

Mark Scheme (Results)

Summer 2014

IAL Chemistry (WCH05/01)

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Summer 2014

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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 (multiple choice)**

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

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

| Question Number | Correct Answer | Reject | Mark |
|-----------------|----------------|--------|------|
| <b>3(a)</b>     | D              |        | 1    |
| <b>(b)</b>      | A              |        | 1    |

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

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

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

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

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

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

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

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

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

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

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

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

| Question Number | Correct Answer | Reject | Mark |
|-----------------|----------------|--------|------|
| <b>16</b>       | D              |        | 1    |

| Question Number | Correct Answer | Reject | Mark |
|-----------------|----------------|--------|------|
| <b>17</b>       | D              |        | 1    |

| Question Number | Correct Answer | Reject | Mark |
|-----------------|----------------|--------|------|
| <b>18</b>       | C              |        | 1    |

| Question Number | Correct Answer | Reject | Mark |
|-----------------|----------------|--------|------|
| <b>19</b>       | B              |        | 1    |

**Total for Section A = 20 marks**

## Section B

| Question Number  | Acceptable Answers  | Reject | Mark                         |                  |    |                  |    |           |    |          |      |  |   |
|------------------|---|--------|------------------------------|------------------|----|------------------|----|-----------|----|----------|------|--|---|
| <b>20(a)(i)</b>  | <table border="1" style="margin-left: auto; margin-right: auto;"> <thead> <tr> <th>Ion</th> <th>Oxidation number of vanadium</th> </tr> </thead> <tbody> <tr> <td><math>V(H_2O)_6^{2+}</math></td> <td>+2</td> </tr> <tr> <td><math>V(H_2O)_6^{3+}</math></td> <td>+3</td> </tr> <tr> <td><math>VO^{2+}</math></td> <td>+4</td> </tr> <tr> <td><math>VO_2^+</math></td> <td>(+5)</td> </tr> </tbody> </table> <p>All three correct <b>(1)</b></p> <p>IGNORE omission of '+'</p> | Ion    | Oxidation number of vanadium | $V(H_2O)_6^{2+}$ | +2 | $V(H_2O)_6^{3+}$ | +3 | $VO^{2+}$ | +4 | $VO_2^+$ | (+5) |  | 1 |
| Ion              | Oxidation number of vanadium  |        |                              |                  |    |                  |    |           |    |          |      |  |   |
| $V(H_2O)_6^{2+}$ | +2  |        |                              |                  |    |                  |    |           |    |          |      |  |   |
| $V(H_2O)_6^{3+}$ | +3  |        |                              |                  |    |                  |    |           |    |          |      |  |   |
| $VO^{2+}$        | +4  |        |                              |                  |    |                  |    |           |    |          |      |  |   |
| $VO_2^+$         | (+5)  |        |                              |                  |    |                  |    |           |    |          |      |  |   |

| Question Number  | Acceptable Answers   | Reject   | Mark |
|------------------|--|--|------|
| <b>20(a)(ii)</b> | <p>Electronic configuration of V: <math>[Ar]3d^3 4s^2</math></p> <p>ALLOW<br/> <math>1s^2 2s^2 2p^6 3s^2 3p^6 3d^3 4s^2</math><br/> <math>[Ar] 4s^2 3d^3</math><br/> <math>1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^3</math></p> <p>IGNORE<br/>           Additional [Ar] <b>(1)</b></p> <p>5 electrons in valence shell / available for bonding<br/>           ALLOW<br/>           5 electrons in outer shell<br/>           (So max ON = +5)<br/>           OR<br/>           Uses the 2 4s and 3 3d electrons <b>(1)</b></p> <p>ALLOW<br/>           Lose 5 electrons (to form Ar structure)</p> <p>No TE on incorrect electronic configuration except <math>3d^5 (4s^0)</math></p> <p>IGNORE<br/>           Stability of +5 oxidation state</p> | <p>Gives electronic structure of Ar</p> <p>Loss of electrons from a (single) d orbital</p> | 2    |





| Question Number  | Acceptable Answers  | Reject                         | Mark |
|------------------|---|--------------------------------|------|
| <b>20(a)(iv)</b> | <p><math>V^{5+}</math> is (small &amp;) <b>highly</b> charged /has a (very) <b>high</b> charge density <b>(1)</b></p> <p>Would polarize / distort <math>H_2O</math> / <math>H_2O</math> electron clouds / O–H bond</p> <p>ALLOW<br/>O-H bond weakening / breaking<br/>OR<br/>Deprotonation <b>(1)</b></p> <p>IGNORE<br/>References to ionization energy of V / highly electropositive</p> | Just 'Polarize'<br>Ionic bonds | 2    |

| Question Number | Acceptable Answers  | Reject | Mark |
|-----------------|---|--------|------|
| <b>20(a)(v)</b> | <p>No. Because <math>V^{5+}</math> has no d electrons / d sub-shell is empty / d orbitals are empty.</p> <p>IGNORE<br/>Any mention of 4s<br/><math>V^{5+}</math> has no partially filled d orbitals</p> |        | 1    |

| Question Number | Acceptable Answers   | Reject  | Mark |
|-----------------|--|---|------|
| <b>20(b)(i)</b> | <p data-bbox="440 254 526 281">Either</p> <p data-bbox="440 317 870 352"><b>Method 1 (using equations)</b></p> <p data-bbox="440 415 1032 485"><math>4\text{H}^+ + \text{SO}_4^{2-} + 2\text{e}^- \rightarrow \text{H}_2\text{SO}_3 + \text{H}_2\text{O} \quad E^\circ = +0.17 \text{ (V)}</math></p> <p data-bbox="440 516 1040 585"><math>\text{VO}^{2+} + 2\text{H}^+ + \text{e}^- \rightarrow \text{V}^{3+} + \text{H}_2\text{O} \quad E^\circ = +0.34 \text{ (V)} \quad \text{(1)}</math></p> <p data-bbox="440 648 1040 718"><math>2\text{VO}^{2+} + \text{H}_2\text{SO}_3 \rightarrow 2\text{V}^{3+} + \text{SO}_4^{2-} + \text{H}_2\text{O} \quad \text{(1)}</math></p> <p data-bbox="440 749 984 919"><math>E_{\text{cell}} (\text{SO}_2) = 0.34 - 0.17 = (+)0.17 \text{ (V)}</math><br/>AND<br/>So reduces V(IV) to V(III) / reaction is feasible<br/><b>(1)</b></p> <p data-bbox="440 951 488 978"><b>OR</b></p> <p data-bbox="440 1014 1000 1050"><b>Method 2 (using anticlockwise rule)</b></p> <p data-bbox="440 1081 992 1150">When half reactions are placed in order (more negative first)</p> <p data-bbox="440 1182 1000 1251"><math>4\text{H}^+ + \text{SO}_4^{2-} + 2\text{e}^- \rightarrow \text{H}_2\text{SO}_3 + \text{H}_2\text{O} \quad E^\circ = +0.17 \text{ V}</math></p> <p data-bbox="440 1283 902 1352"><math>\text{VO}^{2+} + 2\text{H}^+ + \text{e}^- \rightarrow \text{V}^{3+} + \text{H}_2\text{O} \quad E^\circ = +0.34 \text{ V}</math></p> <p data-bbox="440 1383 1040 1520">Required reaction 'goes' in anticlockwise direction<br/>Arrows on half equations and explanation<br/><b>(2)</b></p> <p data-bbox="440 1551 1040 1621"><math>2\text{VO}^{2+} + \text{H}_2\text{SO}_3 \rightarrow 2\text{V}^{3+} + \text{SO}_4^{2-} + \text{H}_2\text{O} \quad \text{(1)}</math></p> | <p data-bbox="1068 254 1243 352">Use of thiosulphate half cell =0</p> <p data-bbox="1068 653 1235 722">Uncancelled electrons</p> <p data-bbox="1068 1551 1235 1621">Uncancelled electrons</p> | 3    |

| Question Number  | Acceptable Answers   | Reject | Mark |
|------------------|--|--------|------|
| <b>20(b)(ii)</b> | $2V^{3+} + H_2O \rightarrow V^{2+} + VO^{2+} + 2H^+$<br><br>ALLOW<br>$V(H_2O)_6^{3+}$ and $V(H_2O)_6^{2+}$ |        | 1    |

| Question Number   | Acceptable Answers   | Reject | Mark |
|-------------------|--|--------|------|
| <b>20(b)(iii)</b> | <p>( Relevant electrode potentials are</p> $VO^{2+} + 2H^+ + e^- \rightarrow V^{3+} + H_2O \quad E^{\circ} = +0.34 \text{ V}$<br>$V^{3+} + e^- \rightarrow V^{2+} \quad E^{\circ} = -0.26 \text{ V} )$ <p><math>E_{\text{cell}}</math> (disproportionation )<br/> <math>= ( -0.26 - 0.34 ) = -0.6(0) \text{ (V)}</math><br/> <b>(1)</b></p> <p><math>E_{\text{cell}}</math> negative so disproportionation not (thermodynamically) feasible.<br/> <b>(1)</b></p> <p>TE for second mark only if value given</p> |        | 2    |

**Total for Question 20 = 16 marks**

| Question Number | Acceptable Answers   | Reject | Mark |
|-----------------|--|--------|------|
| <b>21(a)(i)</b> | (pale) pink<br>OR<br>First permanent pink<br><br>Ignore<br>'Colourless to' | purple | 1    |

| Question Number  | Acceptable Answers  | Reject | Mark |
|------------------|---|--------|------|
| <b>21(a)(ii)</b> | $2\text{MnO}_4^- + 5\text{C}_2\text{O}_4^{2-} + 16\text{H}^+ \rightarrow 2\text{Mn}^{2+} + 10\text{CO}_2 + 8\text{H}_2\text{O}$ |        | 1    |

| Question Number   | Acceptable Answers  | Reject | Mark |
|-------------------|---|--------|------|
| <b>21(a)(iii)</b> | <p>Amount <math>\text{MnO}_4^- = 24.55 \times .0205 \times 10^{-3}</math><br/> <math>= 5.03275 \times 10^{-4} \text{ mol (ans *)}</math> <b>(1)</b></p> <p>Amount <math>\text{C}_2\text{O}_4^{2-}</math> in <math>25 \text{ cm}^3 = \text{ans. *} \times 5 / 2</math><br/> <math>= 5.03275 \times 10^{-4} \times 5/2</math><br/> <math>= 1.2581875 \times 10^{-3} \text{ mol}</math> <b>(1)</b></p> <p>In <math>250 \text{ cm}^3 = 1.2581875 \times 10^{-2} \text{ mol (ans **)}</math><br/> <math>= \text{amount Ca}^{2+} = \text{amount CaCO}_3</math> <b>(1)</b></p> <p>Mass <math>\text{CaCO}_3 = (\text{ans**}) \times 100.1</math><br/> <math>= 1.2581875 \times 10^{-2} \times 100.1</math><br/> <math>= 1.2594457 \text{ g (ans***)}</math> <b>(1)</b></p> <p><math>\% \text{ CaCO}_3 = 100 \times (\text{ans***}) / 1.77 = 71.15512</math><br/> <math>= 71.2 ( \% )</math> <b>(1)</b></p> <p>ALLOW</p> <p>Final answer 71.1 / 71.2 / 71.3 scores 5 marks</p> <p>Final answer must be to 3 SF ( max 4 if not)</p> <p>Until final answer ignore SF except 1 SF (penalise once)<br/> TE at each stage unless mass <math>\text{CaCO}_3 &gt; 1.77</math></p> <p>NOTE<br/> Use of ethanedioate mass of 88 in step 4 gives final answer of 62.6% ( max 4 )<br/> Use of calcium ethanedioate mass of 128.1 / 128 in step 4 gives final answer of 91.0% ( max 4 )</p> |        | 5    |

| Question Number | Acceptable Answers   | Reject                        | Mark |
|-----------------|--|-------------------------------|------|
| <b>21(b)(i)</b> | <p>Excess ethanedioate ( ions in the solution) must be removed <b>(1)</b></p> <p>ALLOW</p> <p>Remove ethanedioic acid</p> <p>Otherwise more <math>\text{KMnO}_4</math> will be used (in the titration) / bigger titre <b>(1)</b></p> <p>MP2 dependent on MP1</p> | <p>Impurities</p> <p>Acid</p> | 2    |

| Question Number  | Acceptable Answers   | Reject                                  | Mark                                 |   |                                      |         |        |              |                   |                  |                     |                            |       |         |                    |                            |      |         |                       |                            |                   |  |   |
|------------------|--|---|--------------------------------------|---|--------------------------------------|---------|--------|--------------|-------------------|------------------|---------------------|----------------------------|-------|---------|--------------------|----------------------------|------|---------|-----------------------|----------------------------|-------------------|--|---|
| <b>21(b)(ii)</b> | <table border="1"> <thead> <tr> <th>Apparatus</th> <th>Value</th> <th>Maximum total error on the stated value</th> <th>Percentage error on the stated value</th> </tr> </thead> <tbody> <tr> <td>Balance</td> <td>1.77 g</td> <td><math>\pm 0.01</math> g</td> <td>0.56<br/>(0.56497)</td> </tr> <tr> <td>Volumetric flask</td> <td>250 cm<sup>3</sup></td> <td><math>\pm 0.12</math> cm<sup>3</sup></td> <td>0.048</td> </tr> <tr> <td>Pipette</td> <td>25 cm<sup>3</sup></td> <td><math>\pm 0.06</math> cm<sup>3</sup></td> <td>0.24</td> </tr> <tr> <td>Burette</td> <td>24.55 cm<sup>3</sup></td> <td><math>\pm 0.10</math> cm<sup>3</sup></td> <td>0.41<br/>(0.40733)</td> </tr> </tbody> </table> <p>All % calculations correct <b>(2)</b><br/> Any two or three calculations correct <b>(1)</b></p> <p>1 mark lost if 2 or more correct answers are not given to 2 SF</p> | Apparatus                               | Value                                | Maximum total error on the stated value | Percentage error on the stated value | Balance | 1.77 g | $\pm 0.01$ g | 0.56<br>(0.56497) | Volumetric flask | 250 cm <sup>3</sup> | $\pm 0.12$ cm <sup>3</sup> | 0.048 | Pipette | 25 cm <sup>3</sup> | $\pm 0.06$ cm <sup>3</sup> | 0.24 | Burette | 24.55 cm <sup>3</sup> | $\pm 0.10$ cm <sup>3</sup> | 0.41<br>(0.40733) |  | 2 |
| Apparatus        | Value  | Maximum total error on the stated value | Percentage error on the stated value |   |                                      |         |        |              |                   |                  |                     |                            |       |         |                    |                            |      |         |                       |                            |                   |  |   |
| Balance          | 1.77 g   | $\pm 0.01$ g                            | 0.56<br>(0.56497)                    |   |                                      |         |        |              |                   |                  |                     |                            |       |         |                    |                            |      |         |                       |                            |                   |  |   |
| Volumetric flask | 250 cm <sup>3</sup>  | $\pm 0.12$ cm <sup>3</sup>              | 0.048                                |   |                                      |         |        |              |                   |                  |                     |                            |       |         |                    |                            |      |         |                       |                            |                   |  |   |
| Pipette          | 25 cm <sup>3</sup>   | $\pm 0.06$ cm <sup>3</sup>              | 0.24                                 |   |                                      |         |        |              |                   |                  |                     |                            |       |         |                    |                            |      |         |                       |                            |                   |  |   |
| Burette          | 24.55 cm <sup>3</sup>  | $\pm 0.10$ cm <sup>3</sup>              | 0.41<br>(0.40733)                    |   |                                      |         |        |              |                   |                  |                     |                            |       |         |                    |                            |      |         |                       |                            |                   |  |   |

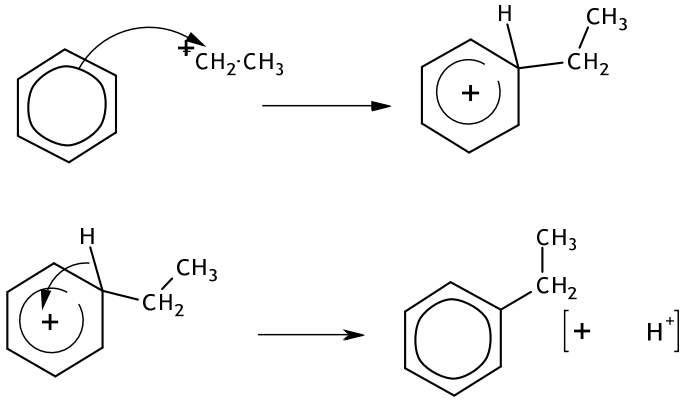
| Question Number   | Acceptable Answers   | Reject | Mark |
|-------------------|--|--------|------|
| <b>21(b)(iii)</b> | <p><b>First mark</b></p> <p>EITHER</p> <p>Max. mass of CaC<sub>2</sub>O<sub>4</sub> precipitated<br/> <math>= 0.015 \times 128.1</math><br/> <math>= 1.9215 \text{ g}</math></p> <p>OR</p> <p><math>0.0067/2 = 0.00335 \text{ g}</math> remains in solution<br/> <b>(1)</b></p> <p><b>Second Mark</b></p> <p>% error = <math>100 \times 0.00335 / (1.9215 + 0.00335)</math><br/> <math>= 100 \times 0.00335 / 1.92485</math><br/> <math>= 0.174040 = 0.174 \%</math></p> <p>ALLOW<br/> % error = <math>100 \times 0.00335 / 1.9215</math><br/> <math>= 0.174343 = 0.174 \%</math></p> <p>If <math>M_r (\text{CaC}_2\text{O}_4) = 128</math> used = <math>0.174479 \%</math><br/> <b>(1)</b></p> <p><b>Third Mark</b></p> <p>Error comparable to / smaller than apparatus uncertainty / less than the worst / less than the balance / less than the total<br/> And so acceptable<br/> <b>(1)</b></p> <p>IGNORE SF but penalise incorrect rounding once</p> <p>NOTE</p> <p>No TE for mark 2 from mark 1 BUT TE for mark 3. Accept reverse argument for large percentage.</p> |        | 3    |

**Total for Question 21 = 14 marks**

| Question Number | Acceptable Answers   | Reject  | Mark |
|-----------------|--|---|------|
| <b>22(a)</b>    | <p><b>A</b> = PCl<sub>5</sub> / phosphorus(V) chloride / phosphorus pentachloride / PCl<sub>3</sub> / phosphorus(III) chloride / phosphorus trichloride / SOCl<sub>2</sub> / thionyl chloride / thionyl dichloride<br/><b>(1)</b></p> <p><b>B</b> = benzene / C<sub>6</sub>H<sub>6</sub> or ring structures<br/><b>(1)</b></p> <p><b>C</b> = bromine / Br<sub>2</sub><br/><b>(1)</b></p> | Bromine water /<br>Bromine and<br>FeBr <sub>3</sub> | 3    |

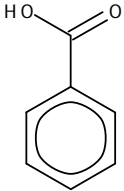
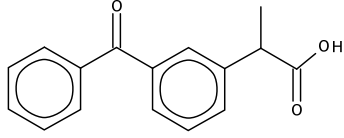
| Question Number | Acceptable Answers  | Reject                                  | Mark |
|-----------------|---|---|------|
| <b>22(b)(i)</b> | <p>CH<sub>3</sub>CH<sub>2</sub>Br + AlBr<sub>3</sub> → CH<sub>3</sub>CH<sub>2</sub><sup>+</sup> + AlBr<sub>4</sub><sup>-</sup><br/><b>(1)</b></p> <p>ALLOW<br/>C<sub>2</sub>H<sub>5</sub><sup>+</sup><br/>+ sign anywhere on formula of electrophile</p> <p>(AlBr<sub>3</sub> is an) electron pair acceptor / lone pair acceptor / Lewis acid / Friedal-Crafts catalyst<br/><b>(1)</b></p> <p>ALLOW polarizes C-Br bond</p> <p>IGNORE<br/>Halogen carrier</p> | Accepts<br>electrons<br>Just 'catalyst' | 2    |



| Question Number  | Acceptable Answers  | Reject  | Mark |
|------------------|---|---|------|
| <b>22(b)(ii)</b> |  <p>TE on incorrect electrophile in (b)(i)</p> <p>Curly arrow from on or within the circle to positively charged carbon</p> <p>ALLOW<br/>Curly arrow from anywhere within the hexagon</p> <p>Arrow to <b>any</b> part of the electrophile including to the + charge <b>(1)</b></p> <p>Intermediate structure including charge with horseshoe covering at least 3 carbon atoms, <b>and</b> facing the tetrahedral carbon <b>and</b> with some part of the positive charge within the horseshoe</p> <p>ALLOW<br/>dotted horseshoe <b>(1)</b></p> <p>Curly arrow from C—H bond to anywhere in the benzene ring reforming delocalized structure <b>(1)</b></p> <p>Correct Kekulé structures score full marks</p> <p>Ignore any involvement of <math>\text{AlX}_4^-</math> in the final step</p> <p>NOTE<br/><math>\text{C}_2\text{H}_5^+</math> as electrophile can score all 3 marks</p> | <p>Curly arrow on or outside the hexagon</p> <p>Partial bonds to H and <math>\text{CH}_3</math></p> | 3    |

| Question Number | Acceptable Answers   | Reject                        | Mark |
|-----------------|--|-------------------------------|------|
| <b>22(c)(i)</b> | KCN / potassium cyanide / NaCN / sodium cyanide <b>(1)</b><br>In ethanol (dependent on mark 1 )<br><br>ALLOW<br>alcohol / aqueous ethanol / aqueous alcohol <b>(1)</b><br><br>ethanolic or alcoholic KCN (etc) scores both marks<br><br>BUT<br>CN <sup>-</sup> / HCN in ethanol scores second mark | cyanide / CN <sup>-</sup> HCN | 2    |

| Question Number  | Acceptable Answers   | Reject   | Mark |
|------------------|--|--|------|
| <b>22(c)(ii)</b> | Name / formula of any strong aqueous acid<br><br>OR<br>named strong aqueous alkali followed by acidification<br><br>Ignore heat / reflux / dilute / conc | H <sup>+</sup> / H <sub>3</sub> O <sup>+</sup> | 1    |

| Question Number | Acceptable Answers  | Reject | Mark |
|-----------------|---|--------|------|
| <b>22(d)(i)</b> | <div style="display: flex; justify-content: space-around; align-items: flex-start;"> <div style="text-align: center;"> <div style="border: 1px solid black; padding: 2px;">1700-1680 (cm<sup>-1</sup>)</div>  <p>benzenecarboxylic acid</p> </div> <div style="text-align: center;"> <div style="border: 1px solid black; padding: 2px;">1700-1680 (cm<sup>-1</sup>)</div>  <p>ketoprofen</p> </div> </div> <div style="text-align: right; margin-top: 10px;"> <div style="border: 1px solid black; padding: 2px;">1725-1700</div> </div> <p>1 mark for each correct range / reverse range<br/>Single numbers within range = max 2 marks</p> |        | 3    |

| Question Number  | Acceptable Answers   | Reject                         | Mark |
|------------------|--|--------------------------------|------|
| <b>22(d)(ii)</b> | <p>Only (the carboxylic acid group in) ketoprofen will give a peak at <math>1725 - 1700 \text{ cm}^{-1}</math></p> <p>ALLOW</p> <p>Ketoprofen has 2 absorptions whilst benzenecarboxylic acid has one</p> <p>Correct TE identifying a unique range</p> | Just ketoprofen has more peaks | 1    |

**Total for Question 22 = 15 marks**

| Question Number | Acceptable Answers  | Reject | Mark |
|-----------------|---|--------|------|
| <b>23(a)</b>    | Volume of CO <sub>2</sub> is less than volume of oxygen (and only other product is water).<br><br>OR<br>Fewer moles / molecules of gaseous products (than reactants). |        | 1    |

| Question Number | Acceptable Answers   | Reject | Mark |
|-----------------|--|--------|------|
| <b>23(b)</b>    | Potassium hydroxide / KOH absorbs CO <sub>2</sub><br><br>OR<br>CO <sub>2</sub> reacts with potassium hydroxide / KOH<br><br>OR<br>CO <sub>2</sub> dissolves in potassium hydroxide / KOH |        | 1    |

| Question Number | Acceptable Answers   | Reject | Mark |
|-----------------|--|--------|------|
| <b>23(c)</b>    | So $10x = 40$<br>$x = 4$ <b>(1)</b><br><br>So $10 + 10(x + (y/4)) - 10x = 20$<br><br>$10(y/4) = 10$<br>$y = 4$ <b>(1)</b><br><br>$C_xH_y = C_4H_4$ <b>(1)</b><br><br>Correct formula with no working or explanation scores 3 |        | 3    |

**Total for Question 23 = 5 marks**  
**Total for Section B = 50 marks**

### Section C

| Question Number | Acceptable Answers   | Reject | Mark |
|-----------------|--|--------|------|
| <b>24(a)(i)</b> | <p>Circles around <b>both</b> asymmetric centres needed</p> <p>ALLOW<br/>Any correct labelling</p> |        | 1    |

| Question Number  | Acceptable Answers  | Reject | Mark |
|------------------|---|--------|------|
| <b>24(a)(ii)</b> | <p>ALLOW<br/>Any (correct) representation of carboxylic acid groups (e.g. COOH / CO<sub>2</sub>H)<br/>Any orientation of carboxylic acid groups<br/>Fischer diagrams ONLY if labelled as such</p> |        | 1    |

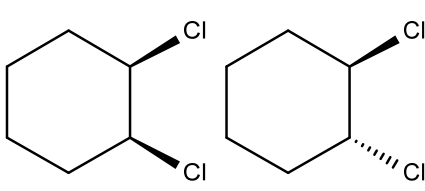
| Question Number   | Acceptable Answers   | Reject | Mark |
|-------------------|--|--------|------|
| <b>24(a)(iii)</b> | <p>The enantiomers will rotate the plane of plane-polarized light</p> <p style="text-align: right;"><b>(1)</b></p> <p>Mark 1 must see rotate, plane and polarized (equally) in opposite directions</p> <p>ALLOW<br/>Clockwise and anticlockwise / left and right / + and</p> <p style="text-align: right;"><b>(1)</b></p> <p>IGNORE<br/>Different directions</p> |        | 2    |

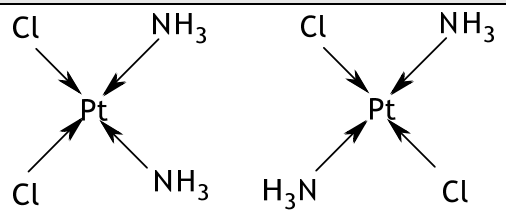
| Question Number  | Acceptable Answers  | Reject | Mark |
|------------------|---|--------|------|
| <b>24(a)(iv)</b> | <p>No because the proton / H environments are the same (in both enantiomers)</p> <p>ALLOW<br/>No, the same peaks / spectrum</p> |        | 1    |

| Question Number | Acceptable Answers   | Reject | Mark |
|-----------------|--|--------|------|
| <b>24(a)(v)</b> | <p>(S<sub>N</sub>2) Because nucleophile must <b>attack</b> only from one side (of the molecule) / from the opposite side (to the leaving group)</p> <p><b>OR</b><br/>( Not S<sub>N</sub>1 ) Because nucleophile would <b>attack</b> on both sides (of the intermediate) (and form a racemic mixture) <b>(1)</b></p> <p>Substitution must be S<sub>N</sub>2</p> <p><b>OR</b><br/>Substitution cannot be S<sub>N</sub>1 <b>(1)</b></p> <p>NOTE<br/>For mark 1 IGNORE references to structure of intermediate</p> |        | 2    |

| Question Number  | Acceptable Answers   | Reject             | Mark |
|------------------|--|--------------------|------|
| <b>24(a)(vi)</b> | <p>Superimposable on its mirror image (allow enantiomer / isomer) / it has a plane of symmetry</p> <p>ALLOW<br/>The molecule is identical to its mirror image</p> <p>(Two chiral centres produce) equal but opposite rotation (of plane polarized light)</p> | Centre of symmetry | 1    |

| Question Number | Acceptable Answers  | Reject  | Mark |
|-----------------|---|---|------|
| <b>24(b)(i)</b> | Rotation (about the bond) reduces (lateral) overlap<br><b>(1)</b><br>to an energetically less favourable alignment<br>OR<br>so bond weaker<br>OR<br>(π) bond breaks<br><b>(1)</b> | π bond restricts rotation<br><br>Double bond breaks | 2    |

| Question Number  | Acceptable Answers  | Reject | Mark |
|------------------|---|--------|------|
| <b>24(b)(ii)</b> | <br>Both structures needed<br>ALLOW<br>Hydrogens to be shown<br>Perspective diagrams |        | 1    |

| Question Number | Acceptable Answers  | Reject | Mark |
|-----------------|---|--------|------|
| <b>24(c)(i)</b> | <br>Both structures needed<br>Dative covalent bonds need not be shown. |        | 1    |

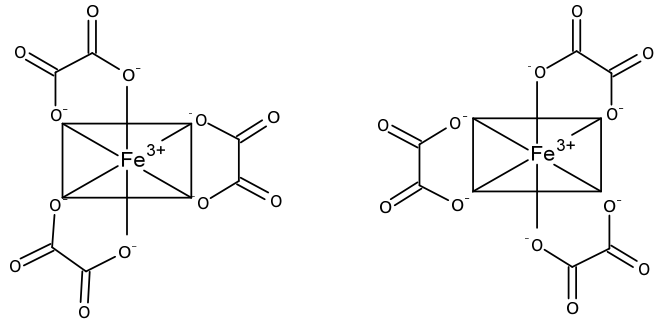


| Question Number  | Acceptable Answers  | Reject | Mark |
|------------------|---|--------|------|
| <b>24(c)(ii)</b> | <p>One of:<br/>Only one isomer is (biochemically) active</p> <p>One isomer is more active than the other</p> <p>One isomer is beneficial but the other has a negative effect</p> <p>Different isomers have different (biochemical) properties</p> |        | 1    |

| Question Number   | Acceptable Answers   | Reject                   | Mark |
|-------------------|--|--------------------------|------|
| <b>24(c)(iii)</b> | <p>Any <b>three</b> from:</p> <ol style="list-style-type: none"> <li>1. Avoids waste of substances (compounds, solvents etc) (used in the synthesis)</li> </ol> <p>ALLOW<br/>No waste product(s).</p> <ol style="list-style-type: none"> <li>2. Avoids any need to separate enantiomers.</li> <li>3. Unwanted enantiomer(s) might have negative effects / be toxic / harmful.</li> <li>4. (Synthesising specific isomers results in ) more effective / lower dosage of medicines.</li> </ol> <p>IGNORE</p> <p>Cost / yield / atom economy / (harmful) side effects</p> | Just 'easier to prepare' | 3    |

| Question Number | Acceptable Answers   | Reject | Mark |
|-----------------|--|--------|------|
| <b>24(d)(i)</b> | <p>A bidentate ligand occupies two coordination positions (around a central ion)</p> <p>OR</p> <p>Can donate / has two lone pairs that can bond (separately) (to the central ion)</p> <p>OR</p> <p>Can form two dative bonds</p> |        | 1    |

| Question Number  | Acceptable Answers  | Reject                                  | Mark |
|------------------|---|---|------|
| <b>24(d)(ii)</b> | (Conversion of a monodentate ligand complex to a bidentate ligand complex) increases the number of particles so $\Delta S_{\text{tot}}$ / $\Delta S_{\text{sys}}$ / entropy increases | Bidentate complexes have higher entropy | 1    |

| Question Number   | Acceptable Answers  | Reject | Mark |
|-------------------|---|--------|------|
| <b>24(d)(iii)</b> |  <p>1 mark for each structure</p> <p>Penalise incorrect charges once only</p> <p>ALLOW</p> <p>Complexes with overall 3<sup>-</sup></p> <p>For 1 mark 2 optical isomers with non displayed C<sub>2</sub>O<sub>4</sub> linked</p> |        | 2    |

**Total for Question 24 = 20 marks**  
**Total for Section C = 20 marks**

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