



# Mark Scheme (Results)

Summer 2016

Pearson Edexcel  
International Advanced Level  
in Chemistry (WCH05) Paper 01  
General Principles of Chemistry II

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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

**Section A (multiple choice)**

Question Number	Correct Answer	Reject	Mark
<b>1</b>	D		<b>(1)</b>

Question Number	Correct Answer	Reject	Mark
<b>2</b>	B		<b>(1)</b>

Question Number	Correct Answer	Reject	Mark
<b>3(a)</b>	B		<b>(1)</b>

Question Number	Correct Answer	Reject	Mark
<b>3(b)</b>	D		<b>(1)</b>

Question Number	Correct Answer	Reject	Mark
<b>4(a)</b>	C		<b>(1)</b>

Question Number	Correct Answer	Reject	Mark
<b>4(b)</b>	D		<b>(1)</b>

Question Number	Correct Answer	Reject	Mark
<b>5</b>	C		<b>(1)</b>

Question Number	Correct Answer	Reject	Mark
<b>6</b>	C		<b>(1)</b>

Question Number	Correct Answer	Reject	Mark
<b>7</b>	C		<b>(1)</b>

Question Number	Correct Answer	Reject	Mark
<b>8</b>	A		<b>(1)</b>

Question Number	Correct Answer	Reject	Mark
<b>9</b>	D		<b>(1)</b>

Question Number	Correct Answer	Reject	Mark
<b>10</b>	A		<b>(1)</b>

Question Number	Correct Answer	Reject	Mark
<b>11</b>	C		<b>(1)</b>

Question Number	Correct Answer	Reject	Mark
<b>12</b>	B		<b>(1)</b>

Question Number	Correct Answer	Reject	Mark
<b>13</b>	A		<b>(1)</b>

Question Number	Correct Answer	Reject	Mark
<b>14</b>	B		<b>(1)</b>

Question Number	Correct Answer	Reject	Mark
<b>15</b>	A		<b>(1)</b>

Question Number	Correct Answer	Reject	Mark
<b>16</b>	A		<b>(1)</b>

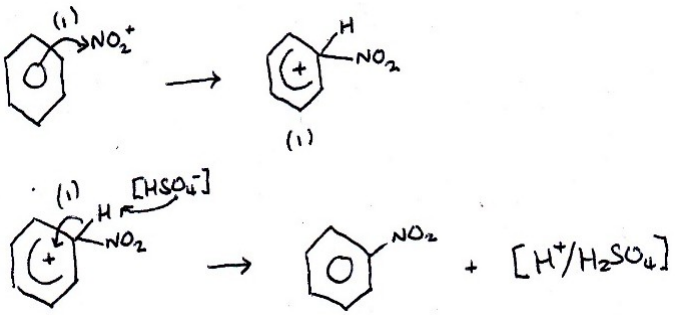
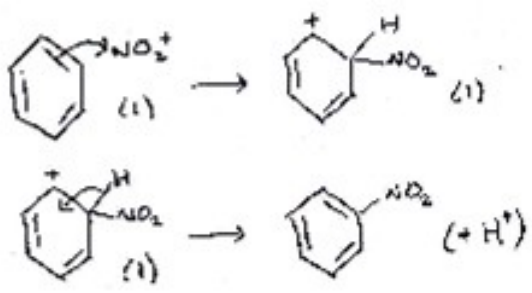
Question Number	Correct Answer	Reject	Mark
<b>17</b>	C		<b>(1)</b>

Question Number	Correct Answer	Reject	Mark
<b>18</b>	A		<b>(1)</b>

## Section B


Question Number	Acceptable Answers	Reject	Mark
19* (a)	<p>ALLOW reverse arguments for Kekule structure Any <b>three</b> points from</p> <p><b>Type of reaction</b> Benzene reacts by (mostly electrophilic) substitution OR does not react by (electrophilic) addition</p> <p>OR Benzene does not react like alkenes / does not decolourise bromine water</p> <p>ALLOW Other suitable reactions / benzene needs a catalyst /halogen carrier to react with bromine (1)</p> <p><b>Di-substitution</b> There are only 3 isomers of di-substituted compounds (not 4)</p> <p>OR Some di-substituted compounds are the same, e.g. 1,2 and 1,6 (1)</p> <p><b>Thermochemical</b> Benzene's (standard) enthalpy (change) of <b>hydrogenation</b> is less exothermic than if it had (three localised C=C) double bonds / is not three times the value for three (localised C=C) double bonds</p> <p>ALLOW Benzene is more stable by <math>\sim 150 \text{ kJ mol}^{-1}</math></p> <p>OR stated enthalpies (of hydrogenation) <math>-205</math> to <math>-210 \text{ kJ mol}^{-1}</math> for benzene and <math>-360 \text{ kJ mol}^{-1}</math> for 3 (localised C=C) double bonds</p> <p>OR (Standard) enthalpy (change) of combustion is less exothermic than if it had three (localised C=C) double bonds</p>	<p>Additional incorrect points</p> <p>Nucleophilic substitution</p> <p>Lower / just 'different' hydration</p> <p>Lower / just 'different'</p> <p>Just "less"</p>	(3)

	<p>ALLOW (Standard) enthalpy (change) of formation of benzene is less endothermic than that of "cyclohexa-1,3,5-triene" (1)</p> <p>IGNORE Just 'thermodynamically more stable'</p> <p><b>X-ray diffraction</b> – does not need to be mentioned The C-C bond lengths in benzene are mid-way between that of a single bond and a double bond / are all the same length</p> <p>OR Benzene is a regular hexagon (and Kekule structure is not) (1)</p> <p>IGNORE Bond angles are the same</p> <p><b>Infrared</b> The infrared spectrum for benzene has a peak for an aromatic C=C at a different wavenumber / absorption / frequency to an alkene C=C</p> <p>OR Benzene has peaks at 1600, 1580, 1500, 1450 (cm<sup>-1</sup>) rather than 1669 – 1645 (cm<sup>-1</sup>)</p> <p>ALLOW Benzene has no peak for alkene C=C / 1669 – 1645 (cm<sup>-1</sup>) (1)</p> <p>IGNORE different C-H absorptions / just 'different peaks to alkenes'</p> <p>IGNORE References to NMR</p> <p><b>Electron density map</b> Benzene shows an even spread of electrons (1)</p>	C-H bond	
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Question Number	Acceptable Answers	Reject	Mark
19(b)(i)	<p> <math>\text{H}_2\text{SO}_4 + \text{HNO}_3 \rightarrow \text{NO}_2^+ + \text{H}_2\text{O} + \text{HSO}_4^-</math>  OR  <math>\text{H}_2\text{SO}_4 + \text{HNO}_3 \rightarrow \text{H}_2\text{NO}_3^+ + \text{HSO}_4^-</math>  <b>and</b>  <math>\text{H}_2\text{NO}_3^+ \rightarrow \text{NO}_2^+ + \text{H}_2\text{O}</math>  OR  <math>2\text{H}_2\text{SO}_4 + \text{HNO}_3 \rightarrow \text{NO}_2^+ + \text{H}_3\text{O}^+ + 2\text{HSO}_4^-</math>  IGNORE state symbols, even if incorrect (1) </p> <p>  </p> <p> Curly arrow from on or within the circle to N of <math>\text{NO}_2^+</math>  ALLOW curly arrow from anywhere <b>within</b> the hexagon  ALLOW curly arrow towards any part of the <math>\text{NO}_2^+</math>, including to the + charge (1) </p> <p> Intermediate structure including charge with horseshoe covering at least 3 carbon atoms <b>and</b> facing the tetrahedral carbon <b>and</b> some part of the positive charge must be within the horseshoe (1) </p> <p> Curly arrow from C-H bond to anywhere in the hexagon reforming the delocalised structure (1) </p> <p> Correct Kekulé structures score full marks </p> <p>  </p>	<p>Half arrow heads</p> <p>Curly arrow on or outside the hexagon</p> <p>Dotted bonds to H and <math>\text{NO}_2</math> unless as part of a 3D structure</p> <p>Curly arrow from H</p>	(4)

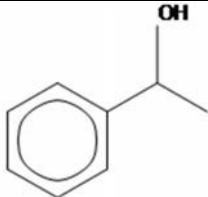


Question Number	Acceptable Answers	Reject	Mark
<b>19(b)(ii)</b>	<p>Higher temperature causes multiple substitution of NO<sub>2</sub> groups / formation of dinitrobenzene / formation of trinitrobenzene</p> <p>ALLOW further nitration / substitution <b>(1)</b></p> <p>IGNORE decomposition of benzene / nitrobenzene / addition of NO<sub>2</sub> groups</p> <p>At lower temperature reaction is (too) slow<b>(1)</b></p> <p>IGNORE</p> <p>References to activation energy / reaction does not occur at low temperature</p>	Different isomers of nitrobenzene	<b>(2)</b>

Question Number	Acceptable Answers	Reject	Mark
<b>19(c)(i)</b>	 <p>Formula of organic product <b>(1)</b></p> <p>Rest of equation correct <b>(1)</b></p> <p>ALLOW Br on any 3 carbon atoms</p> <p>ALLOW <math>\text{C}_6\text{H}_5\text{OH} + 3\text{Br}_2 \rightarrow \text{C}_6\text{H}_2(\text{OH})\text{Br}_3 + 3\text{HBr}</math> for both marks, allow <math>\text{C}_6\text{H}_2(\text{Br}_3)\text{OH}</math>, ignore missing brackets</p> <p>ALLOW correct balanced equations to form mono or di substituted product for 1 mark</p> <p>ALLOW Kekulé structures</p> <p>IGNORE position of bond to OH if vertically above or below the ring / name of product / state symbol</p>	OH-C of benzene on lhs or rhs	<b>(2)</b>

Question Number	Acceptable Answers	Reject	Mark
* 19(c) (ii)	<p><b>MP1</b>  <b>Lone pair of electrons on oxygen</b>  (may be shown on a diagram)</p> <p><b>and</b></p> <p>EITHER  Overlaps with pi cloud /delocalised electrons / delocalised system</p> <p>OR  Feeds into / donates into / interacts with (benzene) ring /delocalised electrons / delocalised system</p> <p>OR  Increases the electron density of the (benzene) ring <b>(1)</b></p> <p><b>MP2</b>  (Increased electron density) makes the ring more susceptible to electrophilic attack</p> <p>ALLOW phenol is a better nucleophile <b>(1)</b></p>	More electro-negative	<b>2</b>

Question Number	Acceptable Answers	Reject	Mark
<b>19(d) (i)</b>	<p>If name and formula are given, both must be correct</p> <p>Ethanoyl chloride / <math>\text{CH}_3\text{COCl}</math> (1)</p> <p>aluminium chloride / <math>\text{AlCl}_3</math> / iron(III) chloride / <math>\text{FeCl}_3</math></p> <p>Conditional on correct reagent or a 'near miss' eg acyl chloride</p> <p>ALLOW corresponding bromides (1)</p> <p>NOTE Reagent and catalyst in either order and they do not need to state which they are</p> <p>IGNORE Friedel-Crafts catalyst / Lewis acid catalyst / any solvent mentioned</p>	<p>Just aluminium or iron</p> <p>Additional reagents</p>	<b>(2)</b>

Question Number	Acceptable Answers	Reject	Mark
<b>19(d) (ii)</b>	 <p>ALLOW skeletal / displayed / structural formulae or any combination of these e.g. <math>\text{C}_6\text{H}_5\text{CH}(\text{OH})\text{CH}_3</math></p>		<b>(1)</b>

Question Number	Acceptable Answers	Reject	Mark
<b>19(d)(iii)</b>	<p>If name and formula are given both must be correct</p> <p>Lithium aluminium hydride / <math>\text{LiAlH}_4</math> / lithium tetrahydridoaluminate((III)) / sodium borohydride / sodium tetrahydridoborate / <math>\text{NaBH}_4</math></p> <p>IGNORE solvents / temperature, even if incorrect</p>	<p>Hydrogen with or without any catalyst</p> <p>Water, if <math>\text{LiAlH}_4</math></p>	<b>(1)</b>

Question Number	Acceptable Answers	Reject	Mark
<b>19(d)(iv)</b>	<p>If name and formula are given, both must be correct</p> <p>Phosphorus(V) chloride / phosphorus pentachloride / <math>\text{PCl}_5</math> / phosphorus(III) chloride / phosphorus trichloride / <math>\text{PCl}_3</math> / phosphorus and chlorine / P and <math>\text{Cl}_2</math> thionyl chloride / <math>\text{SOCl}_2</math> / conc hydrochloric acid / HCl <b>and</b> zinc chloride / <math>\text{ZnCl}_2</math> / zinc / Zn</p> <p>No TE on 19(d)(ii)</p>	<p>Just (Conc.) hydrochloric acid / HCl</p>	<b>(1)</b>

(Total for Question 19 = 18 marks)

Question Number	Acceptable Answers			Reject	Mark
20(a)	$\text{MnO}_4^-(\text{aq}) + \text{e}^- \rightleftharpoons \text{MnO}_4^{2-}(\text{aq})$		+0.56	Missing +	(1)
	$\text{MnO}_4^{2-}(\text{aq}) + 2\text{H}_2\text{O}(\text{l}) + 2\text{e}^- \rightleftharpoons \text{MnO}_2(\text{s}) + 4\text{OH}^-(\text{aq})$		+0.59		
	Both correct for the mark				

Question Number	Acceptable Answers	Reject	Mark
<b>20(b)</b>	<p>If name and formula are given, both must be correct</p> <p><b>A</b> (Salt bridge containing a solution of) potassium nitrate / <math>\text{KNO}_3</math></p> <p>ALLOW potassium chloride / <math>\text{KCl}</math> / sodium chloride / <math>\text{NaCl}</math> / sodium nitrate / <math>\text{NaNO}_3</math> <b>(1)</b></p> <p><b>B</b> (Electrode made of) platinum / <math>\text{Pt}</math> <b>(1)</b></p> <p><b>C</b> (Solution containing) manganese(II) <b>and</b> manganese(III) ions / <math>\text{Mn}^{2+}</math> <b>and</b> <math>\text{Mn}^{3+}</math> ions</p> <p>ALLOW Soluble salts of manganese(II) and manganese(III) ions <b>(1)</b></p> <p>(Essential condition) <b>stand alone mark</b> <math>1 \text{ mol dm}^{-3}</math></p> <p>ALLOW this if written in <b>C</b></p> <p>ALLOW '1 molar' / <math>1 \text{ M}</math> / equal concentrations of <math>\text{Mn}^{2+}</math> <b>and</b> <math>\text{Mn}^{3+}</math> / manganese(II) <b>and</b> manganese(III) ions <b>(1)</b></p> <p>IGNORE any temperature or pressure</p>	<p>KI NaI</p> <p>Incorrect unit eg <math>\text{mol dm}^3</math></p>	<b>(4)</b>

Question Number	Acceptable Answers	Reject	Mark
<b>20(c) (i)</b>	$2\text{Mn}^{2+} + 5\text{BiO}_3^- + 14\text{H}^+ \rightarrow 2\text{MnO}_4^- + 5\text{Bi}^{3+} + 7\text{H}_2\text{O}$ <p>All correct formulae on both sides</p> <p>ALLOW <math>\rightleftharpoons</math> (1)</p> <p>Balancing correct formulae Conditional on all formulae correct</p> <p>ALLOW multiples (1) IGNORE state symbols, even if incorrect IGNORE other equations as working before final equation</p> <p>IGNORE electrons left in if they have been crossed through</p> <p><b>Note:</b> Balanced equation with uncanceled electrons or uncanceled <math>\text{H}^+</math> ions / <math>\text{H}_2\text{O}</math> scores (1)</p>		<b>(2)</b>

Question Number	Acceptable Answers	Reject	Mark
<b>20(c) (ii)</b>	$(E^\circ_{\text{cell}} = 1.60 - 1.51 =) +0.09 \text{ V}$ <p>Sign, value and unit required</p> <p>TE on incorrect starting oxidation state of manganese</p> <p>For <math>\text{Mn}^{2+}</math> to <math>\text{Mn}^{3+}</math>  <math>(E^\circ_{\text{cell}} = 1.60 - 1.49 =) +0.11 \text{ V}</math> For <math>\text{MnO}_2</math> to <math>\text{MnO}_4^{2-}</math>  <math>(E^\circ_{\text{cell}} = 1.60 - 0.59 =) +1.01 \text{ V}</math> For <math>\text{MnO}_4^{2-}</math> to <math>\text{MnO}_4^-</math>  <math>(E^\circ_{\text{cell}} = 1.60 - 0.56 =) +1.04 \text{ V}</math></p>	+0.1 V	<b>(1)</b>

Question Number	Acceptable Answers	Reject	Mark
<b>20* (d)</b>	<p><b>NOTE</b> This calculation involves 8 individual mathematical operations (see 1 to 8 below), 4 on each titration and an additional subtraction.</p> <p>The first mark is awarded for the first operation finding the number of moles of <math>\text{Fe}^{2+}</math> ions from one of the titrations. The second mark is awarded after three further operations and then each subsequent mark for every other operation. The subtractions scores 1 mark on its own.</p> <p>One possible suggested solution is as follows</p> <p>For the original solution of <b>A</b></p> <p>1. Moles of <math>\text{MnO}_4^-</math> which reacts with <math>25 \text{ cm}^3</math> of original solution <b>A</b></p> $= \frac{16.80 \times 0.0195}{1000}$ $= 3.276 \times 10^{-4} \text{ (mol) (1)}$ <p>2. Moles of <math>\text{Fe}^{2+}</math> in original solution</p> $= \text{Answer to 1} \times 5$ $= 1.638 \times 10^{-3} \text{ (mol)}$ <p>AND</p> <p>3. Moles of <math>\text{Fe}^{2+}</math> in <math>500 \text{ cm}^3</math> of original solution <b>A</b></p> $= \text{Answer to 2} \times 20$ $= 3.276 \times 10^{-2} \text{ (mol)}$ <p>AND</p> <p>4. Mass of <math>\text{Fe}^{2+}</math> in <math>500 \text{ cm}^3</math> of original solution <b>A</b></p> $= \text{Answer to 3} \times 55.8$ $= 1.828 \text{ (g) (1)}$ <p>ALLOW</p> <p>The three operations ( <math>\times 5</math>, <math>\times 20</math> and <math>\times 55.8</math>) in any order.</p> <p><math>A_r \text{ Fe} = 56</math> (instead of 55.8)</p>		<b>(5)</b>

	<p>For the fully reduced solution of <b>A</b></p> <p>5. Moles of <math>\text{MnO}_4^-</math> which reacts with 25 cm<sup>3</sup> of reduced solution</p> $= \frac{18.20 \times 0.0195}{1000}$ $= 3.549 \times 10^{-4} \text{ (mol)}$ <p>AND</p> <p>6. Moles of <math>\text{Fe}^{2+}</math> in the fully reduced solution <b>A</b></p> $= \text{Answer to 1} \times 5$ $= 1.7745 \times 10^{-3} \text{ (mol) (1)}$ <p>7. Moles of <math>\text{Fe}^{2+}</math> in 500 cm<sup>3</sup> of the fully reduced solution <b>A</b></p> $= \text{Answer to 6} \times 20$ $= 3.549 \times 10^{-2} \text{ (mol)}$ <p>AND</p> <p>8. Mass of <math>\text{Fe}^{2+}</math> in 500 cm<sup>3</sup> of reduced solution Y</p> $= \text{Answer to 7} \times 55.8$ $= 1.980342 \text{ (g) (1)}$ <p>Mass of <math>\text{Fe}^{3+}</math> in original solution</p> $= \text{Answer to 8} - \text{Answer to 7}$ $= 0.15288 \text{ (g) (1)}$ <p>ALLOW</p> <p>The three operations ( <math>\times 5</math>, <math>\times 20</math> and <math>\times 55.8</math>) in any order.</p> <p><math>A_r \text{ Fe} = 56</math> (instead of 55.8)</p> <p>ALLOW other methods</p> <p>IGNORE SF except 1SF</p>		(5)
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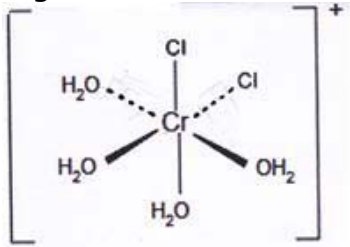
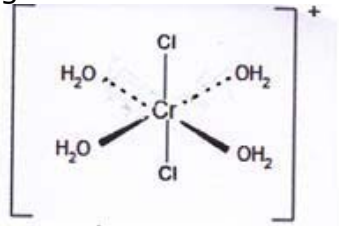
(Total for Question 20 = 13 marks)



Question Number	Acceptable Answers	Reject	Mark
<b>21(a)</b>	<p>Transition metals form at least one <b>ion</b> with an incomplete <b>d</b>-subshell / partially filled d orbital(s)</p> <p>ALLOW forms an <b>ion</b> with unpaired <b>d</b> electron(s)</p> <p>OR</p> <p>Scandium <b>only</b> forms an <b>ion</b> with an empty <b>d</b>-subshell / all <b>d</b> orbitals are empty</p> <p>OR</p> <p>Scandium does not form an <b>ion</b> with an incomplete <b>d</b>-subshell / partially filled d orbital(s) (1)</p> <p>Scandium (only) forms <math>\text{Sc}^{3+}</math></p> <p>ALLOW</p> <p>Sc only has one oxidation state (in compounds) (1)</p> <p><math>\text{Sc}^{3+}</math> is [Ar]</p> <p>OR</p> <p>Sc is <math>[\text{Ar}]3d^1 4s^2</math> / <math>[\text{Ar}]4s^2 3d^1</math> <b>and</b> loses all three outer electrons</p> <p>ALLOW</p> <p>[Ar] written out as <math>1s^2 2s^2 2p^6 3s^2 3p^6</math> (1)</p>	<p>d shell</p> <p>sub-shell / orbital other than 3d</p>	<b>(3)</b>

Question Number	Acceptable Answers	Reject	Mark
<b>21(b)</b>	$[\text{Cr}(\text{H}_2\text{O})_6]^{3+} + 3\text{NH}_3 \rightarrow \text{Cr}(\text{OH})_3 + 3\text{H}_2\text{O} + 3\text{NH}_4^+$ <p>OR</p> $[\text{Cr}(\text{H}_2\text{O})_6]^{3+} + 3\text{NH}_3 \rightarrow [\text{Cr}(\text{OH})_3(\text{H}_2\text{O})_3] + 3\text{NH}_4^+$ <p>Correct formula of chromium(III) hydroxide</p> <p>ALLOW <math>[\text{Cr}(\text{H}_2\text{O})_3(\text{OH})_3]</math> <b>(1)</b></p> <p>IGNORE square brackets</p> <p>Rest of equation and balancing</p> <p>Conditional on correct formula of chromium(III) hydroxide <b>(1)</b></p> <p>IGNORE state symbols even if incorrect</p>	Any equation where $\text{NH}_3$ replaces water ligands	<b>(2)</b>

Question Number	Acceptable Answers	Reject	Mark
<b>21(c)</b>	<p>ALLOW oxidation numbers written by formulae in equations</p> <p><b>First mark</b></p> <p><b>Reaction 1</b> is a redox reaction as chromium decreases / changes in oxidation number from (+)6 / VI to (+)3 / III <b>(1)</b></p> <p><b>Second mark</b></p> <p><b>Reaction 2</b> is not a redox reaction as chromium has oxidation number (+)6(+) / VI in <math>\text{CrO}_4^{2-}</math> and <math>\text{Cr}_2\text{O}_7^{2-}</math> / reactant and product / both species <b>(1)</b></p> <p>IGNORE change in oxidation number of iron</p>		<b>(2)</b>

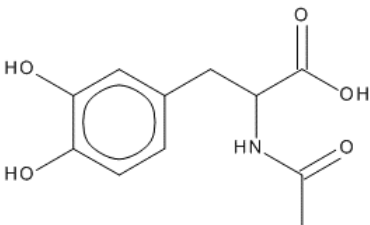
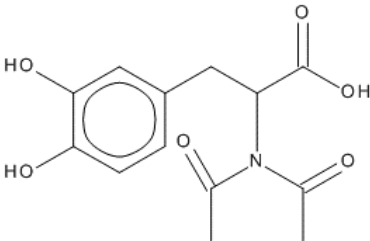
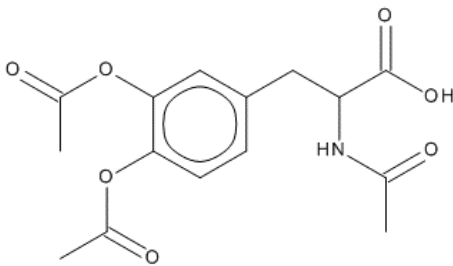
Question Number	Acceptable Answers	Reject	Mark
21(d)(i)	<p>In both complexes:</p> <p>IGNORE charges on ions (<math>\text{Cl}^-</math> or <math>\text{Cr}^{3+}</math>) inside the brackets</p> <p>IGNORE exact position of dative bond from the water</p> <p>Any complex ion showing the two chloride ligands in the 'cis' positions where <math>\text{Cl}-\text{Cr}-\text{Cl}</math> bond angle is <math>90^\circ</math></p> <p>e.g.</p>  <p>(1)</p> <p>Any complex ion showing the two chloride ligands in the 'trans' positions where <math>\text{Cl}-\text{Cr}-\text{Cl}</math> bond angle is <math>180^\circ</math></p> <p>e.g.</p>  <p>(1)</p> <p>ALLOW for one mark two diagrams with correct chlorine, but no water OR two diagrams with correct water, but no chlorines</p> <p>ALLOW for one mark two diagrams with <math>\text{Cl}_2</math> instead of <math>\text{Cl}</math></p>		(2)

Question Number	Acceptable Answers	Reject	Mark
<b>21(d)(ii)</b>	dative(covalent) ALLOW co-ordinate (covalent/ bonding) <b>(1)</b>  (formed from) the lone pair (of electrons) on the oxygen / chloride ion / ligand / water (to the chromium ion) <b>(1)</b>  ALLOW "pair of electrons" for "lone pair"  IGNORE element / molecule / atom		<b>2</b>

Question Number	Acceptable Answers	Reject	Mark
<b>21(d)(iii)</b>	Working is essential  $\text{mol of AgCl} = 3.44/143.4 = 0.023989$ <b>(1)</b>  $\text{ratio Cr}^{3+} : (\text{free Cl}^-) (= 0.012 : 0.023989)$ $= 1 : 2$  ALLOW this written in words <b>(1)</b> so, $[\text{CrCl}(\text{H}_2\text{O})_5]^{2+}$ / (ion) <b>Y</b> (is formed) <b>(1)</b>  ALLOW structure of <b>Y</b> drawn  IGNORE SF except 1SF  ALLOW for two marks <b>Y</b> if 178.8 used for $M_r$ <b>X</b> if 107.8 / 82.5 used for $M_r$ If no other mark is awarded: ALLOW 1 mark for just $[\text{CrCl}(\text{H}_2\text{O})_5]^{2+}$ / (ion) <b>Y</b> (is formed)	No TE on incorrect moles	<b>3</b>

(Total for Question 21 = 14 marks)

Question Number	Acceptable Answers	Reject	Mark
<b>22(a)</b>	$C_9H_{11}NO_4$ ALLOW any order eg $C_9H_{11}O_4N$ IGNORE any additional structural formulae as working		<b>(1)</b>

Question Number	Acceptable Answers	Reject	Mark
<b>22(b)</b>	<p>Must have N linked to <math>CH_3CO</math></p>  <p>OR</p>  <p>OR <math>CH_3CO</math> linked to N and Os on benzene ring e.g.</p>  <p>ALLOW any combination of skeletal, displayed or structural formulae</p> <p>IGNORE bond angles</p>	Ethanoyl group joined to $COOH$ group to form an anhydride	<b>(1)</b>

Question Number	Acceptable Answers	Reject	Mark
<b>22(c)</b>	<p>In each pair, the observation is conditional on a correct or 'near miss' reagent</p> <p>Any matching pair from:</p> <p>Sodium carbonate / <math>\text{Na}_2\text{CO}_3</math> / sodium hydrogencarbonate / <math>\text{NaHCO}_3</math></p> <p>ALLOW other (metal) carbonates <b>(1)</b></p> <p>Effervescence/ fizzing/ bubbles</p> <p>Gas turns lime-water cloudy <b>(1)</b></p> <p>IGNORE "gas given off"</p> <p>OR</p> <p>Add ethanol/ alcohol <b>and</b> <math>\text{H}_2\text{SO}_4</math>/ strong acid<b>(1)</b></p> <p>Fruity smell/ pear drops / "glue smell" <b>(1)</b></p> <p>ALLOW</p> <p>1 mark for sodium/ Na <b>and</b> fizzing</p> <p>ALLOW</p> <p>1 mark for phosphorus(V) chloride/<math>\text{PCl}_5</math> <b>and</b> steamy white fumes</p> <p>IGNORE equations, even if incorrect</p> <p>IGNORE indicators</p>	<p>Incorrect formulae</p> <p>Additional incorrect tests</p> <p>Incorrect gas eg hydrogen</p>	<b>(2)</b>

Question Number	Acceptable Answers	Reject	Mark
<b>22(d)</b>	<div data-bbox="391 280 901 739" data-label="Chemical-Block"> </div> <p data-bbox="379 750 1053 795">amide group (CONH) (1)</p> <p data-bbox="379 817 1053 974">extension bonds (can be solid or dotted) <b>and</b> rest of structure correct with OH groups on carbon atoms 3 and 4 relative to the CH<sub>2</sub> (1)</p> <p data-bbox="379 996 1053 1086">ALLOW any combination of displayed/ skeletal / structural formulae</p> <p data-bbox="379 1108 1053 1153">ALLOW Kekulé structures</p> <p data-bbox="379 1176 1053 1220">IGNORE bond angles / brackets and n</p>	<p data-bbox="1090 772 1337 840">Additional O in amide group</p> <p data-bbox="1090 996 1337 1142">One repeat unit / more than 2 repeat units</p>	<b>(2)</b>

(Total for Question 22 = 6 marks)

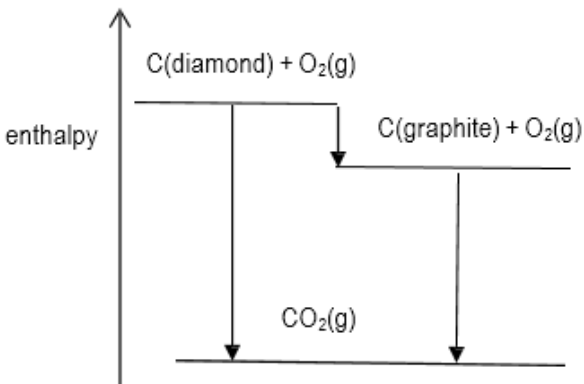
## Section C

Question Number	Acceptable Answers	Reject	Mark
<b>23(a)(i)</b>	<p><b>First mark</b> d-subshell splits / d-orbitals split (in energy) / d energy level(s) split(s) (by the ligands) <b>(1)</b></p> <p><b>Second mark</b> Electron(s) promoted / excited (from lower) to higher energy levels / electron(s) move (from lower) to higher energy d orbitals</p> <p>ALLOW d-d transitions <b>(1)</b></p> <p><b>Third mark</b> Absorbing photons / energy of a certain frequency (in visible region)</p> <p>ALLOW absorbing light <b>(1)</b></p> <p><b>Fourth mark</b> Transmitted / remaining light is coloured</p> <p>ALLOW complementary colour is seen</p> <p>ALLOW reflected / transmitted / remaining light is seen <b>(1)</b></p> <p>IGNORE "opposite" colour / reference to electrons relaxing / dropping to the ground state</p>	<p>Penalise omission of (3)d once only.</p> <p>d-orbital/d-shell splits</p> <p>d-d splitting</p> <p>Just 'absorbing photons/energy'</p> <p>Emitted</p>	<b>(4)</b>



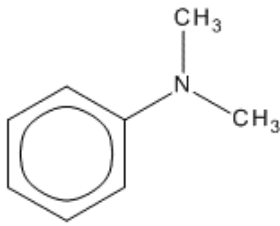
Question Number	Acceptable Answers	Reject	Mark
<b>23(a)(ii)</b>	<p>Sapphires / rubies / they contain different (metal) ions</p> <p>OR</p> <p>Electron transfer between different metal ions</p> <p>OR</p> <p>The colour is caused by charge transfer</p> <p>ALLOW some of the aluminium ions / <math>\text{Al}^{3+}</math> have been replaced by chromium(III) ions / <math>\text{Cr}^{3+}</math></p> <p>ALLOW d-orbitals are split with a different energy gap</p> <p>ALLOW different number of electrons in d- subshell</p> <p>ALLOW different oxidation states (of chromium) have different colours</p> <p>IGNORE</p> <p>Different ligands</p>	<p>Different oxidation states of aluminium</p>	<b>(1)</b>

Question Number	Acceptable Answers	Reject	Mark
*23(b)	<p><b>First mark</b> – diamond In diamond each carbon atom is <b>covalently</b> bonded to four other carbon atoms (in 3 dimensions)</p> <p>ALLOW diamond exists as a giant covalent structure with a tetrahedral arrangement (1)</p> <p>Second mark - graphite Graphite has London / dispersion / van der Waals' forces <b>between the layers</b> (1)</p> <p>Third mark - comparison The (covalent) bonds in diamond are stronger than the (London / dispersion / van der Waals' / (intermolecular) forces in graphite</p> <p>OR Reverse argument (1)</p> <p>ALLOW these marks on labelled diagrams</p>	<p>Ionic / metallic bonding / any intermolecular forces</p> <p>Hydrogen bonding</p> <p>London forces in diamond</p>	(3)

Question Number	Acceptable Answers	Reject	Mark
23(c)(i)	<p style="text-align: center;"><math>\Delta H_r</math></p> <p style="text-align: center;"> <math>\text{C(diamond)} \rightarrow \text{C(graphite)}</math>  <math>+ \text{O}_2(\text{g}) \quad + \text{O}_2(\text{g})</math>  <math>-395.4 \quad -393.5</math>  <math>\text{CO}_2(\text{g})</math> </p> <p> <math>\Delta H = -395.4 - (-393.5)</math>  <math>= -1.9 \text{ (kJ mol}^{-1}\text{)}</math> </p> <p>           ALLOW <math>\text{O}_2(\text{g})</math> missing from cycle            Correct answer, with or without cycle (1)         </p> <p>Diagram must be consistent with sign in calculation</p> <p>One enthalpy level diagram</p>  <p>Both combustions to <math>\text{CO}_2</math>  <b>and</b>            graphite below diamond (1)</p> <p>IGNORE missing enthalpy label and axis / <math>\text{O}_2</math> / state symbols</p> <p>IGNORE activation energy curve</p>	<p style="text-align: center;">(2)</p> <p><math>-2 \text{ (kJ mol}^{-1}\text{)}</math></p> <p>Incorrect units</p> <p>Two energy diagrams</p>	

Question Number	Acceptable Answers	Reject	Mark
<b>23(c) (ii)</b>	$\Delta S_{\text{system}}$ needed to give $\Delta S_{\text{total}}$ (which must be positive)  ALLOW $\Delta S_{\text{system}}$ and $\Delta S_{\text{total}}$ needed  ALLOW If $\Delta S_{\text{total}}$ is positive, reaction is (thermodynamically) feasible  IGNORE references to activation energy / kinetic inertness		<b>(1)</b>

Question Number	Acceptable Answers	Reject	Mark
<b>23(d) (i)</b>	sodium nitrite / sodium nitrate(III) / $\text{NaNO}_2$ <b>and</b> hydrochloric acid / $\text{HCl}$ / sulfuric acid / $\text{H}_2\text{SO}_4$  ALLOW nitrous acid / $\text{HNO}_2$ (and hydrochloric acid / $\text{HCl}$ ) <b>(1)</b>  IGNORE concentration of hydrochloric acid  at 5 °C/ between 0 and 10 °C. Conditional on correct or 'near miss' reagents  ALLOW any temperature or range of temperatures within range /ice bath / less than 5/10°C <b>(1)</b>	Just sodium nitrate $\text{HNO}_3$  Incorrect formula with correct name or vice versa  Conc $\text{H}_2\text{SO}_4$	<b>(2)</b>

Question Number	Acceptable Answers	Reject	Mark
<b>23(d) (ii)</b>	 <p>ALLOW skeletal formula</p>	<p>Missing 'ring'</p> <p>Structure including OH</p>	<b>(1)</b>

Question Number	Acceptable Answers	Reject	Mark
<b>23(d) (iii)</b>	<p><b>Note</b> First mark can only be awarded if there is a partial justification</p> <p>Strong acid-weak alkali</p> <p>ALLOW strong acid-strong alkali / named suitable acids and alkalis e.g. hydrochloric acid and (aqueous) ammonia</p> <p>ALLOW base for alkali <b>(1)</b></p> <p>Conditional on M1  <math>pK_{in}</math> (for methyl red) is 5.1 / pH range (for methyl red) is 4.2-6.3 <b>and</b> this lies (wholly) within the vertical part of the titration curve</p> <p>ALLOW  pH at the end / equivalence point corresponds with the pH range (for methyl red)</p> <p>ALLOW  <math>pK_{in}</math> corresponds with the pH at the equivalence /end point (of the titration) / is in the middle of the vertical part of the titration curve</p> <p>ALLOW  Indicator changes colour (entirely) within vertical part of the titration curve <b>(1)</b></p>		<b>(2)</b>

Question Number	Acceptable Answers	Reject	Mark
<b>23(e) (i)</b>	$[\text{Fe}(\text{H}_2\text{O})_6]^{2+} + 6\text{CN}^- \rightarrow [\text{Fe}(\text{CN})_6]^{4-} + 6\text{H}_2\text{O}$ <p>OR</p> $[\text{Fe}(\text{H}_2\text{O})_6]^{2+} + 6\text{KCN} \rightarrow [\text{Fe}(\text{CN})_6]^{4-} + 6\text{K}^+ + 6\text{H}_2\text{O}$ <p>OR</p> $[\text{Fe}(\text{H}_2\text{O})_6]^{2+} + 6\text{KCN} \rightarrow \text{K}_4[\text{Fe}(\text{CN})_6] + 2\text{K}^+ + 6\text{H}_2\text{O}$ <p>OR</p> $\text{Fe}^{2+} + 6\text{CN}^- \rightarrow [\text{Fe}(\text{CN})_6]^{4-}$ <p>OR</p> $\text{Fe}^{2+} + 6\text{KCN} \rightarrow \text{K}_4[\text{Fe}(\text{CN})_6] + 2\text{K}^+ \quad (1)$ <p>IGNORE missing square brackets on complexes / state symbols</p> <p>Ligand exchange / ligand substitution / ligand replacement <span style="float: right;">(1)</span></p> <p>Mark independently</p>		<b>(2)</b>

Question Number	Acceptable Answers	Reject	Mark
<b>23(e) (ii)</b>	<p>(+)3 / 3+ / III / iron(III)</p> <p>ALLOW <math>\text{Fe}^{3+}</math></p>		<b>(1)</b>

(Total for Question 23 = 19 marks)

