(1)</b><br/> IGNORE<br/> Fragmentation</p> <p>CH<sub>3</sub>COOH /ethanoic acid<br/> <b>(1)</b></p> | CH <sub>3</sub> COOH <sup>+</sup> | 3    |

| Question Number | Acceptable Answers                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Reject | Mark |
|-----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------|------|
| <b>21b(ii)</b>  | <p>(Reacts with sodium to give H<sub>2</sub>) so is an alcohol <b>and</b> cannot be oxidized so a tertiary alcohol<br/> ALLOW<br/> No colour change with (acidified) dichromate to justify tertiary alcohol<br/> <b>(1)</b></p> <p>(CH<sub>3</sub>)<sub>3</sub>COH<br/> ALLOW<br/> Displayed or skeletal formula<br/> 2-methylpropan-2-ol<br/> Structural, displayed or skeletal formula shown in equation<br/> <b>(1)</b></p> <p>(CH<sub>3</sub>)<sub>3</sub>COH + Na → (CH<sub>3</sub>)<sub>3</sub>CO<sup>(-)</sup>Na<sup>(+)</sup><br/> + ½ H<sub>2</sub><br/> ALLOW<br/> C<sub>4</sub>H<sub>9</sub>OH + Na → C<sub>4</sub>H<sub>9</sub>O<sup>(-)</sup>Na<sup>(+)</sup> + ½ H<sub>2</sub><br/> Multiples<br/> TE if primary or secondary alcohol given for structure<br/> <b>(1)</b></p> |        | 3    |

| Question Number | Acceptable Answers                                                                                                                                                                                                                                                   | Reject | Mark |
|-----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------|------|
| <b>21b(iii)</b> | <p>Displayed formula of <math>(\text{CH}_3\text{COOC}(\text{CH}_3)_3)</math></p>  <p>ALLOW<br/>Alkyl groups not fully displayed<br/>TE on primary or secondary alcohol in b(ii)</p> |        | 1    |

| Question Number | Acceptable Answers                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Reject | Mark |
|-----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------|------|
| <b>21b(iv)</b>  | <p>No marks for this part can be awarded unless a structure is shown in either (iii) or (iv)</p> <p>Two peaks because there are 2 different hydrogen environments <b>(1)</b></p> <p>Relative area 3:1/ 9:3/ 1:3 /3:9 (because there are 9H in one, 3H in the other) <b>(1)</b></p> <p>Both singlets <b>because</b> there are no H atoms on adjacent C / by application of <math>n + 1</math> rule <b>(1)</b><br/>ALLOW<br/>TE for ester formed from ethanoic acid and butan-1-ol / butan-2-ol ONLY</p> <p>For butan-1-ol<br/>5 peaks <b>(1)</b><br/>3:2:2:2:3 <b>(1)</b><br/>Singlet, triplet, pentet/quintet, sextet, triplet by application of <math>n + 1</math> rule <b>(1)</b></p> <p>For butan-2-ol<br/>5 peaks <b>(1)</b><br/>3:3:1:2:3 <b>(1)</b><br/>Singlet, doublet, sextet, pentet/quintet, triplet by application of <math>n + 1</math> rule <b>(1)</b></p> |        | 3    |

**(Total for Question 21 = 12 marks)**

**TOTAL FOR PAPER = 90 MARKS**