

Mark Scheme (Results)

Summer 2015

IAL Chemistry (WCH06/01)

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Summer 2015

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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

| Question Number | Acceptable Answers                                     | Reject                      | Mark |
|-----------------|--------------------------------------------------------|-----------------------------|------|
| <b>1(a)(i)</b>  | $\text{SO}_4^{2-}$<br><br>OR<br><br>$\text{SO}_4^{-2}$ | Sulfate<br>$\text{HSO}_4^-$ | 1    |

| Question Number | Acceptable Answers                                                                                                                                                   | Reject                                                                                            | Mark |
|-----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------|------|
| <b>1(a)(ii)</b> | (Dilute) hydrochloric (acid)/ $\text{HCl(aq)}$ /<br>nitric (acid) / $\text{HNO}_3\text{(aq)}$<br><br>ALLOW $\text{HCl}$ / $\text{HNO}_3$<br>Ignore concentrated/conc | Sulfuric acid<br>$\text{H}^+$ / $\text{H}_3\text{O}^+$<br>Carboxylic acid<br>Hydrogen<br>chloride | 1    |

| Question Number | Acceptable Answers                                                                                                                                                                                                                                                                                                                                                | Reject            | Mark |
|-----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|------|
| <b>1(b)(i)</b>  | Water and hydroxide can be in either order<br><br>If name and formula are given, both must be correct<br><br>Copper( <b>II</b> ) hydroxide / $\text{Cu(OH)}_2$ /<br>$\text{Cu(H}_2\text{O)}_4\text{(OH)}_2$<br><br>ALLOW<br><br>$\text{Cu(H}_2\text{O)}_2\text{(OH)}_2$<br><br>IGNORE<br><br>Copper hydroxide<br><br>Square brackets in formula wherever they are | Any other numbers | 1    |

| Question Number | Acceptable Answers                                                                                                                                                                                                                                                                                                                                                               | Reject                                                      | Mark |
|-----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------|------|
| <b>1(b)(ii)</b> | <p>Water and ammonia can be in either order</p> <p>If name and formula are given, both must be correct</p> <p><math>[\text{Cu}(\text{NH}_3)_4]^{2+}</math></p> <p>OR</p> <p><math>[\text{Cu}(\text{H}_2\text{O})_2(\text{NH}_3)_4]^{2+}</math></p> <p>Charge must be included</p> <p>Outer brackets not required</p> <p>IGNORE order of ligands, but numbers must be correct</p> | Any other numbers<br>e.g. $[\text{Cu}(\text{NH}_3)_6]^{2+}$ | 1    |

| Question Number | Acceptable Answers                                                                                                                                                                 | Reject                                                                           | Mark |
|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------|------|
| <b>1(c)</b>     | <p><math>\text{Cu}(\text{H}_2\text{O})_6^{2+}</math></p> <p>OR</p> <p><math>\text{Cu}(\text{H}_2\text{O})_4^{2+}</math></p> <p>IGNORE</p> <p>Square brackets wherever they are</p> | <p><math>\text{Cu}^{2+}</math></p> <p><math>\text{Cu}^{2+}(\text{aq})</math></p> | 1    |

| Question Number | Acceptable Answers                                                                                                                   | Reject                                    | Mark |
|-----------------|--------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------|------|
| <b>1(d)</b>     | <p><math>\text{CuSO}_4</math> / <math>\text{Cu}^{2+}\text{SO}_4^{2-}</math></p> <p>If charges given both must be given correctly</p> | $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ | 1    |

| Question Number | Acceptable Answers                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Reject | Mark |
|-----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------|------|
| <b>1(e)</b>     | <p>Mark independently</p> <p><b>First mark</b></p> <p>The (3)d sub-shell(s) / (3)d-orbital(s) cannot be split</p> <p>OR</p> <p>No d-d splitting</p> <p>OR</p> <p>No d-d transitions (1)</p> <p><b>Second mark</b></p> <p>No colour as no ligands present</p> <p>ALLOW</p> <p>No water (of crystallization) present</p> <p>OR</p> <p>Not hydrated / Anhydrous salt</p> <p>IGNORE</p> <p>Use of copper rather than copper ions (1)</p> <p>Reverse arguments involving the addition of water acceptable</p> |        | 2    |

**(Total for Question 1 = 8 marks)**

| Question Number | Acceptable Answers                                                                               | Reject                         | Mark |
|-----------------|--------------------------------------------------------------------------------------------------|--------------------------------|------|
| <b>2(a)</b>     | $\text{Na}^+$<br>OR<br>$\text{Na}^{+1}$<br>OR<br>$\text{Na}^{1+}$<br>IGNORE sodium or sodium ion | Na<br>Any charge other than +1 | 1    |

| Question Number | Acceptable Answers                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Reject                                   | Mark |
|-----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------|------|
| <b>2(b)(i)</b>  | Measure pH/Use of alkaline buffer solution (1)<br>and acidic buffer solution (1)<br><br>ALLOW<br>Measure pH of a (alkaline) buffer solution... (1)<br>with known pH (1)<br><br><b>ALLOW</b><br>Use of acid /alkali / (de-ionized/ distilled / pure) water / <b>specified</b> neutral solution (e.g. NaCl(aq)) (1)<br>of known pH (1)<br><br><b>OR</b><br>Several solutions of known pH (1)<br>Plot graph of meter reading against (known) pH (to give a calibration curve) (1) | <br><br><br><br><br><br>Neutral for pH=7 | 2    |

| Question Number                    | Acceptable Answers                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Reject      | Mark                    |          |  |  |  |             |                 |               |     |        |              |                 |     |        |                    |                    |     |     |                |                            |     |     |                |                                    |     |        |               |               |     |     |                |                  |     |        |              |           |     |        |             |                   |     |        |              |            |     |     |                |                    |  |     |              |                    |     |        |                |                  |     |        |              |            |     |        |             |                    |     |        |              |                              |     |            |              |                 |     |            |               |                   |      |        |                      |  |   |
|------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------|-------------------------|----------|--|--|--|-------------|-----------------|---------------|-----|--------|--------------|-----------------|-----|--------|--------------------|--------------------|-----|-----|----------------|----------------------------|-----|-----|----------------|------------------------------------|-----|--------|---------------|---------------|-----|-----|----------------|------------------|-----|--------|--------------|-----------|-----|--------|-------------|-------------------|-----|--------|--------------|------------|-----|-----|----------------|--------------------|--|-----|--------------|--------------------|-----|--------|----------------|------------------|-----|--------|--------------|------------|-----|--------|-------------|--------------------|-----|--------|--------------|------------------------------|-----|------------|--------------|-----------------|-----|------------|---------------|-------------------|------|--------|----------------------|--|---|
| <b>2(b)(ii)</b>                    | <p>Universal / full range indicator (paper / solution) (1)</p> <p>Colour changes to (dark) green / blue</p> <p>IGNORE</p> <p>Initial colour (1)</p> <p><b>Comment</b></p> <p><b>ALLOW for 1 mark</b></p> <p>Any named indicator from list below <b>and</b> its colour in alkali</p> <table border="1"> <thead> <tr> <th></th><th><math>pK_{in}(298\text{ K})</math></th><th colspan="2">pH range</th></tr> <tr> <th></th><th></th><th><i>acid</i></th><th><i>alkaline</i></th></tr> </thead> <tbody> <tr> <td>Methyl violet</td><td>0.8</td><td>yellow</td><td>0.0–1.6 blue</td></tr> <tr> <td>Malachite green</td><td>1.0</td><td>yellow</td><td>0.2–1.8 blue/green</td></tr> <tr> <td>Thymol blue (acid)</td><td>1.7</td><td>red</td><td>1.2–2.8 yellow</td></tr> <tr> <td>Methyl yellow (in ethanol)</td><td>3.5</td><td>red</td><td>2.9–4.0 yellow</td></tr> <tr> <td>Methyl orange–xylene cyanole soln.</td><td>3.7</td><td>purple</td><td>3.2–4.2 green</td></tr> <tr> <td>Methyl orange</td><td>3.7</td><td>red</td><td>3.2–4.4 yellow</td></tr> <tr> <td>Bromophenol blue</td><td>4.0</td><td>yellow</td><td>2.8–4.6 blue</td></tr> <tr> <td>Congo red</td><td>4.0</td><td>violet</td><td>3.0–5.0 red</td></tr> <tr> <td>Bromocresol green</td><td>4.7</td><td>yellow</td><td>3.8–5.4 blue</td></tr> <tr> <td>Methyl red</td><td>5.1</td><td>red</td><td>4.2–6.3 yellow</td></tr> <tr> <td>Azolitmin (litmus)</td><td></td><td>red</td><td>5.0–8.0 blue</td></tr> <tr> <td>Bromocresol purple</td><td>6.3</td><td>yellow</td><td>5.2–6.8 purple</td></tr> <tr> <td>Bromothymol blue</td><td>7.0</td><td>yellow</td><td>6.0–7.6 blue</td></tr> <tr> <td>Phenol red</td><td>7.9</td><td>yellow</td><td>6.8–8.4 red</td></tr> <tr> <td>Thymol blue (base)</td><td>8.9</td><td>yellow</td><td>8.0–9.6 blue</td></tr> <tr> <td>Phenolphthalein (in ethanol)</td><td>9.3</td><td>colourless</td><td>8.2–10.0 red</td></tr> <tr> <td>Thymolphthalein</td><td>9.7</td><td>colourless</td><td>8.3–10.6 blue</td></tr> <tr> <td>Alizarin yellow R</td><td>12.5</td><td>yellow</td><td>10.1–13.0 orange/red</td></tr> </tbody> </table> |             | $pK_{in}(298\text{ K})$ | pH range |  |  |  | <i>acid</i> | <i>alkaline</i> | Methyl violet | 0.8 | yellow | 0.0–1.6 blue | Malachite green | 1.0 | yellow | 0.2–1.8 blue/green | Thymol blue (acid) | 1.7 | red | 1.2–2.8 yellow | Methyl yellow (in ethanol) | 3.5 | red | 2.9–4.0 yellow | Methyl orange–xylene cyanole soln. | 3.7 | purple | 3.2–4.2 green | Methyl orange | 3.7 | red | 3.2–4.4 yellow | Bromophenol blue | 4.0 | yellow | 2.8–4.6 blue | Congo red | 4.0 | violet | 3.0–5.0 red | Bromocresol green | 4.7 | yellow | 3.8–5.4 blue | Methyl red | 5.1 | red | 4.2–6.3 yellow | Azolitmin (litmus) |  | red | 5.0–8.0 blue | Bromocresol purple | 6.3 | yellow | 5.2–6.8 purple | Bromothymol blue | 7.0 | yellow | 6.0–7.6 blue | Phenol red | 7.9 | yellow | 6.8–8.4 red | Thymol blue (base) | 8.9 | yellow | 8.0–9.6 blue | Phenolphthalein (in ethanol) | 9.3 | colourless | 8.2–10.0 red | Thymolphthalein | 9.7 | colourless | 8.3–10.6 blue | Alizarin yellow R | 12.5 | yellow | 10.1–13.0 orange/red |  | 2 |
|                                    | $pK_{in}(298\text{ K})$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | pH range    |                         |          |  |  |  |             |                 |               |     |        |              |                 |     |        |                    |                    |     |     |                |                            |     |     |                |                                    |     |        |               |               |     |     |                |                  |     |        |              |           |     |        |             |                   |     |        |              |            |     |     |                |                    |  |     |              |                    |     |        |                |                  |     |        |              |            |     |        |             |                    |     |        |              |                              |     |            |              |                 |     |            |               |                   |      |        |                      |  |   |
|                                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | <i>acid</i> | <i>alkaline</i>         |          |  |  |  |             |                 |               |     |        |              |                 |     |        |                    |                    |     |     |                |                            |     |     |                |                                    |     |        |               |               |     |     |                |                  |     |        |              |           |     |        |             |                   |     |        |              |            |     |     |                |                    |  |     |              |                    |     |        |                |                  |     |        |              |            |     |        |             |                    |     |        |              |                              |     |            |              |                 |     |            |               |                   |      |        |                      |  |   |
| Methyl violet                      | 0.8                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | yellow      | 0.0–1.6 blue            |          |  |  |  |             |                 |               |     |        |              |                 |     |        |                    |                    |     |     |                |                            |     |     |                |                                    |     |        |               |               |     |     |                |                  |     |        |              |           |     |        |             |                   |     |        |              |            |     |     |                |                    |  |     |              |                    |     |        |                |                  |     |        |              |            |     |        |             |                    |     |        |              |                              |     |            |              |                 |     |            |               |                   |      |        |                      |  |   |
| Malachite green                    | 1.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | yellow      | 0.2–1.8 blue/green      |          |  |  |  |             |                 |               |     |        |              |                 |     |        |                    |                    |     |     |                |                            |     |     |                |                                    |     |        |               |               |     |     |                |                  |     |        |              |           |     |        |             |                   |     |        |              |            |     |     |                |                    |  |     |              |                    |     |        |                |                  |     |        |              |            |     |        |             |                    |     |        |              |                              |     |            |              |                 |     |            |               |                   |      |        |                      |  |   |
| Thymol blue (acid)                 | 1.7                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | red         | 1.2–2.8 yellow          |          |  |  |  |             |                 |               |     |        |              |                 |     |        |                    |                    |     |     |                |                            |     |     |                |                                    |     |        |               |               |     |     |                |                  |     |        |              |           |     |        |             |                   |     |        |              |            |     |     |                |                    |  |     |              |                    |     |        |                |                  |     |        |              |            |     |        |             |                    |     |        |              |                              |     |            |              |                 |     |            |               |                   |      |        |                      |  |   |
| Methyl yellow (in ethanol)         | 3.5                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | red         | 2.9–4.0 yellow          |          |  |  |  |             |                 |               |     |        |              |                 |     |        |                    |                    |     |     |                |                            |     |     |                |                                    |     |        |               |               |     |     |                |                  |     |        |              |           |     |        |             |                   |     |        |              |            |     |     |                |                    |  |     |              |                    |     |        |                |                  |     |        |              |            |     |        |             |                    |     |        |              |                              |     |            |              |                 |     |            |               |                   |      |        |                      |  |   |
| Methyl orange–xylene cyanole soln. | 3.7                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | purple      | 3.2–4.2 green           |          |  |  |  |             |                 |               |     |        |              |                 |     |        |                    |                    |     |     |                |                            |     |     |                |                                    |     |        |               |               |     |     |                |                  |     |        |              |           |     |        |             |                   |     |        |              |            |     |     |                |                    |  |     |              |                    |     |        |                |                  |     |        |              |            |     |        |             |                    |     |        |              |                              |     |            |              |                 |     |            |               |                   |      |        |                      |  |   |
| Methyl orange                      | 3.7                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | red         | 3.2–4.4 yellow          |          |  |  |  |             |                 |               |     |        |              |                 |     |        |                    |                    |     |     |                |                            |     |     |                |                                    |     |        |               |               |     |     |                |                  |     |        |              |           |     |        |             |                   |     |        |              |            |     |     |                |                    |  |     |              |                    |     |        |                |                  |     |        |              |            |     |        |             |                    |     |        |              |                              |     |            |              |                 |     |            |               |                   |      |        |                      |  |   |
| Bromophenol blue                   | 4.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | yellow      | 2.8–4.6 blue            |          |  |  |  |             |                 |               |     |        |              |                 |     |        |                    |                    |     |     |                |                            |     |     |                |                                    |     |        |               |               |     |     |                |                  |     |        |              |           |     |        |             |                   |     |        |              |            |     |     |                |                    |  |     |              |                    |     |        |                |                  |     |        |              |            |     |        |             |                    |     |        |              |                              |     |            |              |                 |     |            |               |                   |      |        |                      |  |   |
| Congo red                          | 4.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | violet      | 3.0–5.0 red             |          |  |  |  |             |                 |               |     |        |              |                 |     |        |                    |                    |     |     |                |                            |     |     |                |                                    |     |        |               |               |     |     |                |                  |     |        |              |           |     |        |             |                   |     |        |              |            |     |     |                |                    |  |     |              |                    |     |        |                |                  |     |        |              |            |     |        |             |                    |     |        |              |                              |     |            |              |                 |     |            |               |                   |      |        |                      |  |   |
| Bromocresol green                  | 4.7                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | yellow      | 3.8–5.4 blue            |          |  |  |  |             |                 |               |     |        |              |                 |     |        |                    |                    |     |     |                |                            |     |     |                |                                    |     |        |               |               |     |     |                |                  |     |        |              |           |     |        |             |                   |     |        |              |            |     |     |                |                    |  |     |              |                    |     |        |                |                  |     |        |              |            |     |        |             |                    |     |        |              |                              |     |            |              |                 |     |            |               |                   |      |        |                      |  |   |
| Methyl red                         | 5.1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | red         | 4.2–6.3 yellow          |          |  |  |  |             |                 |               |     |        |              |                 |     |        |                    |                    |     |     |                |                            |     |     |                |                                    |     |        |               |               |     |     |                |                  |     |        |              |           |     |        |             |                   |     |        |              |            |     |     |                |                    |  |     |              |                    |     |        |                |                  |     |        |              |            |     |        |             |                    |     |        |              |                              |     |            |              |                 |     |            |               |                   |      |        |                      |  |   |
| Azolitmin (litmus)                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | red         | 5.0–8.0 blue            |          |  |  |  |             |                 |               |     |        |              |                 |     |        |                    |                    |     |     |                |                            |     |     |                |                                    |     |        |               |               |     |     |                |                  |     |        |              |           |     |        |             |                   |     |        |              |            |     |     |                |                    |  |     |              |                    |     |        |                |                  |     |        |              |            |     |        |             |                    |     |        |              |                              |     |            |              |                 |     |            |               |                   |      |        |                      |  |   |
| Bromocresol purple                 | 6.3                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | yellow      | 5.2–6.8 purple          |          |  |  |  |             |                 |               |     |        |              |                 |     |        |                    |                    |     |     |                |                            |     |     |                |                                    |     |        |               |               |     |     |                |                  |     |        |              |           |     |        |             |                   |     |        |              |            |     |     |                |                    |  |     |              |                    |     |        |                |                  |     |        |              |            |     |        |             |                    |     |        |              |                              |     |            |              |                 |     |            |               |                   |      |        |                      |  |   |
| Bromothymol blue                   | 7.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | yellow      | 6.0–7.6 blue            |          |  |  |  |             |                 |               |     |        |              |                 |     |        |                    |                    |     |     |                |                            |     |     |                |                                    |     |        |               |               |     |     |                |                  |     |        |              |           |     |        |             |                   |     |        |              |            |     |     |                |                    |  |     |              |                    |     |        |                |                  |     |        |              |            |     |        |             |                    |     |        |              |                              |     |            |              |                 |     |            |               |                   |      |        |                      |  |   |
| Phenol red                         | 7.9                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | yellow      | 6.8–8.4 red             |          |  |  |  |             |                 |               |     |        |              |                 |     |        |                    |                    |     |     |                |                            |     |     |                |                                    |     |        |               |               |     |     |                |                  |     |        |              |           |     |        |             |                   |     |        |              |            |     |     |                |                    |  |     |              |                    |     |        |                |                  |     |        |              |            |     |        |             |                    |     |        |              |                              |     |            |              |                 |     |            |               |                   |      |        |                      |  |   |
| Thymol blue (base)                 | 8.9                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | yellow      | 8.0–9.6 blue            |          |  |  |  |             |                 |               |     |        |              |                 |     |        |                    |                    |     |     |                |                            |     |     |                |                                    |     |        |               |               |     |     |                |                  |     |        |              |           |     |        |             |                   |     |        |              |            |     |     |                |                    |  |     |              |                    |     |        |                |                  |     |        |              |            |     |        |             |                    |     |        |              |                              |     |            |              |                 |     |            |               |                   |      |        |                      |  |   |
| Phenolphthalein (in ethanol)       | 9.3                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | colourless  | 8.2–10.0 red            |          |  |  |  |             |                 |               |     |        |              |                 |     |        |                    |                    |     |     |                |                            |     |     |                |                                    |     |        |               |               |     |     |                |                  |     |        |              |           |     |        |             |                   |     |        |              |            |     |     |                |                    |  |     |              |                    |     |        |                |                  |     |        |              |            |     |        |             |                    |     |        |              |                              |     |            |              |                 |     |            |               |                   |      |        |                      |  |   |
| Thymolphthalein                    | 9.7                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | colourless  | 8.3–10.6 blue           |          |  |  |  |             |                 |               |     |        |              |                 |     |        |                    |                    |     |     |                |                            |     |     |                |                                    |     |        |               |               |     |     |                |                  |     |        |              |           |     |        |             |                   |     |        |              |            |     |     |                |                    |  |     |              |                    |     |        |                |                  |     |        |              |            |     |        |             |                    |     |        |              |                              |     |            |              |                 |     |            |               |                   |      |        |                      |  |   |
| Alizarin yellow R                  | 12.5                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | yellow      | 10.1–13.0 orange/red    |          |  |  |  |             |                 |               |     |        |              |                 |     |        |                    |                    |     |     |                |                            |     |     |                |                                    |     |        |               |               |     |     |                |                  |     |        |              |           |     |        |             |                   |     |        |              |            |     |     |                |                    |  |     |              |                    |     |        |                |                  |     |        |              |            |     |        |             |                    |     |        |              |                              |     |            |              |                 |     |            |               |                   |      |        |                      |  |   |

| Question Number  | Acceptable Answers                                                                                                                                                                                                                                                                                                                                                                                    | Reject                                                                          | Mark |
|------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------|------|
| <b>2(b)(iii)</b> | <p>A pH meter because...</p> <p>... difficult to match colour of indicator to pH</p> <p>OR</p> <p>...the colour of universal indicator covers a range of pH</p> <p>ALLOW</p> <p>pH meters measure to at least one decimal place (after calibration)</p> <p>OR</p> <p>pH meter with any reasonable attempt at an explanation<br/>e.g.<br/>indicators cover a range<br/>pH meters give exact values</p> | <p>pH meter alone</p> <p>Any untrue statement about pH meters or indicators</p> | 1    |

| Question Number | Acceptable Answers                                                                                                                                                                                                                                                                                                                                                                                    | Reject                                                                                   | Mark |
|-----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------|------|
| <b>2(c)(i)</b>  | <p><b>First mark - Observation</b></p> <p>Effervescence / bubbles (of gas)<br/>(1)</p> <p>IGNORE</p> <p>Test for carbon dioxide<br/>Gas evolved<br/>(Solid) sodium carbonate dissolves</p> <p><b>Second mark - Explanation</b></p> <p>because the sodium carbonate reacts with / neutralises <b>acid</b>(s) present (to form carbon dioxide)</p> <p>ALLOW</p> <p>carbon dioxide is formed<br/>(1)</p> | <p>Incorrect observations e.g.<br/>Solid/precipitate forms</p> <p>Negates first mark</p> | 2    |

| Question Number | Acceptable Answers                                                                                 | Reject | Mark |
|-----------------|----------------------------------------------------------------------------------------------------|--------|------|
| <b>2(c)(ii)</b> | Ester<br><br>OR<br><br>Methyl ester<br><br>IGNORE<br><br>compound (of carboxylic acid and alcohol) |        | 1    |

| Question Number | Acceptable Answers                                                                                                                                                                                                                                                                                                                                                                     | Reject                            | Mark |
|-----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------|------|
| <b>2(d)</b>     | <b>S</b> $\text{CH}_3\text{COOCH}_3$ (1)<br><b>R</b> $\text{CH}_3\text{COOH}$ (1)<br><b>P</b> $\text{CH}_3\text{COO}^{(-)}\text{Na}^{(+)}$ (1)<br>ALLOW displayed/skeletal formulae<br>ALLOW TE as below:<br>TE from 2(a)<br>TE for <b>R</b> and <b>P</b> based on their formula for <b>S</b><br>TE for <b>P</b> based on their formula for <b>R</b><br>Ignore names even if incorrect | $\text{CH}_3\text{COO}-\text{Na}$ | 3    |

**(Total for Question 2 = 12 marks)**



| Question Number  | Acceptable Answers                                                                                      | Reject      | Mark |
|------------------|---------------------------------------------------------------------------------------------------------|-------------|------|
| <b>3(c)(iii)</b> | From blue-black to colourless<br><br>ALLOW<br><br>From blue / black/ dark blue/ deep blue to colourless | ...to clear | 1    |

| Question Number | Acceptable Answers                             | Reject | Mark |
|-----------------|------------------------------------------------|--------|------|
| <b>3(d)(i)</b>  | 24.1(0) 23.8(0) 23.55 23.45 (cm <sup>3</sup> ) |        | 1    |

| Question Number | Acceptable Answers                                                                                                                                                                            | Reject | Mark |
|-----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------|------|
| <b>3(d)(ii)</b> | The third and fourth /<br>23.55 and 23.45 (cm <sup>3</sup> )<br><br><b>and</b><br><br>They are concordant<br><br>OR<br><br>Within $\pm 0.2/0.1$ (cm <sup>3</sup> )<br><br>IGNORE<br>Anomalous |        | 1    |

| Question Number  | Acceptable Answers                                                                                                | Reject | Mark |
|------------------|-------------------------------------------------------------------------------------------------------------------|--------|------|
| <b>3(d)(iii)</b> | 23.5(0) (cm <sup>3</sup> )<br><br>ALLOW<br><br>TE including second titre value, mean = 23.6(0) (cm <sup>3</sup> ) |        | 1    |

| Question Number | Acceptable Answers                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Reject | Mark |
|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------|------|
| <b>3(d)(iv)</b> | <p>Correct answer 74.6% / 75%</p> <p>OR 74.9% (TE from 23.60 average titre)</p> <p>Ignore SF except 1SF</p> <p>With no working <b>(5)</b></p> <p>Number of mol of thiosulfate<br/> <math display="block">= \frac{23.50 \times 0.200}{1000} \quad (1)</math> <math display="block">= 4.70 \times 10^{-3} / 0.00470</math> <b>Second mark</b><br/> EITHER<br/> Number of mol of iodine<br/> <math display="block">= \frac{4.70 \times 10^{-3}}{2}</math> <math display="block">= 2.35 \times 10^{-3} / 0.00235</math> <b>AND</b><br/> Number of moles of copper ion<br/> <math display="block">= 2 \times 2.35 \times 10^{-3} \quad (1)</math> <math display="block">= 4.70 \times 10^{-3} / 0.00470 \text{ in } 10 \text{ cm}^3</math> OR<br/> From equations amount of iodine is half amount of thiosulfate and amount of copper is twice amount of iodine, so amount of copper equals amount of thiosulfate for this mark<br/> Number of moles of copper in solid</p> |        | 5    |

|  |                                                                                                                                                                                                                                                         |  |  |
|--|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--|--|
|  | $= 10 \times 4.70 \times 10^{-3} \quad (1)$ $= 4.70 \times 10^{-2}/0.0470$                                                                                                                                                                              |  |  |
|  | <p>Mass of copper in solid</p> $= 4.70 \times 10^{-2} \times 63.5 \text{ (g)}$ $= 2.9845 \quad (1)$                                                                                                                                                     |  |  |
|  | <p>Percentage copper</p> $= \frac{2.9845 \times 100}{4.00}$ $= 74.6125$ $= 74.6\% \quad (1)$                                                                                                                                                            |  |  |
|  | <p>Using 23.60 by averaging titres 2, 3 and 4</p> $4.72 \times 10^{-3}/0.00472 \quad (1)$ $2.36 \times 10^{-3}/0.00236$ <p>AND</p> $4.72 \times 10^{-3}/0.00470 \quad (1)$ $4.72 \times 10^{-2}/0.0470 \quad (1)$ $2.9972 \quad (1)$ $74.9\% \quad (1)$ |  |  |
|  | Answers greater than 100% max 3                                                                                                                                                                                                                         |  |  |

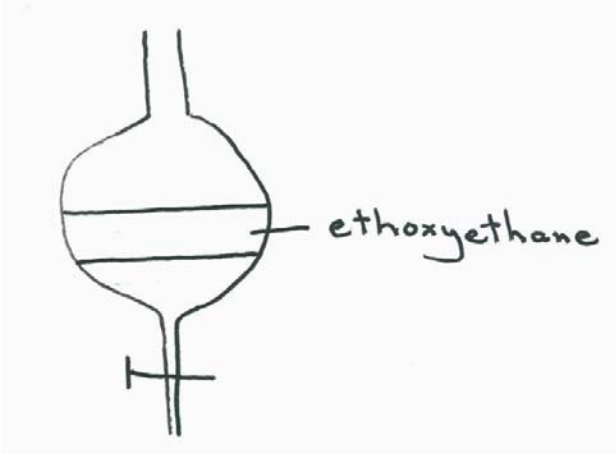
| Question Number | Acceptable Answers                                                                                                                                                                                                                                                                                                                                                                                                                         | Reject | Mark |
|-----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------|------|
| <b>3(d)(v)</b>  | <p><b>First Mark</b></p> <p>Uncertainty in titre value:</p> $\frac{2 \times 0.05}{23.55} \times 100 =$ $(\pm)0.42/0.425/0.4246\% (1)$ <p><b>Second Mark</b></p> <p>Uncertainty in the mass measurement:</p> $\frac{2 \times 0.005 \times 100}{4.0} = (\pm)0.25\%$ <p><b>OR</b></p> $\frac{1 \times 0.005 \times 100}{4.0} = (\pm)0.125\%$ <p>so it would / would not be worth using a 3 dp balance (1)</p> <p>Ignore SF including 1 SF</p> |        | 2    |

**(Total for Question 3 = 15 marks)**

| Question Number | Acceptable Answers                                                                                                                                                                                                                                                                                                                                                                                                      | Reject                        | Mark |
|-----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------|------|
| <b>4(a)</b>     | <p>Mass of bromine = <math>6.0 \times 3.1</math> (1)<br/>(= 18.6 (g))</p> <p>Number of moles of bromine<br/>= <math>\frac{6.0 \times 3.1}{2 \times 79.9}</math><br/><br/>= 0.116(40)<br/><br/>= 0.12 (1)</p> <p>ALLOW<br/>Number of moles of bromine<br/>= <math>\frac{18.6}{2 \times 80}</math><br/><br/>= 0.11625<br/><br/>= 0.12</p> <p>Correct answer no working scores (2)</p> <p>IGNORE</p> <p>SF except 1 SF</p> | $\frac{6.0 \times 3.1}{1000}$ | 2    |

| Question Number | Acceptable Answers                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Reject                                      | Mark |
|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------|------|
| <b>4(b)</b>     | <p>Mark Independently</p> <p><math>2\text{Fe} + 3\text{Br}_2 \rightarrow 2\text{FeBr}_3</math></p> <p>OR multiples (1)</p> <p><math>\text{Br}_2 + \text{FeBr}_3 \rightarrow \text{Br}^{\delta+} \dots \text{Br}^{\delta-} \text{FeBr}_3</math><br/>Allow any attachment between the centre bromine atom and the iron and / or the other bromine atom. e.g. <math>\text{Br}^{\delta+} - \text{Br}^{\delta-} \cdot \text{FeBr}_3</math></p> <p>OR</p> <p><math>\text{Br}_2 + \text{FeBr}_3 \rightarrow \text{Br}^+ + \text{FeBr}_4^-</math> (1)</p> <p>Ignore states even if incorrect</p> | $\rightarrow \text{Br}^- + \text{FeBr}_4^+$ | 2    |

| Question Number | Acceptable Answers                                                                                                                          | Reject                       | Mark |
|-----------------|---------------------------------------------------------------------------------------------------------------------------------------------|------------------------------|------|
| <b>4(c)</b>     | To neutralize / react with HBr (formed)<br><br>ALLOW<br><br>To neutralize / react with acid<br><br>OR<br><br>To remove / react with bromine | To neutralize (the solution) | 1    |

| Question Number | Acceptable Answers                                                                                                                                                                                                                                   | Reject                   | Mark |
|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------|------|
| <b>4(d)</b>     |  <p>Separating funnel which must have narrower neck than the container (capable of taking a stopper) <b>and</b> a tap (1)</p> <p>Upper layer ethoxyethane (1)</p> | Burette<br>Filter funnel | 2    |

| Question Number | Acceptable Answers                                                                                                              | Reject                                                                                                                                                  | Mark |
|-----------------|---------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| <b>4(e)</b>     | (Concentrated) nitric acid/<br>$\text{HNO}_3$<br><br><b>and</b><br><br>(concentrated) sulfuric acid/<br>$\text{H}_2\text{SO}_4$ | <b>Dilute</b> sulfuric acid<br><br>Any additional chemicals like<br>Ammonia/ $\text{NH}_3$<br>Bromine/ $\text{Br}_2$<br>Sodium hydroxide/ $\text{NaOH}$ | 1    |

| Question Number | Acceptable Answers                                                                                           | Reject                                     | Mark |
|-----------------|--------------------------------------------------------------------------------------------------------------|--------------------------------------------|------|
| <b>4(f)</b>     | $(0.75 \times 0.70 \times 0.70 \times 100 =)$<br>36.75 / 36.8 / 37 (%)<br><br>Correct answer with no working | Any other answers<br>e.g. 36.7 / 37.0 / 40 | 1    |

| Question Number | Acceptable Answers                                                                                                                                                                    | Reject | Mark |
|-----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------|------|
| <b>4(g)(i)</b>  | (While rotating the tube) heat one end of the tube in a Bunsen flame (until the glass starts to melt)<br><br>ALLOW<br><br>Heat in a flame<br><br>OR<br><br>Heat (one end of the) tube |        | 1    |

| Question Number | Acceptable Answers                                                                                                                                                                                                                                           | Reject | Mark |
|-----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------|------|
| <b>4(g)(ii)</b> | <p>By gently tapping or dropping the tube / rubbing the open end with a milled coin</p> <p>ALLOW</p> <p>Hit / flick tube with finger</p> <p>OR</p> <p>Use (very small) dry crystals</p> <p>IGNORE</p> <p>Shaking / use of wire / sticks / pins / needles</p> | Heat   | 1    |

| Question Number  | Acceptable Answers                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Reject                                                                         | Mark |
|------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------|------|
| <b>4(g)(iii)</b> | <p><b>Any two from</b></p> <p>High boiling temperature/ point (compared with sample melting temperature) OR not volatile</p> <p>Does not decompose / oxidize (at high temperature)</p> <p>Mobile / non-viscous / non-sticky</p> <p>IGNORE</p> <p>Any reference to thermal conductivity and heat capacity</p> <p><b>ALLOW</b></p> <p>Clear liquid (ignore colourless)</p> <p>High ignition temperature/non-(in)flammable</p> <p>Non-toxic</p> <p>IGNORE</p> <p>Unreactive alone / safety aspects</p> | <p>High melting temperature</p> <p>Just 'does not react with the crystals'</p> | 2    |

| Question Number | Acceptable Answers                                                                                                                                                                                                                                                                     | Reject                                              | Mark |
|-----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------|------|
| <b>4(g)(iv)</b> | <p><b>Before recrystallization</b></p> <p>185 – 201°C</p> <p>A range of at least 5°C</p> <p>ALLOW<br/>180 - 205 °C</p> <p>A range of at least 5°C (1)</p> <p><b>After recrystallization</b></p> <p>199 – 201°C</p> <p>ALLOW<br/>197 - 203°C</p> <p>A range of no more than 4°C (1)</p> | <p>Single temperature</p> <p>Single temperature</p> | 2    |

**(Total for Question 4 = 15 marks)**

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