Pearson Edexcel

Mark Scheme (Results)

January 2022

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

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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.

Section A (multiple choice)

Question Number	Correct Answer	Mark
1(a)	**The only correct answer is B** (covalent and dative covalent only) ***A*** *is incorrect because there is no ionic bonding* ***within*** *the complex* ***C*** *is incorrect because there is dative covalent bonding between the metal ion and the ligand* ***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** ($[CoCl_4]^{2-}$) ***A*** *is incorrect because* $[Pt(NH_3)_2Cl_2]$ *is square planar* ***B*** *is incorrect because* $[Cu(H_2O)_4(OH)_2]$ *is octahedral* ***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** $[Ni(NH_2CH_2CH_2NH_2)_3]^{2+}$ ***A*** *is incorrect because the ligand is tridentate* ***B*** *is incorrect because both the ligands are monodentate* ***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** ($H_2(g) \rightarrow 2H^+(aq) + 2e^-$) ***A*** *is incorrect because this is the reaction at the cathode* ***B*** *is incorrect because this is the reverse of the reaction at the cathode* ***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) ***A*** *is incorrect because methanol produces more energy per mole* ***C*** *is incorrect because the hydrogen gas is more difficult to store* ***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) ***B*** *is incorrect because silver hydroxide is insoluble* ***C*** *is incorrect because silver chloride is insoluble* ***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 $VO^{2+}(aq)$ ***A*** *is incorrect because the electrolyte will be 0.5 mol* dm^{-3} *wrt the vanadate ions* ***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} ***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** ($VO_2^+(aq) + Ag(s) + 2H^+(aq) \rightarrow VO^{2+}(aq) + Ag^+(aq) + H_2O(l)$) ***A*** *is incorrect because* Ag^+ *cannot oxidise* VO^{2+} *(under standard conditions)* ***C*** *is incorrect because the reaction is not feasible and is unbalanced* ***D*** *is incorrect because the reaction is not feasible and is unbalanced*	**(1)**

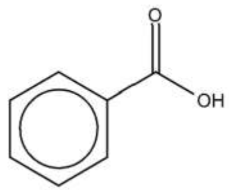
Question Number	Correct Answer	Mark
3(d)	**The only correct answer is C** (+ 0.20) ***A*** *is incorrect because the expression* $E^{\ominus}_{cell} = -(E_R + E_L)$ *was used* ***B*** *is incorrect because the expression* $E^{\ominus}_{cell} = E_L - E_R$ *was used* ***D*** *is incorrect because the expression*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

Question Number	Correct Answer	Mark
3(e)	**The only correct answer is B** ($Ag(s) \mid Ag^{+}(aq) \parallel [VO_2^{+}(aq) + 2H^{+}(aq)], [VO^{2+}(aq) + H_2O(l)] \mid Pt(s)$) ***A*** *is incorrect because a solid line is used to separate species in the same phase* ***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* ***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) ***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 $Fe_2(SO_4)_3$* ***B*** *is incorrect because this uses only 1 mol of SO_4^{2-} ions per mole of $Fe_2(SO_4)_3$* ***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**  ***B*** *is incorrect because the structure has no C=O group* ***C*** *is incorrect because the structure has no O-H group* ***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) ***A*** *is incorrect because it assumes all the carbon atoms are in a different environment* ***B*** *is incorrect because it assumes only two of the benzene ring carbon atoms are in the same environment* ***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) ***A*** *is incorrect because the nitrating mixture produces an electrophile,* NO_2^+*, and addition does not occur due to stability of ring system* ***B*** *is incorrect because the nitrating mixture produces an electrophile,* NO_2^+*,* ***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)) ***B*** *is incorrect because the scaling factor for the yield is incorrect* ***C*** *is incorrect because the scaling factor for the yield is incorrect* ***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) ***B** is incorrect because it uses O = 16* ***C** is incorrect because it has 5 hydrogens in the structure instead of 4* ***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) ***A** is incorrect because the ratio of thiosulfate to chlorine used in the calculation is 1 : 2* ***B** is incorrect because the ratio of thiosulfate to chlorine used in the calculation is 1 : 1* ***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* ***B*** *is incorrect because this is the exact amount if the concentration is 0.040* ***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) ***A*** *is incorrect because the colour change is the wrong way around and without the starch indicator* ***B*** *is incorrect because this is the colour change without the starch indicator* ***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* ***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* ***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*	

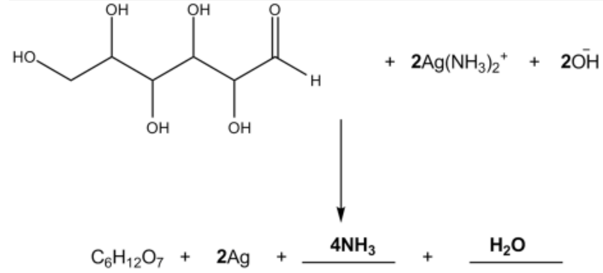
(Total for Question 9 = 1 mark)

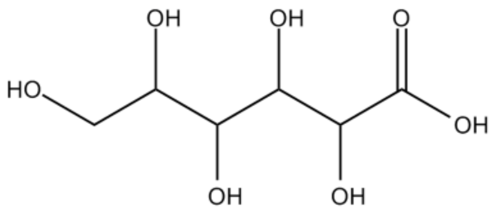
TOTAL FOR SECTION A = 20 MARKS

Section B

Question Number	Acceptable Answers	**Additional Guidance**	Mark
10(a)(i)	An explanation that makes reference to the following points: • the shape is linear / bond angle is 180° **(1)** • as there are 2 pairs of (bonding) electrons (around central Ag^+) / each N donates a (lone) pair of electrons (to Ag^+) **(1)** • which adopt a position to minimise repulsion (between electron pairs / bonds) **(1)**	allow straight Shape / angle can be shown on a diagram Ignore planar Allow each ammonia donates a (lone) pair of electrons Allow which adopt a position to maximise separation (between electron pairs / bonds) 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: • Ag^+ / silver ion has a full d-subshell / d-orbital**s** **(1)** • 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] $4d^{10}$ Do not award the subshell is empty Do not award d orbital (singular) is full unless clarified by $4d^{10}$ / later reference to orbital**s** Ignore references to all light is reflected / no light is absorbed Do not award the subshell / orbitals cannot be split 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: • correct products **(1)** • balancing of equation **(1)** M2 is dependent on M1	 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 Allow carboxylate ion Do not award -HO on terminal OH groups	**(1)**

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

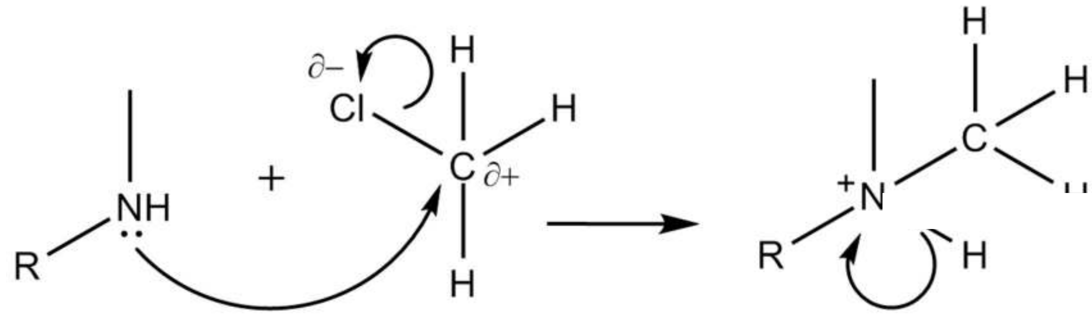
(Total for Question 10 = 9 marks)

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

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

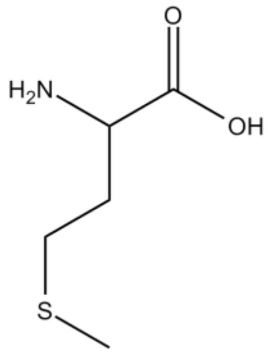
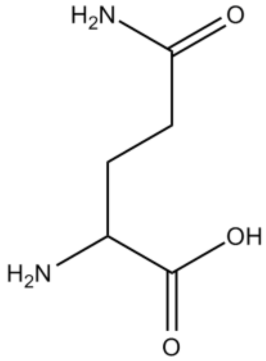
Question Number	Acceptable Answers	Additional Guidance	Mark
11(c)	An answer that makes reference to the following points • arrow from lone pair on nitrogen atom to carbon atom **(1)** • dipole shown and arrow from C–Cl bond to Cl or just beyond **(1)** • formula of intermediate including the + charge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

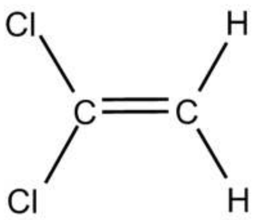
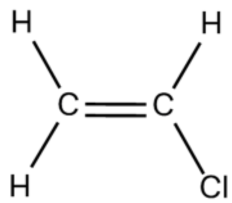
<u>Example of mechanism</u>



(+ organic product + HCl)

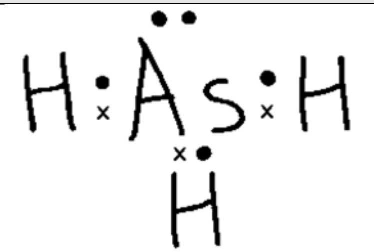
(Total for Question 11 = 9 marks)

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)** • calculation of number of repeat units **(1)**	Example of calculation (12 × 12) + 14 = 158 (g mol^{-1}) 300 000 ÷ 158 = 1898.73 = 1900 (units) Allow 1898 / 1899 i.e allow the value to be rounded up or rounded down Ignore SF Final answer must be whole number 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 Allow all dots or all crosses Allow overlapping circles Allow lone pair to be shown as separate electrons Ignore lines between As and H	**(1)**

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

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

(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.

Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.

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

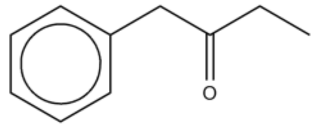
calculation of mass of carbon (1)
calculation of mass of hydrogen and oxygen (1)
calculation of moles of carbon, hydrogen and oxygen (1)
calculation of ratio (1)

alternative method

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

M4 show that O = 1

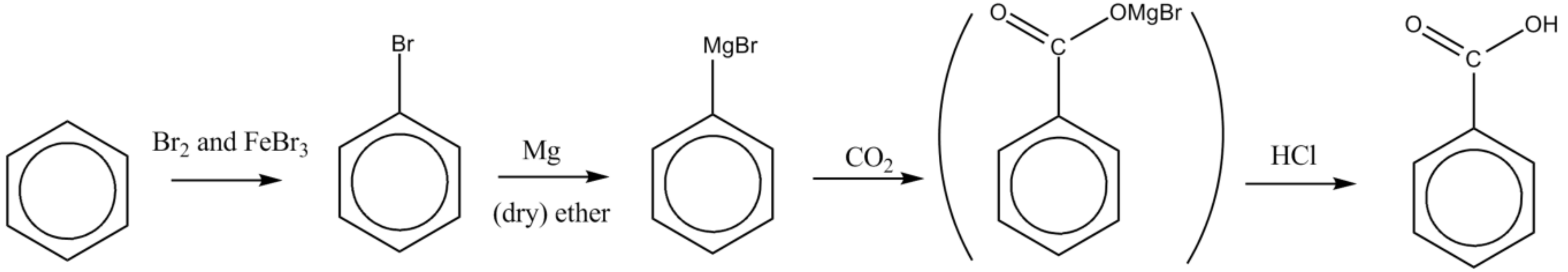
(10 x 12) + (12 x 1) + (16 x number of oxygen atoms) = 148 , so O = 1
</td>
<td>
<u>Example of calculation</u>
<table>
<tr><th></th><th>C</th><th>H</th><th>O</th></tr>
<tr><td>mass =</td><td>14.6 x (12÷44)
= 3.982 (g)</td><td>3.58 x (2÷18)
= 0.398 (g)</td><td>4.91 –
(3.982+0.398)
=0.53 (g)</td></tr>
<tr><td>Moles =</td><td>= 3.982 ÷12
= 0.332 (mol)</td><td>= 0.398 ÷ 1
= 0.398 (mol)</td><td>0.53 ÷ 16
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: **structure** • correct structure **(1)** **chemical shifts -** allow any three from four • 4 peaks / chemical shifts means 4 (different) hydrogen environments **(1)** • peak at 7.5 ppm is due (hydrogen atoms on) benzene ring **(1)** • peak at 2.3 ppm is due **H**-C-C=O / ketone / C=O **(1)** • peak at 1.0 ppm is due to **H**-C-C / alkyl group / methyl group / alkane **(1)** **splitting patterns** - allow any two from three • 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)** **Or** • peak at 1.0 ppm is a triplet as there are 2 hydrogens on neighbouring carbon / bonded to a CH_2 **(1)** **Or** • peak at 3.6 ppm is a singlet as there are no hydrogens on neighbouring carbon **(1)** **area under curve** • (area of 5 for peak at 7.5 ppm) shows the benzene ring has (only) 1 side group / is C_6H_5 **(1)**	 Allow chemical environment Ignore references to peak at 3.6 ppm Do not award aldehyde 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 Ignore references to splitting of peak at 7.5 ppm Allow benzene has 5 H (atoms) DNA if more than 1 side group on structure	**(7)**

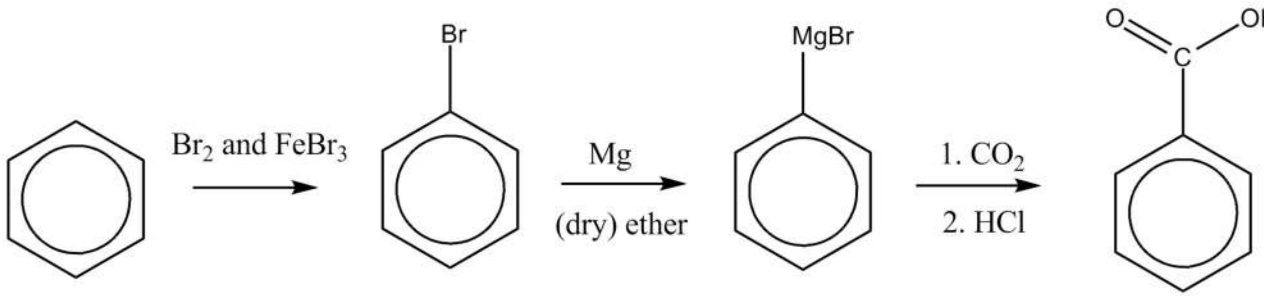
(Total for Question 15 = 11 marks) (Total for Section B = 49 marks)

Section C

Question Number	Acceptable Answers	Additional Guidance	Mark
16(a)	An answer that makes reference to the following points: • reaction of benzene with Br_2 and $FeBr_3$ / $AlBr_3$ **(1)** • reaction of bromobenzene with Mg **(1)** • in (dry) ether **(1)** • structure of Grignard reagent **(1)** • reaction of Grignard reagent with CO_2 / **(1)** • (hydrolysis of acid salt) with dilute HCl **(1)** Alternative route for M5 and M6 • reaction of Grignard reagent with HCHO **(1)** • (hydrolysis of acid salt) with dilute HCl **and** oxidation (of primary alcohol) with acidified $Cr_2O_7^{2-}$ **(1)**	See below for reaction scheme Ignore references to heating / refluxing throughout Allow Fe & Br_2 Allow other halogens and halides Allow aluminium halide 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) Allow any dilute acid / H^+ Ignore structure of salt Ignore H_2O	**(6)**

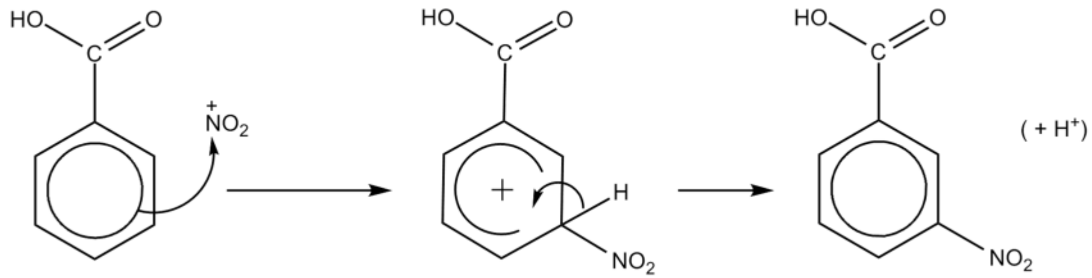


Allow CO_2 and HCl as parts 1 and 2 of the final step if clearly labelled e.g.



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

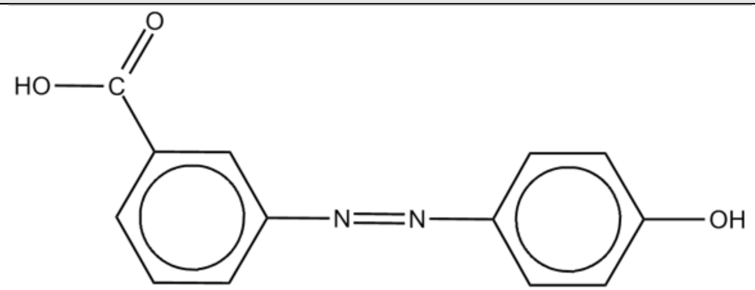
Example of mechanism for 16bi



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 Do not award other acids e.g. sulfuric acid Do not award $LiAlH_4$ Do not award Sn is a catalyst Do not award dilute HCl Do not award 'followed by NaOH' 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: • any temperature between 0°C and 10°C , inclusive **(1)** • to prevent formation of by-products / phenol (compounds) **(1)**	Mark independently Allow just 'less than 10°C' / 'below 5°C' 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 Allow reaction is too slow at temperatures below 0°C / low temperatures Do not award decomposition of $NaNO_2$ / nitro group	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
16(b)(iv)		Ignore additional products Ignore connectivity of -OH group Do not award if OH or COOH are at incorrect positions on ring Do not award carboxylate ion Do not award $-N_2-$ in between two rings 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)** • calculation of amount of $Pb(C_6H_5COO)_2$ **(1)** • deduction of amount of $Ca(C_6H_5COO)_2.xH_2O$ **(1)** • calculation of M_r of $Ca(C_6H_5COO)_2.xH_2O$ **(1)** • calculation of mass of water in M_r **(1)** • calculation of amount of water and hence x **(1)** **Alternative route for M4-M6** • calculation of mass of $Ca(C_6H_5COO)_2$ **(1)** • calculation of mass of water in hydrated sample **(1)** • calculation of amount of water and hence x **(1)**	<u>Example of calculation</u> 449.2 can be subsumed within M2 3.89 / 449.2 = 8.65984 x 10^{-3} (mol) 1:1 so 8.65984 x 10^{-3} (mol) M3 can be subsumed in M4 2.60 / 8.65984 x 10^{-3} = 300.24 300.24 – (40.1 + (14x12) + (1x10) + (4x16) = 18.14 18.14 ÷18 = 1, so x = 1 Allow TE throughout Correct value for x with no working scores M6 only 8.65984 x 10^{-3} x 282.1 = 2.44 g 2.60 – 2.44 = 0.16 g 0.16 ÷18 = 0.000889, so x = 1 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

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