Pearson Edexcel

# Mark Scheme (Results)

## January 2022

Pearson Edexcel International Advanced Level in Chemistry (WCH15)
Paper 01:Transition Metals and Organic Nitrogen Chemistry

**Section A (multiple choice)**

| Question Number | Correct Answer | Mark |
|---|---|---|
| 1(a) | **The only correct answer is B** (covalent and dative covalent only)<br><br>***A*** *is incorrect because there is no ionic bonding* ***within*** *the complex*<br><br>***C*** *is incorrect because there is dative covalent bonding between the metal ion and the ligand*<br><br>***D*** *is incorrect because there is covalent bonding within* $NH_3$ *and* $H_2O$ | **(1)** |

| Question Number | Correct Answer | Mark |
|---|---|---|
| 1(b) | **The only correct answer is D** ($[CoCl_4]^{2-}$)<br><br>***A*** *is incorrect because* $[Pt(NH_3)_2Cl_2]$ *is square planar*<br><br>***B*** *is incorrect because* $[Cu(H_2O)_4(OH)_2]$ *is octahedral*<br><br>***C*** *is incorrect because* $[Cu(NH_3)_4(H_2O)_2]^{2+}$ *is octahedral* | **(1)** |

| Question Number | Correct Answer | Mark |
|---|---|---|
| 1(c) | **The only correct answer is C** $[Ni(NH_2CH_2CH_2NH_2)_3]^{2+}$<br><br>***A*** *is incorrect because the ligand is tridentate*<br><br>***B*** *is incorrect because both the ligands are monodentate*<br><br>***D*** *is incorrect because the ligand is hexadentate* | **(1)** |

**(Total for Question 1 = 3 marks)**

| Question Number | Correct Answer | Mark |
|---|---|---|
| 2(a) | **The only correct answer is C** ($H_2(g) \rightarrow 2H^+(aq) + 2e^-$)<br><br>***A*** *is incorrect because this is the reaction at the cathode*<br><br>***B*** *is incorrect because this is the reverse of the reaction at the cathode*<br><br>***D*** *is incorrect because this is the reverse of the reaction at the anode* | **(1)** |

| Question Number | Correct Answer | Mark |
|---|---|---|
| 2(b) | **The only correct answer is B** (emissions do not contribute to climate change)<br><br>***A*** *is incorrect because methanol produces more energy per mole*<br><br>***C*** *is incorrect because the hydrogen gas is more difficult to store*<br><br>***D*** *is incorrect because both can be made from renewable resources* | **(1)** |

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

| Question Number | Correct Answer | Mark |
|---|---|---|
| 3(a) | **The only correct answer is A** (silver nitrate)<br><br>***B*** *is incorrect because silver hydroxide is insoluble*<br><br>***C*** *is incorrect because silver chloride is insoluble*<br><br>***D*** *is incorrect because silver carbonate is insoluble* | **(1)** |

| Question Number | Correct Answer | Mark |
|---|---|---|
| 3(b) | **The only correct answer is B (**2 mol $dm^{-3}$ acidified $VO_2^+(aq)$ and 2 mol $dm^{-3}$ acidified $VO^{2+}(aq)$<br><br>***A*** *is incorrect because the electrolyte will be 0.5 mol* $dm^{-3}$ *wrt the vanadate ions*<br><br>***C*** *is incorrect because the electrolyte does not contain any* $VO^{2+}(aq)$ *ions and the concentration wrt* $VO_2^+$ *ions is 0.5 mol* $dm^{-3}$<br><br>***D*** *is incorrect because the electrolyte does not contain any* $VO_2^+(aq)$ *ions and the concentration wrt* $VO^{2+}$ *ions is 0.5 mol* $dm^{-3}$ | **(1)** |

| Question Number | Correct Answer | Mark |
|---|---|---|
| 3(c) | **The only correct answer is B** ($VO_2^+(aq) + Ag(s) + 2H^+(aq) \rightarrow VO^{2+}(aq) + Ag^+(aq) + H_2O(l)$)<br><br>***A*** *is incorrect because* $Ag^+$ *cannot oxidise* $VO^{2+}$*(under standard conditions)*<br><br>***C*** *is incorrect because the reaction is not feasible and is unbalanced*<br><br>***D*** *is incorrect because the reaction is not feasible and is unbalanced* | **(1)** |

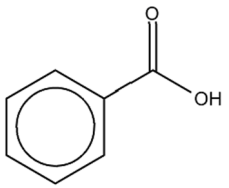
| Question Number | Correct Answer | Mark |
|---|---|---|
| 3(d) | **The only correct answer is C** (+ 0.20)<br><br>***A*** *is incorrect because the expression* $E^{\ominus}_{cell} = -(E_R + E_L)$ *was used*<br><br>***B*** *is incorrect because the expression* $E^{\ominus}_{cell} = E_L - E_R$ *was used*<br><br>***D*** *is incorrect because the expression* $E^{\ominus}_{cell} = E_R + E_L$ *was used* | **(1)** |

| Question Number | Correct Answer | Mark |
|---|---|---|
| 3(e) | **The only correct answer is B** ( $Ag(s) \mid Ag^+(aq) \mid\mid [VO_2^+(aq) + 2H^+(aq)], [VO^{2+}(aq) + H_2O(l)] \mid Pt(s)$ )<br><br>***A*** *is incorrect because a solid line is used to separate species in the same phase*<br><br>***C*** *is incorrect because the order of species is R-O-R-O and a solid line is used to separate species in the same phase*<br><br>***D*** *is incorrect because the order of species is R-O-R-O* | **(1)** |

**(Total for Question 3 = 5 marks)**

| Question Number | Correct Answer | Mark |
|---|---|---|
| 4 | **The only correct answer is D** (0.15)<br><br>***A*** *is incorrect because the volume of the solution has not been scaled up to 1 dm$^3$ and uses only 1 mol of $SO_4^{2-}$ ions per mole of $Fe_2(SO_4)_3$*<br><br>***B*** *is incorrect because this uses only 1 mol of $SO_4^{2-}$ ions per mole of $Fe_2(SO_4)_3$*<br><br>***C*** *is incorrect because this is the concentration of $Fe^{3+}(aq)$* | **(1)** |

**(Total for Question 4 = 1 mark)**

| Question Number | Correct Answer | Mark |
|---|---|---|
| 5 | **The only correct answer is A**<br><br>  <br><br><br>***B*** *is incorrect because the structure has no C=O group*<br><br>***C*** *is incorrect because the structure has no O-H group*<br><br>***D*** *is incorrect because the structure has no O-H group* | **(1)** |

**(Total for Question 5 = 1 mark)**

| Question Number | Correct Answer | Mark |
|---|---|---|
| 6(a) | **The only correct answer is C** (five)<br><br>***A*** *is incorrect because it assumes all the carbon atoms are in a different environment*<br><br>***B*** *is incorrect because it assumes only two of the benzene ring carbon atoms are in the same environment*<br><br>***D*** *is incorrect because it assumes the carbon atoms at position 1 and position 4 of the ring are in the same environment* | **(1)** |

| Question Number | Correct Answer | Mark |
|---|---|---|
| 6(b) | **The only correct answer is D** (electrophilic substitution)<br><br>***A*** *is incorrect because the nitrating mixture produces an electrophile, $NO_2^+$, and addition does not occur due to stability of ring system*<br><br>***B*** *is incorrect because the nitrating mixture produces an electrophile, $NO_2^+$,*<br><br>***C*** *is incorrect because addition does not occur due to stability of ring system* | **(1)** |

| Question Number | Correct Answer | Mark |
|---|---|---|
| 6(c) | **The only correct answer is A** ((10 x 85 x 227) ÷ (92 x 100))<br>***B*** *is incorrect because the scaling factor for the yield is incorrect*<br><br>***C*** *is incorrect because the scaling factor for the yield is incorrect*<br><br>***D*** *is incorrect because the scaling factor for the yield is incorrect* | **(1)** |

**(Total for Question 6 = 3 marks)**

| Question Number | Correct Answer | Mark |
|---|---|---|
| 7 | **The only correct answer is A** (92.0261)<br><br>***B*** *is incorrect because it uses O = 16*<br><br>***C*** *is incorrect because it has 5 hydrogens in the structure instead of 4*<br><br>***D*** *is incorrect because it has 5 hydrogens in the structure instead of 4 and uses O = 16* | **(1)** |

**(Total for Question 7 = 1 mark)**

| Question Number | Correct Answer | Mark |
|---|---|---|
| 8(a) | **The only correct answer is C** (0.040)<br><br>***A*** *is incorrect because the ratio of thiosulfate to chlorine used in the calculation is 1 : 2*<br><br>***B*** *is incorrect because the ratio of thiosulfate to chlorine used in the calculation is 1 : 1*<br><br>***D*** *is incorrect because the ratio of thiosulfate to chlorine used in the calculation is 4 : 1* | **(1)** |

| Question Number | Correct Answer | Mark |
|---|---|---|
| 8(b) | **The only correct answer is D** (10.0) | **(1)** |

| | | |
|---|---|---|
| | ***A** is incorrect because this is the exact amount if the concentration is 0.038*<br>***B** is incorrect because this is the exact amount if the concentration is 0.040*<br>***C** is incorrect because this is the exact amount if the concentration is 0.042* | |

| Question Number | Correct Answer | Mark |
|---|---|---|
| **8(c)** | **The only correct answer is D** (blue-black to colourless)<br><br>***A** is incorrect because the colour change is the wrong way around and without the starch indicator*<br>***B** is incorrect because this is the colour change without the starch indicator*<br>***C** is incorrect because the colour change is the wrong way around* | **(1)** |

**(Total for Question 8 = 3 marks)**

| Question Number | Correct Answer | Mark |
|---|---|---|
| **9** | **The only correct answer is B** (two) | **(1)** |

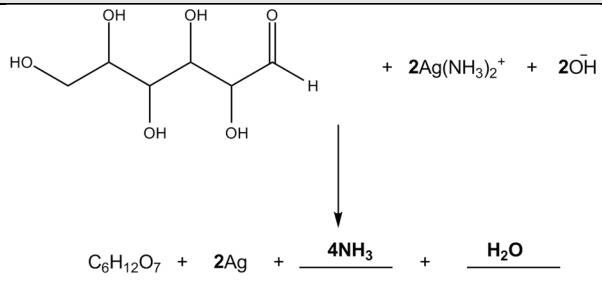
| | | |
|---|---|---|
| | ***A*** *is incorrect as both* $AlO_2^-$ *and* $[CrCl_2(H_2O)_4]^+$ *contain a metal with oxidation number of +3*<br><br>***C*** *is incorrect as the Fe in* $[Fe(CN)_6]^{4-}$ *has an oxidation number of +2 and the Cr in* $CrO_4^{2-}$ *has an oxidation number of +6*<br><br>***D*** *is incorrect as the Fe in* $[Fe(CN)_6]^{4-}$ *has an oxidation number of +2 and the Cr in* $CrO_4^{2-}$ *has an oxidation number of +6* | |

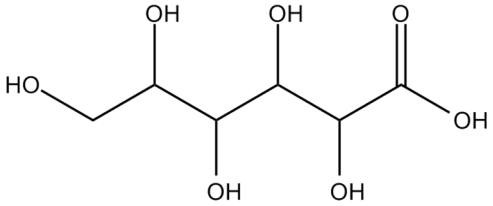
**(Total for Question 9 = 1 mark)**
**TOTAL FOR SECTION A = 20 MARKS**

**Section B**

| Question Number | Acceptable Answers | **Additional Guidance** | Mark |
|---|---|---|---|
| **10(a)(i)** | An explanation that makes reference to the following points:<br><br>• the shape is linear / bond angle is 180°<br>**(1)**<br><br>• as there are 2 pairs of (bonding) electrons (around central $Ag^+$) / each N donates a (lone) pair of electrons (to $Ag^+$) **(1)**<br><br>• which adopt a position to minimise repulsion (between electron pairs / bonds)<br>**(1)** | <br><br>allow straight<br>Shape / angle can be shown on a diagram<br>Ignore planar<br><br>Allow each ammonia donates a (lone) pair of electrons<br><br>Allow which adopt a position to maximise separation (between electron pairs / bonds)<br>Do not award just minimising repulsion between ligands / ammonia | **(3)** |

| Question Number | Acceptable Answers | **Additional Guidance** | Mark |
|---|---|---|---|
| **10(a)(ii)** | An explanation that makes reference to the following points:<br><br>• $Ag^+$ / silver ion has a full d-subshell / d-orbital**s** **(1)**<br><br>• so electrons cannot be promoted (to higher d orbitals) / no d-d transitions / no excitation of electrons / no transition of electrons **(1)** | M1 can be shown with a correct electron configuration, [Kr] $4d^{10}$<br>Do not award the subshell is empty<br>Do not award d orbital (singular) is full unless clarified by $4d^{10}$ / later reference to orbital**s**<br><br>Ignore references to all light is reflected / no light is absorbed<br>Do not award the subshell / orbitals cannot be split<br>Do not award the wavelength / frequency is outside the visible region | **(2)** |

| Question Number | Acceptable Answers | **Additional Guidance** | Mark |
|---|---|---|---|
| **10(b)(i)** | An answer that makes reference to the following points:<br>• correct products **(1)**<br>• balancing of equation **(1)**<br>M2 is dependent on M1 |  <br>Ignore state symbols even if incorrect | **(2)** |

| Question Number | Acceptable Answers | **Additional Guidance** | Mark |
|---|---|---|---|
| **10(b)(ii)** |  | Allow displayed / structural / skeletal formula or any correct hybrid of the 3 types of structure<br><br>Allow carboxylate ion<br>Do not award -HO on terminal OH groups | **(1)** |

| Question Number | Acceptable Answers | **Additional Guidance** | Mark |
|---|---|---|---|
| **10(c)** | • $Zn + 2OH^- \rightarrow Zn(OH)_2 + 2e^-$ | $Zn + 2OH^- - 2e^- \rightarrow Zn(OH)_2$<br>Allow $Zn \rightarrow Zn^{2+} + 2e^-$<br>Allow 2e<br>Ignore state symbols even if incorrect<br>Do not award '⇌' | **(1)** |

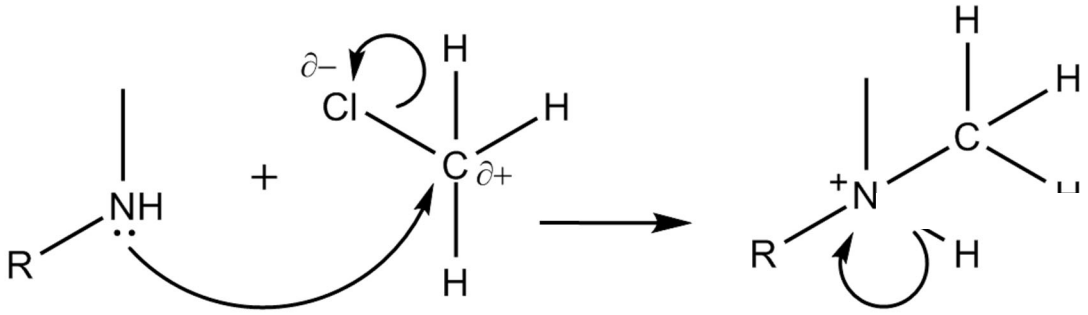
**(Total for Question 10 = 9 marks)**

| Question Number | Acceptable Answers | Additional Guidance | Mark |
|---|---|---|---|
| **11(a)** | • tertiary (amine) / 3° (amine) | Allow tertiary / tertiery / tertiary<br><br>Do not award '3rd / third (amine)<br>Do not award tertiary amide / 3° amide<br>Ignore attempts to explain classification | **(1)** |

| Question Number | Acceptable Answers | Additional Guidance | Mark |
|---|---|---|---|
| **11(b)** | An explanation that makes reference to the following points:<br><br>• the **nitrogen / N** (atom) has a lone pair of electrons **(1)**<br><br>• which can forms a hydrogen bond to water (to the ∂+ hydrogen) **(1)**<br><br>• and can accept a $H^+$ ion (from water) / form $C_5H_5NH^+$ / form a dative bond to a $H^+$ ion (from water) **(1)**<br><br>• leaving a (slight excess) of hydroxide ions **(1)** | Mark Independently<br><br>M1 and M2 can be shown on a diagram<br>Allow '**nitrogen / N** is electronegative (and small)'<br><br>Allow pyridine can form intermolecular forces with water that are strong enough to overcome the hydrogen bonds in water<br><br>M3 and M4 can be shown by correct equation<br>$C_5H_5N + H_2O \rightarrow C_5H_5NH^+ + OH^-$ | **(4)** |

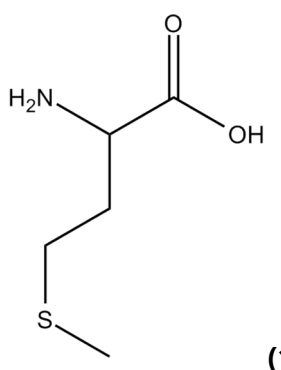
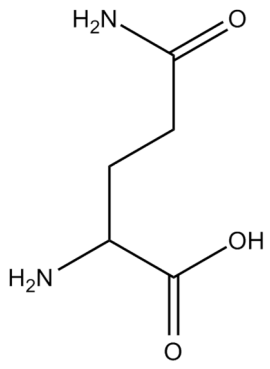
| Question Number | Acceptable Answers | Additional Guidance | Mark |
|---|---|---|---|
| **11(c)** | An answer that makes reference to the following points<br><br>• arrow from lone pair on nitrogen atom to carbon atom **(1)**<br><br>• dipole shown and arrow from C–Cl bond to Cl or just beyond **(1)**<br><br>• formula of intermediate including the + charge on the N atom **(1)**<br><br>• arrow from N-H bond to N(+) **(1)** | Allow M1 and M2 via formation of a carbocation<br>Ignore $\partial^-$ on N<br>Do not award $N^-$ | **(4)** |

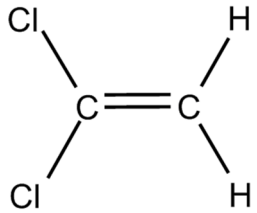
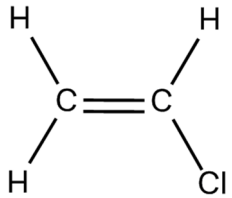
Example of mechanism




(+ organic product + HCl)

**(Total for Question 11 = 9 marks)**

| Question Number | Acceptable Answers | Additional Guidance | Mark |
|---|---|---|---|
| **12(a)** |  **(1)**  **(1)** | Do not award acyl chlorides | **(2)** |

| Question Number | Acceptable Answers | Additional Guidance | Mark |
|---|---|---|---|
| **12(b)** |  **(1)**  **(1)** | Allow displayed / structural / skeletal formula or any correct hybrid of the 3 types of structure e.g. $CCl_2CH_2$ (1) and $CH_2CHCl$ (1) | **(2)** |

| Question Number | Acceptable Answers | Additional Guidance | Mark |
|---|---|---|---|
| **12(c)** | • calculation of molar mass of repeat unit **(1)**<br>• calculation of number of repeat units **(1)** | <u>Example of calculation</u><br>(12 × 12) + 14 = 158 (g $mol^{-1}$)<br>300 000 ÷ 158 = 1898.73<br>= 1900 (units)<br>Allow 1898 / 1899 i.e allow the value to be rounded up or rounded down<br>Ignore SF<br>Final answer must be whole number<br>Allow TE for incorrect molar mass | **(2)** |

**(Total for Question 12 = 6 marks)**

| Question Number | Acceptable Answers | Additional Guidance | Mark |
|---|---|---|---|
| **13(a)** |  | Allow reversal of dots and crosses<br>Allow all dots or all crosses<br>Allow overlapping circles<br><br>Allow lone pair to be shown as separate electrons<br><br>Ignore lines between As and H | **(1)** |

| Question Number | Acceptable Answers | Additional Guidance | Mark |
|---|---|---|---|
| **13(b)(i)** | $AsH_3 \rightarrow As + 3H^+ + 3e^{(-)}$ | Allow $AsH_3 - 3e^{(-)} \rightarrow As + 3H^+$<br><br>Ignore state symbols even if incorrect | **(1)** |

| Question Number | Acceptable Answers | Additional Guidance | Mark |
|---|---|---|---|
| **13(b)(ii)** | • calculation of amount of $Ce^{4+}$ **(1)**<br>• calculation of $T$ in K and $V$ in $m^3$ **(1)**<br>• rearrangement of $pV = nRT$ **(1)**<br>• calculation of $n$ for arsine **(1)**<br>• deduction of whole number ratio of $AsH_3$ : $Ce^{4+}$ **(1)**<br>• deduction of oxidation state of cerium in product **(1)** | <u>Example of calculation</u><br><br>(488/1000) × 0.102 = 0.049776 (mol)<br><br>293 K, 350 × $10^{-6}$ $m^3$<br>Allow 0.35 ($dm^3$) for V if P converted to 115 (kPa)<br>$n = pV / RT$<br>Can be subsumed in M4<br><br>(115000 × 350 × $10^{-6}$) / (8.31 × 293) = 0.016531<br><br>1:3 / 0.049776 ÷ 0.016531 = 3<br>Allow 2:7 if molar gas volume used to calculate n<br><br>$Ce^{3+}$ / (+)3<br>Allow TE throughout<br><br>Allow estimation of n using molar gas volume = 24 $dm^3$ as alternative to M3 and M4<br>Do not award M6 if 2:7 ratio used in M5<br>Ignore SF throughout | **(6)** |

**(Total for Question 13 = 8 marks)**

<table>
<tr><th>Question Number</th><th>Acceptable Answers</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr>
<td>14</td>
<td>
This question assesses the student's ability to show a coherent and logically structured answer with linkages and fully sustained reasoning.<br><br>
Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.<br><br>
The following table shows how the marks should be awarded for indicative content.
<table>
<tr><th>Number of indicative marking points seen in answer</th><th>Number of marks awarded for indicative marking points</th></tr>
<tr><td>6</td><td>4</td></tr>
<tr><td>5-4</td><td>3</td></tr>
<tr><td>3-2</td><td>2</td></tr>
<tr><td>1</td><td>1</td></tr>
<tr><td>0</td><td>0</td></tr>
</table>
The following table shows how the marks should be awarded for structure and lines of reasoning
<table>
<tr><th></th><th>Number of marks awarded for structure of answer and sustained lines of reasoning</th></tr>
<tr><td>Answer shows a coherent logical structure with linkages and fully sustained lines of reasoning demonstrated throughout</td><td>2</td></tr>
<tr><td>Answer is partially structured with some linkages and lines of reasoning</td><td>1</td></tr>
<tr><td>Answer has no linkages between points and is unstructured</td><td>0</td></tr>
</table>
</td>
<td>
Guidance on how the mark scheme should be applied:<br>
The mark for indicative content should be added to the mark for lines of reasoning. For example, a response with four indicative marking points that is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning).<br>
If there were no linkages between the points, then the same indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and zero marks for linkages).
</td>
<td></td>
</tr>
</table>

| | | | |
|---|---|---|---|
| | **Indicative Points**<br><br>Sodium hydroxide<br>**IP1** pink solution to blue precipitate / pink solution to pink precipitate on standing (deprotonation / precipitation / acid-base)<br><br>**IP2** $[Co(H_2O)_6]^{2+} + 2OH^- \rightarrow [Co(H_2O)_4(OH)_2] + 2H_2O$<br><br>Ammonia<br>**IP3** (formation of) straw/yellow/yellow-brown/brown solution (ligand exchange)<br><br>**IP4** $[Co(H_2O)_6]^{2+} + 6NH_3 \rightarrow [Co(NH_3)_6]^{2+} + 6H_2O$<br><br>Concentrated hydrochloric acid<br>**IP5** (formation of dark) blue solution (ligand exchange)<br><br>**IP6** $[Co(H_2O)_6]^{2+} + 4Cl^-(aq) \rightarrow [CoCl_4]^{2-} + 6H_2O$ /<br>$[Co(H_2O)_6]^{2+} + 4HCl(aq) \rightarrow [CoCl_4]^{2-} + 6H_2O + 4H^+$ | The initial colour of cobalt sulfate must be mentioned once<br><br>Do not award 'precipitate dissolves in excess NaOH(aq)'<br><br>Allow $Co^{2+} + 2OH^- \rightarrow Co(OH)_2$ /<br>$CoSO_4 + 2NaOH \rightarrow Co(OH)_2 + Na_2SO_4$<br><br>Ignore formation of blue or green ppt on initial addition of $NH_3$<br><br>Allow $[Co(H_2O)_4(OH)_2] + 6NH_3 \rightarrow [Co(NH_3)_6]^{2+} + 4H_2O + 2OH^-$<br>$Co(OH)_2 + 6NH_3 \rightarrow [Co(NH_3)_6]^{2+} + 2OH^-$<br><br>Allow<br>$CoSO_4 + 4HCl \rightarrow [CoCl_4]^{2-} + 4H^+ + SO_4^{2-}$<br>/ $Co^{2+} + 4Cl^- \rightarrow [CoCl_4]^{2-}$<br><br>In IP2, IP4 and IP6 ignore state symbols even if incorrect<br>Ignore adjectives before colours | |

**(Total for Question 14 = 6 marks)**

<table>
<tr><th>Question Number</th><th>Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td>15(a)</td><td>

- calculation of mass of carbon **(1)**
- calculation of mass of hydrogen and oxygen **(1)**
- calculation of moles of carbon, hydrogen and oxygen **(1)**
- calculation of ratio **(1)**

alternative method

M1 moles of Q = 4.91 ÷ 148 = 0.0332 (mol)<br>M2 moles of $CO_2$ = 14.6 ÷ 44 = 0.332 (mol)<br>**and** moles of $H_2O$ = 3.58 ÷ 18 = 0.199 (mol)<br>M3 calculation of the ratio 10 : 12

M4 show that O = 1

(10 x 12) + (12 x 1) + (16 x number of oxygen atoms) = 148 , so O = 1

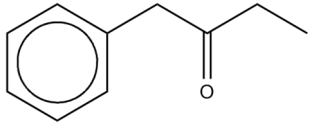
</td><td>

<u>Example of calculation</u>

<table>
<tr><td></td><td>C</td><td>H</td><td>O</td></tr>
<tr><td>mass =</td><td>14.6 x (12÷44)<br>= 3.982 (g)</td><td>3.58 x (2÷18)<br>= 0.398 (g)</td><td>4.91 –<br>(3.982+0.398)<br>=0.53 (g)</td></tr>
<tr><td>Moles =</td><td>= 3.982 ÷12<br>= 0.332 (mol)</td><td>= 0.398 ÷ 1<br>= 0.398 (mol)</td><td>0.53 ÷ 16<br>0.0331 (mol)</td></tr>
<tr><td>Ratio</td><td>10</td><td>12</td><td>1</td></tr>
<tr><td>Formula =</td><td colspan="3">$C_{10}H_{12}O$</td></tr>
</table>

Allow TE from M1 to M3

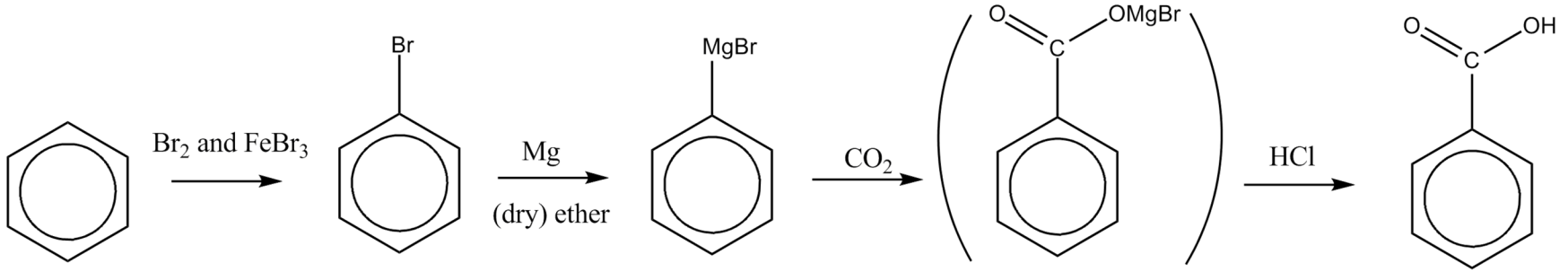
</td><td>(4)</td></tr>
</table>

| Question Number | Acceptable Answers | Additional Guidance | Mark |
|---|---|---|---|
| **15(b)** | An explanation that makes reference to the following points:<br>**structure**<br>• correct structure **(1)**<br>**chemical shifts -** allow any three from four<br>• 4 peaks / chemical shifts means 4 (different) hydrogen environments **(1)**<br>• peak at 7.5 ppm is due (hydrogen atoms on) benzene ring **(1)**<br>• peak at 2.3 ppm is due **H**-C-C=O / ketone / C=O **(1)**<br>• peak at 1.0 ppm is due to **H**-C-C / alkyl group / methyl group / alkane **(1)**<br>**splitting patterns** - allow any two from three<br>• peak at 2.3 ppm is a quartet as there are 3 hydrogens on neighbouring carbon / it is bonded to a $CH_3$ group **(1)**<br>**Or**<br>• peak at 1.0 ppm is a triplet as there are 2 hydrogens on neighbouring carbon / bonded to a $CH_2$ **(1)**<br>**Or**<br>• peak at 3.6 ppm is a singlet as there are no hydrogens on neighbouring carbon **(1)**<br>**area under curve**<br>• (area of 5 for peak at 7.5 ppm) shows the benzene ring has (only) 1 side group / is $C_6H_5$ **(1)** |  <br><br>Allow chemical environment<br>Ignore references to peak at 3.6 ppm<br>Do not award aldehyde<br>If no reference to neighbouring hydrogens in M4, M5 or M6 allow 1 mark for idea that a quartet-triplet pattern is due to $CH_2CH_3$<br>Ignore references to splitting of peak at 7.5 ppm<br>Allow benzene has 5 H (atoms)<br>DNA if more than 1 side group on structure | **(7)** |

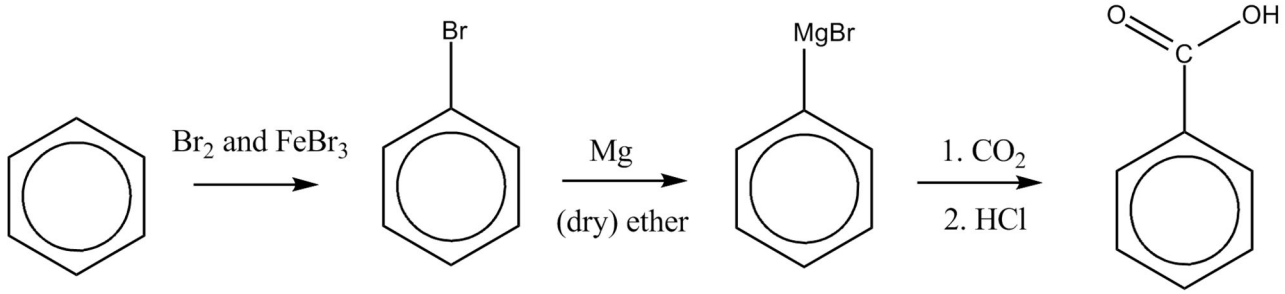
**(Total for Question 15 = 11 marks) (Total for Section B = 49 marks)**

**Section C**

| Question Number | Acceptable Answers | Additional Guidance | Mark |
|---|---|---|---|
| **16(a)** | An answer that makes reference to the following points:<br><br>• reaction of benzene with $Br_2$ and $FeBr_3$ / $AlBr_3$ **(1)**<br><br>• reaction of bromobenzene with Mg **(1)**<br><br>• in (dry) ether **(1)**<br><br>• structure of Grignard reagent **(1)**<br><br>• reaction of Grignard reagent with $CO_2$ / **(1)**<br><br>• (hydrolysis of acid salt) with dilute HCl **(1)**<br><br>Alternative route for M5 and M6<br><br>• reaction of Grignard reagent with HCHO **(1)**<br><br>• (hydrolysis of acid salt) with dilute HCl<br>**and**<br>oxidation (of primary alcohol) with acidified $Cr_2O_7^{2-}$ **(1)** | See below for reaction scheme<br>Ignore references to heating / refluxing throughout<br>Allow Fe & $Br_2$<br>Allow other halogens and halides<br>Allow aluminium halide<br><br>M5 and M6 with $CO_2$ can be shown in the same part of the process providing it it's clear that each step is separate e.g. by labelling (see example below)<br><br>Allow any dilute acid / $H^+$<br>Ignore structure of salt<br>Ignore $H_2O$ | **(6)** |

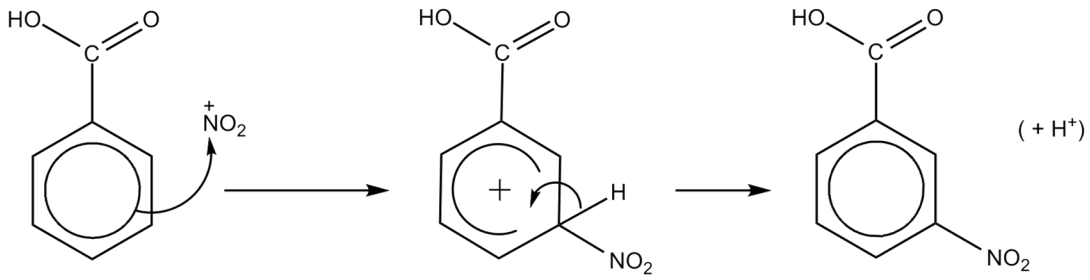



Allow $CO_2$ and HCl as parts 1 and 2 of the final step if clearly labelled e.g.



| Question Number | Acceptable Answers | Additional Guidance | Mark |
|---|---|---|---|
| **16(b)(i)** | An answer that makes reference to the following points:<br>• equation to show formation of electrophile **(1)** | $HNO_3 + H_2SO_4 \rightarrow NO_2^+ + HSO_4^- + H_2O$<br>Or<br>$HNO_3 + 2H_2SO_4 \rightarrow NO_2^+ + 2HSO_4^- + H_3O^+$<br>Or<br>$HNO_3 + H_2SO_4 \rightarrow H_2NO_3^+ + HSO_4^-$ and $H_2NO_3^+ \rightarrow NO_2^+ + H_2O$<br>Do not award $H_3SO_5^-$ in M1 but allow as potential TE in M5 | **(5)** |
| | • curly arrow from anywhere on the central ring to positive **nitrogen** **(1)** | Allow curly arrow from anywhere **within** the hexagon | |
| | • structure of intermediate **(1)** | Horseshoe facing the tetrahedral carbon and covering at least three carbon atoms.<br>Some part of the positive charge in the horseshoe<br>Do not award dotted lines unless clearly part of a 3D structure | |
| | • curly arrow from C-H bond to reform the ring **(1)** | Do not award M4 if substitution position is incorrect | |
| | • equation showing regeneration of catalyst **(1)** | $HSO_4^- + H^+ \rightarrow H_2SO_4$<br>Allow M5 as part of mechanism, with curly arrow from oxygen of $HSO_4^-$ to H on benzene ring | |

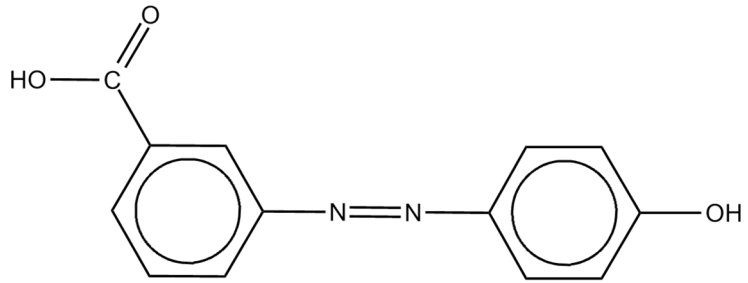
Example of mechanism for 16bi




Ignore postion of '+' in $NO_2^+$
No TE from incorrect species from equation in M1 to M2
Use of benzene can score M1, M2, M3 and M5

| Question Number | Acceptable Answers | Additional Guidance | Mark |
|---|---|---|---|
| **16(b)(ii)** | • Sn and (concentrated) HCl / tin and (concentrated) hydrochloric acid | Allow Fe for Sn<br>Do not award other acids e.g. sulfuric acid<br>Do not award $LiAlH_4$<br>Do not award Sn is a catalyst<br>Do not award dilute HCl<br>Do not award 'followed by NaOH'<br>Ignore heating / reflux / stated temperatures | **(1)** |

| Question Number | Acceptable Answers | Additional Guidance | Mark |
|---|---|---|---|
| **16(b)(iii)** | An explanation that makes reference to the following points:<br><br>• any temperature between 0°C and 10°C , inclusive **(1)**<br><br>• to prevent formation of by-products / phenol (compounds) **(1)** | Mark independently<br><br>Allow just 'less than 10°C' / 'below 5°C'<br><br>Allow to prevent decomposition of $HNO_2$ / to prevent decomposition of diazonium ion/ diazonium ion is unstable / to prevent weak C-N bond breaking / prevent formation of (stable) nitrogen<br>Allow reaction is too slow at temperatures below 0°C / low temperatures<br><br>Do not award decomposition of $NaNO_2$ / nitro group | **(2)** |

| Question Number | Acceptable Answers | Additional Guidance | Mark |
|---|---|---|---|
| **16(b)(iv)** |  | Ignore additional products<br>Ignore connectivity of -OH group<br>Do not award if OH or COOH are at incorrect positions on ring<br>Do not award carboxylate ion<br>Do not award $-N_2-$ in between two rings<br>Do not award N≡N | **(1)** |

| Question Number | Acceptable Answers | Additional Guidance | Mark |
|---|---|---|---|
| **16(c)** | • calculation of molar mass of $Pb(C_6H_5COO)_2$ **(1)**<br>• calculation of amount of $Pb(C_6H_5COO)_2$ **(1)**<br>• deduction of amount of $Ca(C_6H_5COO)_2.xH_2O$ **(1)**<br>• calculation of $M_r$ of $Ca(C_6H_5COO)_2.xH_2O$ **(1)**<br>• calculation of mass of water in $M_r$ **(1)**<br>• calculation of amount of water and hence x **(1)**<br><br>**Alternative route for M4-M6**<br>• calculation of mass of $Ca(C_6H_5COO)_2$ **(1)**<br>• calculation of mass of water in hydrated sample **(1)**<br>• calculation of amount of water and hence x **(1)** | <u>Example of calculation</u><br>449.2 can be subsumed within M2<br>3.89 / 449.2 = $8.65984 \times 10^{-3}$ (mol)<br>1:1 so $8.65984 \times 10^{-3}$ (mol)<br>M3 can be subsumed in M4<br>$2.60 / 8.65984 \times 10^{-3} = 300.24$<br>300.24 – (40.1 + (14x12) + (1x10) + (4x16) = 18.14<br>18.14 ÷18 = 1, so x = 1<br>Allow TE throughout<br>Correct value for x with no working scores M6 only<br>$8.65984 \times 10^{-3} \times 282.1 = 2.44$ g<br>2.60 – 2.44 = 0.16 g<br>0.16 ÷18 = 0.000889, so x = 1<br>Ignore SF except 1 SF for M1-M5 | **(6)** |

**(Total for Question 16 = 21 marks)**
**(Total for Section C = 21 marks)**
**Total for Paper = 90 marks**