

**GCE**

**Chemistry B**

**H433/01: Fundamentals of chemistry**

Advanced GCE

**Mark Scheme for November 2020**

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This mark scheme is published as an aid to teachers and students, to indicate the requirements of the examination. It shows the basis on which marks were awarded by examiners. It does not indicate the details of the discussions which took place at an examiners' meeting before marking commenced.

All examiners are instructed that alternative correct answers and unexpected approaches in candidates' scripts must be given marks that fairly reflect the relevant knowledge and skills demonstrated.

Mark schemes should be read in conjunction with the published question papers and the report on the examination.

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## Annotations

| Annotation  | Meaning                                |
|---|--|
|    | Correct response                       |
|    | Incorrect response                     |
|    | Omission mark                          |
|    | Benefit of doubt given                 |
|    | Contradiction                          |
|    | Rounding error                         |
|    | Error in number of significant figures |
|    | Error carried forward                  |
|    | Level 1                                |
|    | Level 2                                |
|    | Level 3                                |
|    | Benefit of doubt not given             |
|  | Noted but no credit given              |
|  | Ignore                                 |

Abbreviations, annotations and conventions used in the detailed Mark Scheme (to include abbreviations and subject-specific conventions).

| <b>Annotation</b>   | <b>Meaning</b>   |
|---------------------|--|
| <b>DO NOT ALLOW</b> | Answers which are not worthy of credit                     |
| <b>IGNORE</b>       | Statements which are irrelevant                            |
| <b>ALLOW</b>        | Answers that can be accepted                               |
| ( )                 | Words which are not essential to gain credit               |
| —                   | Underlined words must be present in answer to score a mark |
| <b>ECF</b>          | Error carried forward                                      |
| <b>AW</b>           | Alternative wording  |
| <b>ORA</b>          | Or reverse argument  |

## Section A

| Question | Key | Mark | AO element |
|----------|-----|------|------------|
| 1        | C   | 1    | 1.1        |
| 2        | B   | 1    | 1.1        |
| 3        | B   | 1    | 1.1        |
| 4        | A   | 1    | 1.2        |
| 5        | D   | 1    | 1.2        |
| 6        | C   | 1    | 1.2        |
| 7        | C   | 1    | 1.1        |
| 8        | C   | 1    | 2.1        |
| 9        | C   | 1    | 1.2        |
| 10       | D   | 1    | 1.1        |
| 11       | D   | 1    | 2.1        |
| 12       | B   | 1    | 2.5        |
| 13       | B   | 1    | 2.7        |
| 14       | B   | 1    | 2.7        |
| 15       | A   | 1    | 1.2        |
| 16       | C   | 1    | 2.8        |
| 17       | C   | 1    | 2.6        |
| 18       | A   | 1    | 1.2        |
| 19       | C   | 1    | 1.2        |
| 20       | C   | 1    | 2.2        |
| 21       | B   | 1    | 2.8        |
| 22       | A   | 1    | 1.1        |
| 23       | D   | 1    | 1.2        |
| 24       | C   | 1    | 1.2        |
| 25       | D   | 1    | 2.5        |
| 26       | B   | 1    | 2.3        |
| 27       | A   | 1    | 2.8        |
| 28       | C   | 1    | 1.2        |
| 29       | B   | 1    | 1.1        |
| 30       | D   | 1    | 1.2        |

## Section B

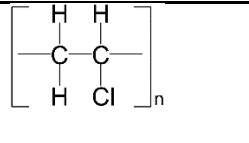
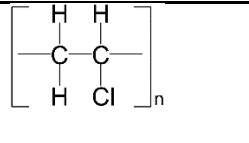
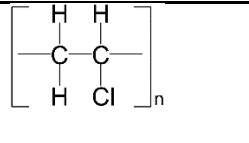
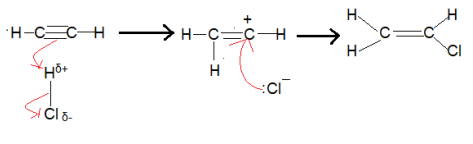
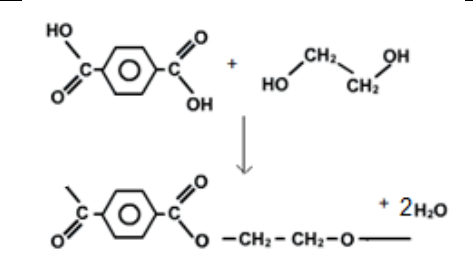
| Question |          | Answer   | Mark | AO Element | Guidance  |
|----------|----------|--|------|------------|---|
| 31       | (a)      | $C_{16}H_{34} + 24\frac{1}{2} O_2 \rightarrow 16CO_2 + 17H_2O$ ✓   | 1    | 2.5        | <b>ALLOW</b> multiples.<br><b>IGNORE</b> state symbols  |
| 31       | (b) (i)  | Heterogeneous ✓<br>catalyst and reagents are in different states. ✓  | 2    | 1.1 x 2    | Mark independently<br>States, if given, must be correct, (g) and (S) for catalyst   |
| 31       | (b) (ii) | Provides a route of lower $E_A$ ✓  | 1    | 1.1        | Must mention activation, not just energy/enthalpy and alternate route.  |
| 31       | (c) (i)  | Colourless gas ✓<br>turns brown ✓  | 2    | 1.1 x 2    |   |
| 31       | (c) (ii) | $N_2 + O_2 \rightarrow 2NO$ ✓  | 1    | 1.1        | If state symbols are shown they must be correct (all (g))   |
| 31       | (d) (i)  | <b>FIRST CHECK THE ANSWER ON THE ANSWER LINE</b><br><b>If answer = 319 (K) award 3 marks</b><br><br>$\Delta S_{sys} = \text{products} - \text{reactants}$ ✓<br><br>$= 213.6 + (2 \times 192.3) - 69.9 - 173.9$<br>$= (+) 354.4$ ✓<br><br>$\text{temp} = 113000/354.4$<br>$318.8 \text{ K}$ ✓ | 3    | 2.6 x 3    | ALLOW 2 or more sf<br><br><b>ALLOW</b> ecf on incorrect $\Delta S_{sys}$<br>Second mark subsumes first<br>354.4 gains 2 marks |
| 31       | (d) (ii) | $4NO + 4NH_3 + O_2 \rightarrow 4N_2 + 6H_2O$ OR<br>$2NH_3 + NO + O_2 \rightarrow 1\frac{1}{2} N_2 + 3H_2O$ ✓   | 1    | 2.1        | <b>ALLOW</b> halves/ multiples<br><b>IGNORE</b> state symbols   |

| Question |     | Answer   | Mark | AO Element               | Guidance  |
|----------|-----|--|------|--------------------------|---|
| 31       | (e) | <p>On short journeys the engine has not yet reached high temperature ✓</p> <p>(Equation 31.1 is) <u>endothermic</u> so (position of) eqm will be on the left ✓</p> <p>Less ammonia available to remove oxides of nitrogen ✓</p> <p>At lower temp the <u>rate</u> of formation of <u>ammonia</u> will be slower ✓</p>   | 4    | 3.1<br>2.5<br>3.1<br>2.5 | ORA   |
| 31       | (f) | <p><b>FIRST CHECK THE ANSWER ON THE ANSWER LINE</b><br/> <b>If answer = 0.67 dm<sup>6</sup> mol<sup>-2</sup> award 4 marks</b></p> <p>Expression for K<sub>c</sub> ✓</p> <p>Eqm conc of hydrogen = 3 (mol dm<sup>-3</sup>) <b>AND</b><br/>           Eqm conc of nitrogen = 2 (mol dm<sup>-3</sup>) ✓</p> <p>(K<sub>c</sub> = 6<sup>2</sup>/2 x 3<sup>3</sup>) = 0.67 ✓</p> <p>units dm<sup>6</sup> mol<sup>-2</sup> ✓</p> | 4    | 2.6 x 4                  | <p><b>ALLOW</b> one or more sf.</p> <p><b>ALLOW</b> ecf on incorrect [N<sub>2</sub>] and [H<sub>2</sub>]<br/>           MP1 expression, MP2 concs of both, MP3 evaluation, MP4 units<br/>           If an expression for K<sub>c</sub> contains only numbers, it must be clear which substance they relate to for MP1</p> <p><b>ALLOW</b> units in either order</p> |

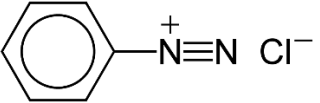
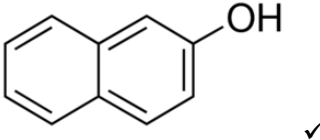
| Question |     |       | Answer  | Mark | AO Element | Guidance  |
|----------|-----|-------|---|------|------------|---|
| 32       | (a) |       | (Chlorine and bromine are) toxic ✓  | 1    | 1.1        | Flammable is <b>CON</b> ,<br><b>IGNORE</b> other correct statements e.g volatile                          |
| 32       | (b) |       | <b>FIRST CHECK THE ANSWER ON THE ANSWER LINE</b><br><b>If answer = <math>4 \times 10^{19}</math> award 3 marks</b><br><br>Unit conversion $5/1000 = 5 \times 10^{-3} \text{ g/cm}^3$ <b>AND</b><br>Mole conversion $5 \times 10^{-3}/79.9 = 6.258 \times 10^{-5}$ moles ✓<br><br>Multiplication by $N_A$ ✓<br><br>$= 4 \times 10^{19}$ ✓  | 3    | 2.2 x 3    | 3.7625...to 2 or more sf scores 2 marks.<br><br><b>ALLOW</b> evaluation of any expression to 1 sf for MP3 |
| 32       | (c) | (i)   | Orange/brown solution forms ✓   | 1    | 1.1        | <b>IGNORE</b> starting colour if green/colourless/yellow<br><b>NOT</b> Red                                |
| 32       | (c) | (ii)  | $\text{Cl}_2 + 2\text{Br}^- \rightarrow 2\text{Cl}^- + \text{Br}_2$ ✓   | 1    | 1.1        | <b>IGNORE</b> state symbols   |
|          | (c) | (iii) | Chlorine better able to attract electrons than bromine/ Cl better oxidising agent so removes electrons from Br ✓  | 1    | 1.1        | Must be comparative   |
| 32       | (c) | (iv)  | <b>FIRST CHECK THE ANSWER ON THE ANSWER LINE</b><br><b>If answer = <math>5.70 \times 10^4</math> (dm<sup>3</sup>) award 4 marks</b><br><br>Volume of water electrolysed = $1000/1.24 = 806.45 \text{ dm}^3$ ✓<br><br>Moles of $\text{Cl}^-$ ions = $806.45 \times 208/35.5 = 4725.12$ ✓<br><br>Volume of chlorine = $4725.12 \times 24/2 = 56701 \text{ dm}^3$ ✓<br><br>$= 5.70 \times 10^4$ (dm <sup>3</sup> ) ✓ | 4    | 2.6 x 4    | <b>ALLOW</b> 2 or more sf<br>57000,<br>$1.13 \times 10^5$ ,<br>$8.72 \times 10^4$<br>score 3 marks.       |



| Question |     |      | Answer  | Mark | AO Element | Guidance   |
|----------|-----|------|---|------|------------|--|
| 32       | (d) | (i)  | Simple molecules with weak pd-pd forces/intermolecular bonds between ✓                              | 1    | 2.5        | If the type of imb is specified, it must be pd-pd. Must mention molecules or intermolecular            |
| 32       | (d) | (ii) | $\text{HCl} + \text{H}_2\text{O} \rightarrow \text{H}_3\text{O}^+ + \text{Cl}^-$ ✓                  | 1    | 1.2        | <b>ALLOW</b> $\text{HCl} \rightarrow \text{H}^+ + \text{Cl}^-$<br><b>NOT</b> eqm sign                  |
| 32       | (e) | (i)  | Oxidation states of bromine -1 <b>AND</b> 0 ✓<br><br>Oxidation states of S +6 <b>AND</b> +4 ✓       | 2    | 1.2 x 2    | <b>IGNORE</b> numbers in other boxes consider as working. Ox states must have signs before the number. |
| 32       | (e) | (ii) | $2\text{HBr} + \text{H}_2\text{SO}_4 \rightarrow \text{Br}_2 + \text{SO}_2 + 2\text{H}_2\text{O}$ ✓ | 1    | 1.2        | <b>IGNORE</b> state symbols  |

| Question  |                        |       | Answer  | Mark        | AO Element             | Guidance   |          |   |     |                                 |
|---|------------------------|-------|---|-------------|------------------------|--|----------|---|-----|---------------------------------|
| 33  | (a)                    |       | <table border="1"> <tr> <td>Repeat unit</td> <td>Type of polymerisation</td> </tr> <tr> <td>  </td> <td>Addition</td> </tr> </table> | Repeat unit | Type of polymerisation |   | Addition | 2 | 1.2 | <b>IGNORE</b> brackets and 'n'. |
| Repeat unit   | Type of polymerisation |       |   |             |                        |  |          |   |     |                                 |
|  | Addition               |       |   |             |                        |  |          |   |     |                                 |
| 33  | (b)                    |       |  <p>Dipole on HCl ✓<br/>Curly arrows ✓<br/>Intermediate and product ✓</p>  | 3           | 2.1 x 3                | Curly arrows must start on bonds (or the lone pair or negative sign on chloride).  |          |   |     |                                 |
| 33  | (c)                    | (i)   | 1,2-dichloroethane ✓  | 1           | 1.1                    | <b>IGNORE</b> dashes, commas and a gap between 'dichloro' and 'ethane'   |          |   |     |                                 |
| 33  | (c)                    | (ii)  | Nucleophilic substitution ✓   | 1           | 2.1                    |  |          |   |     |                                 |
| 33  | (c)                    | (iii) |  <p>Product (1 repeat unit) ✓<br/>Equation fully correct inc water ✓</p>  | 2           | 1.2 x 2                | <b>ALLOW</b> monomers either ways round and single bonded oxygen on either end.<br><b>IGNORE</b> bracket around repeat unit. |          |   |     |                                 |

| Question |     | Answer   | Mark | AO Element         | Guidance  |
|----------|-----|--|------|--------------------|---|
| 33       | (d) | <p><i>Please refer to the marking instructions on pages 4/5 of this mark scheme for guidance on how to mark this question.</i></p> <p><b>Level 3 (5–6 marks)</b><br/>Identifies A as phenol and B as propanone using the evidence from some tests, the mass spectrum for product A and the composition of product B.</p> <p><i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i></p> <p><b>Level 2 (3–4 marks)</b><br/>Identifies A as a phenol and B as a ketone or C<sub>3</sub>H<sub>6</sub>O using the evidence from some tests <b>OR</b> the mass spectrum for product A <b>OR</b> the composition of product B.</p> <p><i>There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.</i></p> <p><b>Level 1 (1–2 marks)</b><br/>Identifies A as a phenol <b>OR</b> B as a ketone using the evidence from some tests <b>OR</b> the mass spectrum for product A <b>OR</b> the composition of product B.</p> <p><i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i></p> <p><b>0 marks</b><br/>No response or no response worthy of credit</p> | 6    | 3.1 x 3<br>3.2 x 3 | <p><b>Indicative scientific points may include:</b></p> <p><b>Product A:</b></p> <ul style="list-style-type: none"> <li>• Is a phenol</li> <li>• It is weakly acidic, but not strong enough to react with sodium carbonate</li> <li>• Gives the purple colour with FeCl<sub>3</sub></li> <li>• Mass spectrum shows that the M<sub>r</sub> is 94</li> <li>• Consistent with phenol, C<sub>6</sub>H<sub>5</sub>OH</li> </ul> <p><b>Product B:</b></p> <ul style="list-style-type: none"> <li>• Moles: C 5.175; H 10.3; O 1.735</li> <li>• Empirical formula is C<sub>3</sub>H<sub>6</sub>O</li> <li>• Not an acid</li> <li>• Can be reduced to an alcohol so is aldehyde or ketone.</li> <li>• Does not get oxidised by Tollen's reagent so is a ketone.</li> <li>• propanone/ CH<sub>3</sub>COCH<sub>3</sub>.</li> </ul> |

| Question |     |      | Answer  | Mark | AO Element | Guidance   |
|----------|-----|------|---|------|------------|--|
| 34       | (a) |      | Below 5°C ✓<br> ✓<br> ✓   | 1    | 1.2 x 3    | Mention of alkaline conditions is <b>CON</b><br><br><b>ALLOW</b> without chloride ion<br><br>Bonding in naphthol must be as shown. |
| 34       | (b) | (i)  | Concentrated sulfuric acid <b>and</b> reflux <b>OR</b> fuming sulfuric acid <b>and</b> 40°C ✓   | 1    | 1.2        | <b>ALLOW</b> 'c'/conc' for concentrated and formula  |
| 34       | (b) | (ii) | Dye <b>C</b> : Not very soluble as only the phenol group (and N atoms) can form H bonds <u>with water</u> . ✓<br><br>The rest of the molecule has weak id-id imbs . ✓<br><br>Dye <b>D</b> : More soluble because SO <sub>3</sub> <sup>-</sup> /O <sup>-</sup> can form ion dipole bonds <u>with water</u> . ✓<br><br>Forms more H bonds with water. ✓ | 4    | 2.7 x 4    | Must mention groups that can H bond to score   |
| 34       | (c) | (i)  | Electrons in the extended delocalised system ✓<br>electrons move to higher energy levels ✓<br>$\Delta E = h\nu$ ✓   | 3    | 1.1 x 3    | Splitting d-orbitals is <b>CON</b> for MP1, <b>IGNORE</b> chromophore alone  |
|          |     | (ii) | Complementary colour is seen/ frequencies not absorbed are seen (AW)  | 1    | 1.1        | Light emitted is <b>CON</b>  |

| Question |     | Answer  | Mark | AO Element                    | Guidance   |
|----------|-----|---|------|-------------------------------|--|
| 34       | (d) | The $\text{NH}_2$ groups on wool become <u>protonated</u> /turn to $\text{NH}_3^+$ in weak acid ✓<br>Ionic interactions between $\text{SO}_3^-/\text{O}^-$ groups and $\text{NH}_3^+$ ✓   | 2    | 2.7 x 2                       |  |
| 34       | (e) | <p><i>Please refer to the marking instructions on pages 4/5 of this mark scheme for guidance on how to mark this question.</i></p> <p><b>Level 3 (5–6 marks)</b><br/>Detailed description of calibration of the colorimeter.<br/><b>AND</b><br/>Detailed description of testing of fabric samples.<br/><b>AND</b><br/>Includes several controlled variables.<br/><i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i></p> <p><b>Level 2 (3–4 marks)</b><br/>Detailed description of calibration of the colorimeter.<br/><b>OR</b><br/>Detailed description of testing of fabric samples.<br/><b>AND</b><br/>Includes several controlled variables.</p> <p><b>OR</b><br/>Outline description of calibration of the colorimeter.<br/><b>AND</b><br/>Outline description of testing of fabric samples.<br/><b>AND</b><br/>Includes a few controlled variables.</p> <p><i>There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.</i></p> | 6    | 3.1 x 2<br>3.3 x 2<br>3.4 x 2 | <p><b>Indicative scientific points may include:</b></p> <p><b>Calibration of the colorimeter:</b></p> <ul style="list-style-type: none"> <li>• Make up several solutions of dye of known concentration.</li> <li>• Select a colour filter complementary to the dye colour.</li> <li>• Zero colorimeter with a cuvette of water.</li> <li>• Measure the absorbance of the standard dye solutions.</li> <li>• Plot a calibration curve.</li> </ul> <p><b>Testing the fabric samples:</b></p> <ul style="list-style-type: none"> <li>• Immerse fabric in water at the desired temperature for a fixed time and stir.</li> <li>• Remove fabric and test remaining water to find absorbance.</li> <li>• Use calibration curve to find concentration of dye washed out of the fabric.</li> <li>• Repeat using water of different temperatures.</li> </ul> <p><b>Controlled variables.</b></p> <ul style="list-style-type: none"> <li>• Immerse the fabric in water for a fixed time.</li> <li>• Use the same volume of water each time.</li> <li>• Keep the stirring constant</li> <li>• Cut the fabric into equal sized pieces for testing.</li> <li>• Same type of fabric</li> </ul> |

| Question |  |  | Answer   | Mark | AO Element | Guidance |
|----------|--|--|--|------|------------|----------|
|          |  |  | <p><b>Level 1 (1–2 marks)</b><br/>           Outline description of calibration of the colorimeter.<br/> <b>OR</b><br/>           Outline description of testing of fabric samples.<br/> <b>OR</b><br/>           Identifies a few controlled variables.</p> <p><i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i></p> <p><b>0 marks</b><br/>           No response or no response worthy of credit</p> |      |            |          |

| Question |     |      | Answer   | Mark | AO Element     | Guidance   |
|----------|-----|------|--|------|----------------|--|
| 35       | (a) | (i)  | White precipitate ✓  | 1    | 1.2            |  |
|          |     | (ii) | $\text{Ag}^+(\text{aq}) + \text{Cl}^-(\text{aq}) \rightarrow \text{AgCl}(\text{s})$ ✓  | 1    | 1.2            |  |
| 35       | (b) |      | <p><b>FIRST CHECK THE ANSWER ON THE ANSWER LINE</b><br/> <b>If answer = 0.53 award 3 marks</b></p> <p>Moles of <math>\text{Cl}^-</math> ions in 25 cm<sup>3</sup> of the diluted sea water = 0.1 x 0.0265 (=2.65 x 10<sup>-3</sup>) ✓</p> <p>Moles of chloride ions in 20 cm<sup>3</sup> original sea water = 0.1 x 0.0265 x 100/25 (=0.0106) ✓</p> <p>Concentration of <math>\text{Cl}^-</math> ions in original sea water = 0.1 x 0.0265 x 100/25 x 1000/20 = 0.53 (mol dm<sup>-3</sup>) ✓</p> | 3    | 2.8 x 3        | <p><b>ALLOW</b> 2 or more significant figures 0.106 scores 2</p> <p><b>OR</b><br/>           conc <math>\text{Cl}^-</math> (in diluted) = 26.5 x 0.1/25 = 0.106 ✓✓<br/>           conc <math>\text{Cl}^-</math> (in undiluted) = 26.5 x 0.1/25 x 5 = 0.53 ✓</p>  |
| 35       | (c) | (i)  | <p>At end point <math>[\text{Ag}^+] = [\text{Cl}^-]</math>, stated or implied ✓</p> <p><math>[\text{Ag}^+] = \sqrt{K_{\text{sp}}}</math> ✓</p>   | 2    | 2.7<br><br>2.8 | Second mark depends on first   |
| 35       | (c) | (ii) | <p><math>[\text{CrO}_4^{2-}] = 2.5 \times 10^{-4} \times 1000/53.50</math><br/> <math>= 4.67 \times 10^{-3}</math> ✓</p> <p><math>[\text{Ag}^+]^2 [\text{CrO}_4^{2-}] = 2 \times 10^{-10} \times 4.67 \times 10^{-3}</math><br/> <math>= 9.35 \times 10^{-13}</math> ✓</p> <p>This is less than the solubility product of silver chromate so no precipitate (of silver chromate) forms (before all the <math>\text{Cl}^-</math> ions have reacted). ✓</p>  | 3    | 3.1 x 3        | <p>Alternative method:<br/> <math>[\text{CrO}_4^{2-}]</math> when ppt forms = <math>3 \times 10^{-12}/[\text{Ag}^+]^2</math><br/> <math>= 0.015</math> ✓</p> <p><math>[\text{CrO}_4^{2-}]</math> in the solution is <math>2.5 \times 10^{-4} \times 1000/53.50</math><br/> <math>= 4.67 \times 10^{-3}</math> ✓</p> <p>This less than the 0.015 needed for a precipitate so no ppt forms ✓</p> <p><b>ALLOW</b> MP3 if a correct conclusion from incorrect calculated numbers</p> |

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