Mark Scheme (Results)

October 2024

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

Section A

Question Number	Answer	Mark
1	**The only correct answer is B** ([Ar] $3d^5$ $4s^1$) ***A*** *is incorrect because it more stable for a 4s electron to occupy a 3d orbital to give a half-filled 3d subshell* ***C*** *is incorrect because this would result in repulsion from two electrons in the same 3d orbital* ***D*** *is incorrect because the 4p orbitals are much higher in energy than either the 3d or the 4s orbitals which are occupied preferentially*	**(1)**

Question Number	Answer	Mark
2	**The only correct answer is B** (Ni^{2+}) ***A*** *is incorrect because all the 3d orbitals are fully occupied in this ion* ***C*** *is incorrect because none of the 3d orbitals is occupied in this ion* ***D*** *is incorrect because all the 3d orbitals are fully occupied in this ion*	**(1)**

Question Number	Answer	Mark
3	**The only correct answer is C** (36.4 %) ***A*** *is incorrect because this is the percentage of only one chlorine in the complex ion* ***B*** *is incorrect because this is the percentage of two chlorines in the compound and not the complex ion* ***D*** *is incorrect because this is the total percentage of chlorine in the compound and not the complex ion*	**(1)**

Question Number	Answer	Mark
4(a)	**The only correct answer is C** (peroxodisulfate ions and iodide ions are both negatively charged) ***A*** *is incorrect because peroxodisulfate ions are strong oxidising agents* ***B*** *is incorrect because iodide ions are strong reducing agents* ***D*** *is incorrect because the stoichiometry of the reaction does not affect the activation energy*	**(1)**

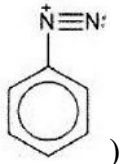
Question Number	Answer	Mark
4(b)	**The only correct answer is C** (the iron(II) ions can be easily oxidised and then reduced) ***A*** *is incorrect because the iron(II) ions are not reduced to iron* ***B*** *is incorrect because iron(II) ions are a homogenous catalyst* ***D*** *is incorrect because the iron(II) ions are oxidised and not reduced*	**(1)**

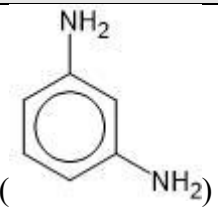
Question Number	Answer	Mark
5	**The only correct answer is D** (strong acid and strong alkali) ***A*** *is incorrect because chromium(III) hydroxide is insoluble in water* ***B*** *is incorrect because chromium(III) hydroxide also dissolves in strong alkalis* ***C*** *is incorrect because chromium(III) hydroxide also dissolves in strong acids*	**(1)**

Question Number	Answer	Mark
6(a)	**The only correct answer is A** (95.1 %) ***B*** *is incorrect because this is the value from dividing the masses* ***C*** *is incorrect because this is the value from dividing the two molar masses* ***D*** *is incorrect because this is the value from using the masses the wrong way round*	**(1)**

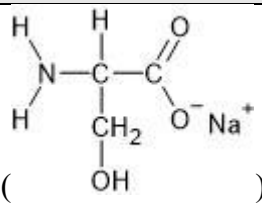
Question Number	Answer	Mark
6(b)	**The only correct answer is C** (the sample of 1-nitronaphthalene was damp) ***A*** *is incorrect because this would result in a yield below 100%* ***B*** *is incorrect because this is likely to give a yield below 100%* ***D*** *is incorrect because the presence of isomers would not result in a yield of more than 100%*	**(1)**

Question Number	Answer	Mark
7(a)	**The only correct answer is A** ($NaNO_2 + HCl \rightarrow HNO_2 + NaCl$) ***B*** *is incorrect because the equation shows the formation of nitric acid and not nitrous acid* ***C*** *is incorrect because nitrous acid is not formed from sodium nitrate and hydrochloric acid* ***D*** *is incorrect because sodium and chlorine are not produced in the reaction between sodium nitrite and hydrochloric acid*	**(1)**

Question Number	Answer	Mark
7(b)	**The only correct answer is D (**  **)** ***A*** *is incorrect because there should be a triple bond between the nitrogen atoms* ***B*** *is incorrect because there should be a triple bond between the nitrogen atoms* ***C*** *is incorrect because the positive charge is should be on the nitrogen bonded to the benzene ring*	**(1)**

Question Number	Answer	Mark
7(c)	**The only correct answer is A (**  **)** ***B*** *is incorrect because the phenol group would not be substituted in a coupling reaction* ***C*** *is incorrect because the amine group would not be substituted in a coupling reaction* ***D*** *is incorrect because two diazonium ions do not couple together to make an azo dye*	**(1)**

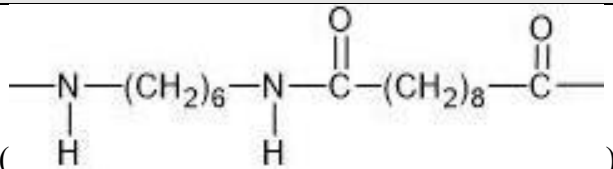
Question Number	Answer	Mark
8(a)	**The only correct answer is D** (2-amino-3-hydroxypropanoic acid) ***A*** *is incorrect because the longest consecutive chain of carbon atoms is three including the carboxy functional group which has priority in the name over the alcohol functional group* ***B*** *is incorrect because the longest consecutive chain of carbon atoms is three and the hydroxy group is not on carbon 1* ***C*** *is incorrect because the hydroxy group is on the third carbon of the chain*	**(1)**

Question Number	Answer	Mark
8(b)	 **The only correct answer is A** ( ) ***B*** *is incorrect because the alcohol group does not react with the sodium hydroxide* ***C*** *is incorrect because the amine group will not be protonated in sodium hydroxide solution* ***D*** *is incorrect because the alcohol group does not react with the sodium hydroxide and the amine group will not be protonated in sodium hydroxide solution*	**(1)**

Question Number	Answer	Mark
9	**The only correct answer is B** (62 %) ***A*** *is incorrect because this is the value calculated from an additional, incorrect hydrogen atom included on the propanone structure* ***C*** *is incorrect because this is the molar mass of phenol* ***D*** *is incorrect because this is the molar mass of phenol with an additional, incorrect hydrogen included*	**(1)**

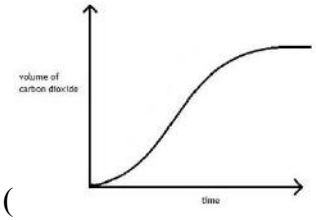
Question Number	Answer	Mark
10(a)	**The only correct answer is B** (all have similar lengths) ***A*** *is incorrect because aromatic systems have similar carbon-carbon bond lengths* ***C*** *is incorrect because aromatic systems have similar carbon-carbon bond lengths* ***D*** *is incorrect because aromatic systems have an intermediate bond length between that of a carbon-carbon double bond and a carbon-carbon single bond*	**(1)**

Question Number	Answer	Mark
10(b)	**The only correct answer is C** (p orbitals) ***A*** *is incorrect because the s orbitals are involved in the formation of sigma and not pi bonds* ***B*** *is incorrect because the aromatic pi bonds are not formed from the overlap of d orbitals* ***D*** *is incorrect because the aromatic pi bonds are not formed from the overlap of d orbitals*	**(1)**

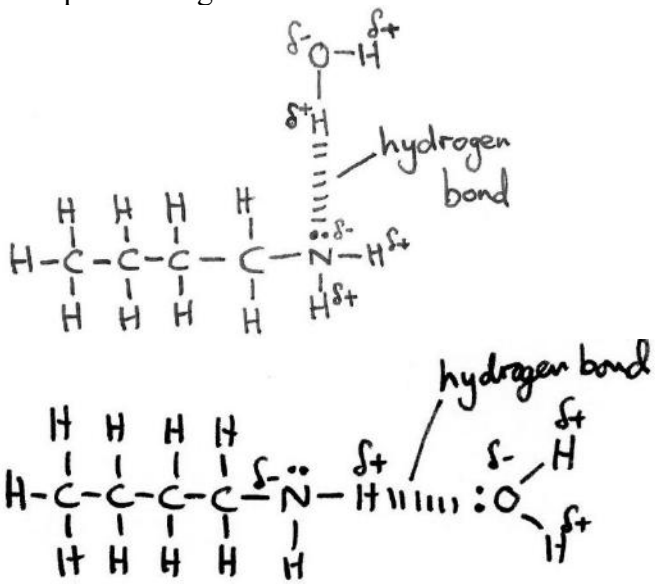
Question Number	Answer	Mark
11	**The only correct answer is D** () ***A*** *is incorrect because the repeat unit is for a nylon made from an amine with ten-carbons and an eight-carbon dicarboxylic acid* ***B*** *is incorrect because the repeat unit is for a nylon made from a twelve-carbon dicarboxylic acid* ***C*** *is incorrect because the repeat unit is for a nylon made from a ten-carbon diamine and a six-carbon dicarboxylic acid*	**(1)**

Question Number	Answer	Mark
12	**The only correct answer is B** (hydrogen bonds) ***A*** *is incorrect because it is possible for covalent bonds to be involved in adsorption* *C is incorrect because it is possible for London forces be involved in adsorption* ***D*** *is incorrect because it is possible for permanent dipole-induced dipole forces to be involved in adsorption*	**(1)**

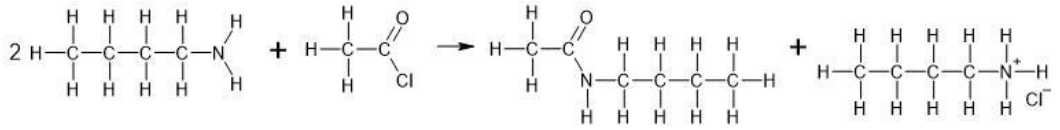
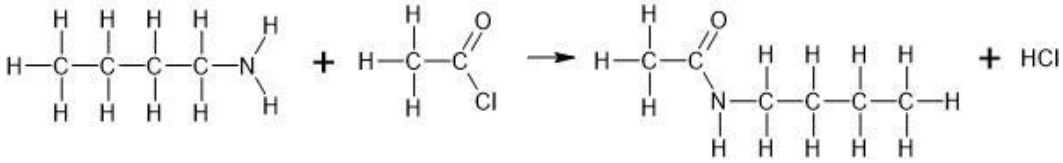
Question Number	Answer	Mark
13	**The only correct answer is D** ($V_2O_5 + SO_2 \rightarrow V_2O_4 + SO_3$ then $V_2O_4 + ½O_2 \rightarrow V_2O_5$) *A is incorrect because the catalyst reacts first with sulfur dioxide followed by oxygen and V_2O_6 does not exist* *B is incorrect because V_2O is not the intermediate formed in this reaction* *C is incorrect because the catalyst reacts first with sulfur dioxide followed by oxygen and VO_3 does not exist*	**(1)**

Question Number	Answer	Mark
14	**The only correct answer is D** () *A is incorrect because there is an initial slow rate before speeding up* *B is incorrect because there is an initial slow rate before speeding up* *C is incorrect because the rate slows as the reactant concentration decreases*	**(1)**

Section B

Question Number	Answer	Additional Guidance	Mark
15(a)	• diagram of hydrogen bond including lone pair (of electrons) **(1)** • dipoles on N, H and O **and** linearity about the central H of the hydrogen bond, e.g. **(1)** N: ···· H–O or O: ···· H–N	Examples of diagram  Allow butyl group C_4H_9 / R Allow dotted/dashed line without label in M1 Do not award M1 if the lone pair is not included in the hydrogen bond If multiple hydrogen bonds drawn then all have to be correct to score (2)	**(2)**

Question Number	Answer	Additional Guidance	Mark
15(b)	• calculation of moles of butylamine **(1)** • calculation of number of butylamine molecules **(1)**	<u>Example of calculation</u> n=(15 x 10^{-3} ÷ 73) = 2.0548 x 10^{-4} (mol) N=(2.0548 x 10^{-4} x 6.02 x 10^{23}) N= 1.2370 x 10^{20} Ignore SF except 1SF Correct answer without working scores (2) TE on incorrect molar mass value/ omission of x 10^{-3}/ TE on incorrect number of moles Allow (1) N= 9.03 x 10^{21} due to (15 x 10^{-3} x 6.02 x 10^{23})	**(2)**

Question Number	Answer	Additional Guidance	Mark
15(c)	• structure of N-butyl ethanamide **(1)** • rest of equation correct **(1)**	Example of equation  Allow  Allow the 'cis' orientation of the CONH group Ignore state symbols even if incorrect Ignore any attempts at mechanisms M2 dependent on M1 Allow (1) for non-displayed formulae of the organic molecules Allow (1) for equation with propanoyl chloride instead of ethanoyl chloride or propylamine instead of butylamine	**(2)**

Question Number	Answer	Additional Guidance	Mark
15(d)	An explanation that makes reference to the following points: • the nitrogen (atom) has a lone pair or acts as a base by accepting a proton **(1)** • (butylamine is a stronger base) because there is greater electron density on the nitrogen (atom) **(1)** • as a result of the butyl/alkyl group releasing electron density (to the nitrogen atom) **(1)**	Accept reverse arguments Allow butylamine accepts protons more readily Allow reference to NH_2 group for the nitrogen Ignore references to electronegativity Do not award the nitrogen is more negative Accept reference to the positive inductive effect of the alkyl group Allow reference to electron 'pushing' for releasing Allow reference to methyl group of butylamine being electron-releasing/donating Ignore references to the positive charge being more distributed for stability with butylamine	**(3)**

(Total for Question 15 = 9 marks)

Question Number	Answer	Additional Guidance	Mark
16		Example of calculation:	**(6)**
	• (**M1**) calculation of moles of manganate(VII) **(1)**	$n(MnO_4^-)$ =(0.0125 x 0.01620)= 2.025 x 10^{-4}/0.0002025 (mol)	
	• (**M2**) calculation of moles of iron(II) from titre **(1)**	$n(Fe^{2+})$ =(2.025 x 10^{-4} x 5=) 1.0125x 10^{-3} / 0.0010125 (mol)	
	• (**M3**) calculation of moles of iron(II) in flask **(1)**	$n(Fe^{2+})$ =(1.0125 x 10^{-3} x 4=) 4.05 x 10^{-3} / 0.00405 (mol)	
	Either		
	• (**M4**) calculation of mass of iron in g **(1)**	$m(Fe^{2+})$ =(4.05 x 10^{-3} x 55.8=) 0.22599 / 2.2599 x 10^{-1} (g)	
	(**M5**) calculation of mass of iron in mg in 25 cm^3 **(1)**	$m(Fe^{2+})$ =(0.22599 x 1000 =) 225.99 (mg)	
	• (**M6**) volume required for a 90 mg dose to 2/3 SF **(1)**	$V(Fe^{2+})$ = (90 ÷ 225.99 x 25 =) = 10 / 9.96 (cm^3)	
	Or		
	• (**M4**) conversion of mass to mg **(1)**	90 x 10^{-3} / 0.090 (g)	
	• (**M5**) calculation of moles of iron in advised dose **(1)**	$n(Fe^{2+})$ =(0.090 ÷ 55.8 =) 1.6129 x 10^{-3}/0.0016129 (mol)	
	• (**M6**) volume required for a 90 mg dose to 2/3 SF **(1)**	$V(Fe^{2+})$ =(0.0016129 ÷ 0.00405 x 25 =) 10 / 9.96 (cm^3)	
		Correct answer with some working scores (6) Ignore SF in M1 to M5 TE at each stage	
		Intermediate acceptable rounding gives 9.94 (cm^3) for (6) Use of Fe = 56 gives 9.92 (cm^3) for (6) Ignore any errors in units during calculation	

(Total for Question 16 = 6 marks)

<table>
<tr><th>Question Number</th><th>Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr>
<td>*17(a)</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>
</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 five 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 no marks for linkages).

In general it would be expected that
5 or 6 indicative points would get 2 reasoning marks
3 or 4 indicative points would get 1 reasoning mark
0, 1 or 2 indicative points would get zero reasoning marks

If there is any incorrect chemistry, deduct mark(s) from the reasoning. If no reasoning mark(s) awarded do not deduct mark(s).

Comment: Look for the indicative marking points first, then consider the mark for the structure of the answer and sustained line of reasoning
</td>
<td>(6)</td>
</tr>
</table>

	Answer has no linkages between points and is unstructured	0		
	Indicative content **IP1** description/diagram of standard hydrogen electrode with $H_2(g)$ and Pt **IP2** conditions of 1 atm **and** 1.0 mol dm^{-3} HCl((aq)) **and** 298 K/25°C **IP3** description of salt bridge using filter paper soaked in (saturated) $KNO_3(aq)$ **IP4** use of a 1.0 mol dm^{-3} named cobalt salt solution e.g. $Co(NO_3)_2(aq)$ **IP5** description of a cobalt electrode and (high resistance) voltmeter (with connecting wires) to complete the circuit **IP6** reference to how the data obtained in the experiment is used to determine the electrode potential of the cobalt(II)/cobalt electrode system		Allow IPs to be credited for labelled diagram Allow CO for Co Allow the electrodes to be on either side Allow H^+ for HCl Allow use of gel/agar with KNO_3 Allow use of other soluble compounds e.g. KCl Accept any soluble cobalt salt Allow reference to solution without aqueous Do not award cobalt hydroxide The circuit needs to be completed which requires a salt bridge but can just be a line for this IP Do not award this IP if solutions not shown or salt bridge not dipping into solutions Allow voltmeter reading = standard electrode potential for cobalt Allow reference to calculating $E^{\ominus}_{cell}$ If IP3 and IP4 not awarded then allow one IP if the salt bridge is not described but KNO_3 mentioned and 1.0 mol dm^{-3} Co^{2+} referred to without the salt Ignore references to cathode and anode/ positive and negative electrodes even if incorrect	

Question Number	Answer	Additional Guidance	Mark
17(b)	An explanation that makes reference to the following points: • (the oxidation of chloride to chlorine is) not (thermodynamically) feasible (under standard conditions) as $E^{\ominus}_{cell} = -0.03$ (V) (but only marginally) **(1)** • (however) using concentrated acid shifts the chlorine electrode system equilibrium (to the left) **and** reduces the chlorine electrode potential / reaction feasible or (however) the concentrated acid shifts the dichromate electrode system to the right **and** increases the dichromate electrode potential / reaction feasible or shifts the overall equation to the right **and** the $E^{\ominus}_{cell}$ value positive/reaction feasible **(1)** • (so) producing toxic chlorine (gas) **(1)**	Allow the chlorine electrode system is more electropositive than the dichromate so oxidation of chloride is not thermodynamically feasible Allow just not feasible as $E^{\ominus}_{cell} = -0.03$ (V) Two aspects required for M2: 1. Shift in equilibrium / reaction 2. Effect on the electrode potential/ $E^{\ominus}_{cell}$ Do not award if M2 reasoning is given with a statement that the E_{cell} becomes negative/not feasible Do not award M2 if one line of reasoning is correct but the other incorrect (+1 −1)	**(3)**

Question Number	Answer	Additional Guidance	Mark
17(c)	• reduction half-equation	Example of equation $VO_2^+ + 2H^+ + e^{(-)} \rightarrow VO^{2+} + H_2O$ Allow use of ⇌ Allow multiples Ignore state symbols even if incorrect Ignore species written above the arrow Do not award if oxidation half-equation unless the reduction half-equation is clearly identified	**(1)**

Question Number	Answer	Additional Guidance	Mark
17(d)(i)	• oxidation half-equation	Example of equation $CH_3OH + H_2O \rightarrow 6H^+ + CO_2 + 6e^{(-)}$ Allow use of ⇌ Allow multiples Ignore state symbols even if incorrect Allow $CH_3OH + 7H_2O \rightarrow 6H_3O^+ + CO_2 + 6e^{(-)}$	**(1)**

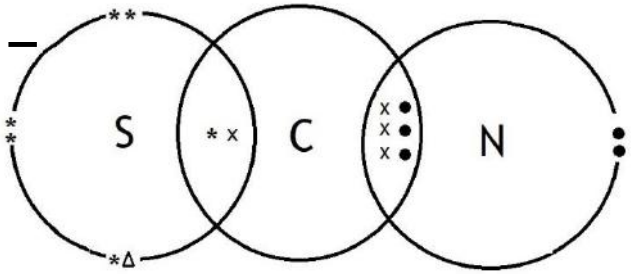
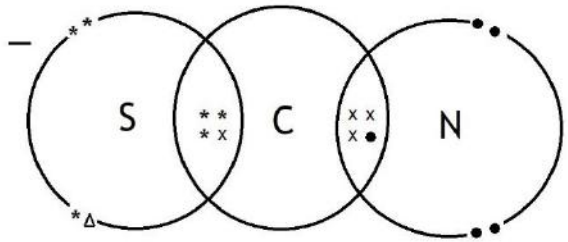
Question Number	Answer	Additional Guidance	Mark
17(d)(ii)	• overall equation	Example of equation: $CH_3OH + 1½O_2 \rightarrow CO_2 + 2H_2O$ Allow use of ⇌ Allow multiples/decimals/fractions Ignore state symbols even if incorrect No TE from part (i)	**(1)**

Question Number	Answer	Additional Guidance	Mark
17(d)(iii)	• calculation of concentration X	Example of calculation: c(X) = inverse ln (((1.20 – 1.23) ÷ 4.277 x 10^{-3})) = 8.9897 x 10^{-4} (mol dm^{-3}) Ignore SF except 1SF Do not award 9 x 10^{-4} Ignore any units given with the numerical value	**(1)**

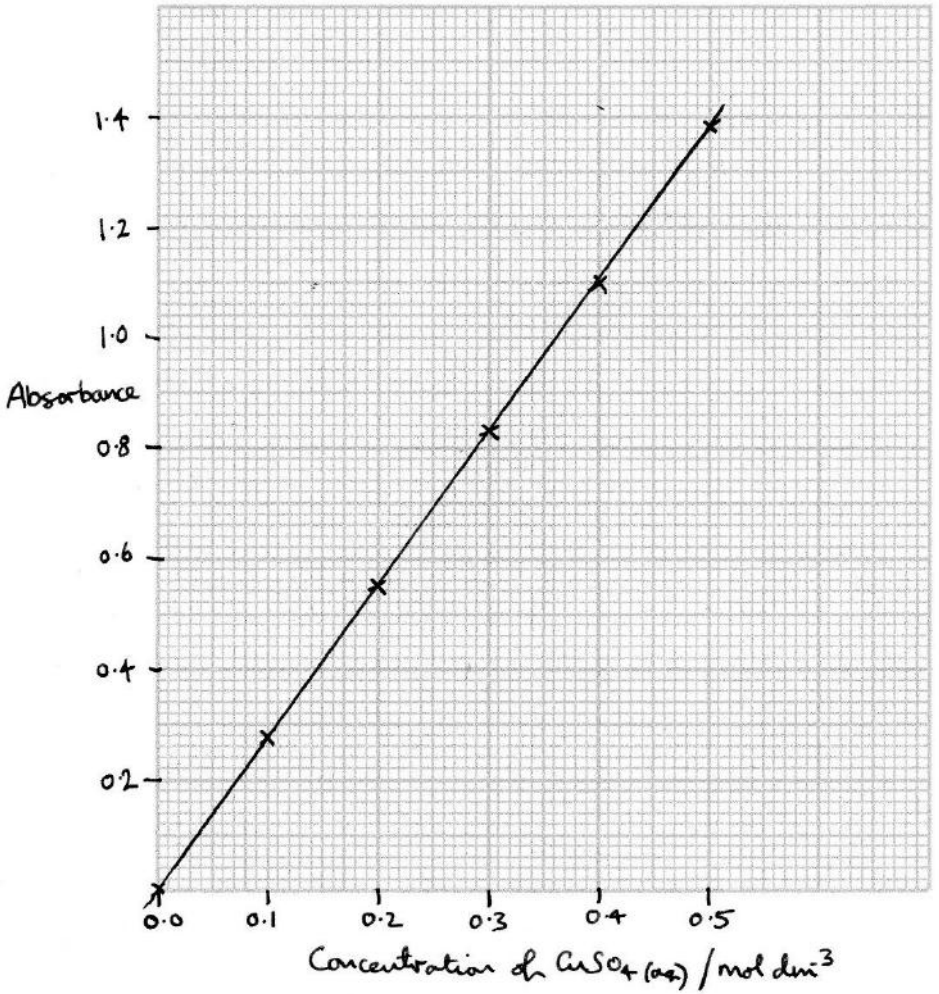
(Total for Question 17 = 13 marks)

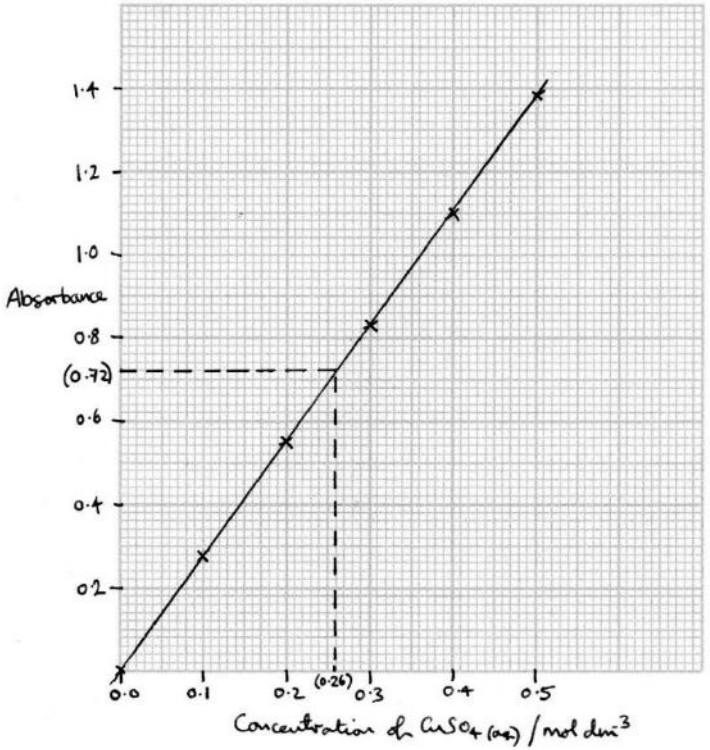
Question Number	Answer	Additional Guidance	Mark
18(a)(i)	An explanation that makes reference to the following points: • splitting in energy of d sub-shell/ d orbitals by water ligands **(1)** • absorption of light/photon/ (electromagnetic) radiation/energy **and** **electron**ic transition **(1)** • origin of observed colour of complex ion **(1)**	water/ligands **and** split the energy of the d-subshell/d-orbitals Do not award d orbital (singular) Allow degenerate d orbitals split into non-degenerate d orbitals by water ligands (visible) light/photon/(electromagnetic) radiation/energy is absorbed **and** promoting **electron**s from lower to higher energy Allow light etc causes d-d **electron** transitions Ignore colour absorbed Do not award reference to electron de-excitation colour due to reflected/transmitted light Allow due to wavelengths/frequencies of light that are not absorbed Allow complementary colour observed Do not award reference to emission/release of light	**(3)**

Question Number	Answer	Additional Guidance	Mark
18(a)(ii)	An answer that makes reference to two of the following points: • the oxidation number of the iron is different in the two complexes **(1)** • (which results in a) different energy gap (due to different splitting of d orbitals) **(1)** • (and so) different wavelength/frequency of light required/ absorbed (to promote electron(s)) **(1)**	Allow reference to the charge on the iron ion is different but ignore just stating formulae Allow reference to the number of d orbital electrons is different Ignore reference to just number of electrons unless qualified Ignore reference to splitting of a singular d orbital Do not award an energy gap between 4s and 3d Ignore references to detailed explanations of colours even if incorrect as this is addressed in (i) Ignore reference to energy Ignore just reflection of colour Penalise once only reference to different ligands	**(2)**

Question Number	Answer	Additional Guidance	Mark
18(b)(i)	• eight electrons around the S and the N using appropriate symbols with the triangle on the S **(1)** • eight electrons around the C using appropriate symbols **(1)**	Examples of diagram:  Allow one mark for a diagram with all dots/ all crosses/all triangles Accept the pairs to be vertical Allow electrons not in pairs Allow(2) for the alternative shown with two dative covalent bonds  	**(2)**

Question Number	Answer	Additional Guidance	Mark
18(b)(ii)	An answer that makes reference to the following points: • (formula) $[Fe(H_2O)_5SCN]^{2+}$ **(1)** (justification) • calculation of moles of Fe^{3+} and calculation of moles of SCN^- **(1)** • 1:1 ratio (indicates one thiocyanate ion in octahedral complex which has six ligands so gives 5 water molecules) **(1)**	Allow missing square brackets Ignore any drawing if formula given, even if incorrect $n(Fe^{3+}) = 0.0128 \times 0.05 = 6.4 \times 10^{-4} / 0.00064$ (mol) $n(SCN^-) = 0.008 \times 0.08 = 6.4 \times 10^{-4} / 0.00064$ (mol) Ignore SF Allow evidence of division to get a value of 1	**(3)**

Question Number	Answer	Additional Guidance	Mark
18(c)(i)	• labelled axes with unit **(1)** • all points plotted accurately **and** line of best fit including (0,0) **(1)** • scale to ensure points cover over half the graph paper in both directions **(1)**	Example of graph  	**(3)**

Question Number	Answer	Additional Guidance	Mark
18(c)(ii)	• use of graph to determine concentration from 0.72 absorbance **(1)** • calculation of original concentration **(1)**	Example of graph  Allow answers in the range from 0.255 – 0.265 (mol dm^{-3}) Do not award M1 if working absent from graph Scaling up from diluted concentration =0.26 x (250 ÷ 50) = 1.3 (mol dm^{-3}) Allow answers in the range 1.275 – 1.325 (mol dm^{-3}) from 0.255 – 0.265 Ignore SF except 1SF TE from incorrect graphical reading	**(2)**

Question Number	Answer	Additional Guidance	Mark
18(c)(iii)	An answer that makes reference to the following point • graph may not be linear above 0.50 mol dm^{-3} / unknown extrapolation above 0.50 mol dm^{-3}	Accept only values between 0 and 0.50 mol dm^{-3} are known Allow references to the limited solubility of copper(II) sulfate/solution may be saturated Allow absorbance is on a log scale and so absorbance above about 2 becomes hard to measure	**(1)**

Question Number	Answer	Additional Guidance	Mark
18(d)(i)	An answer that makes reference to the following point • increase in the number of moles **and** so a positive entropy (of the system)	Accept 4 moles to 7 moles for increase in the number of moles Allow particles for moles Allow positive total entropy/greater disorder Allow entropy increases Do not award references to endothermic/exothermic/enthalpy	**(1)**

Question Number	Answer	Additional Guidance	Mark
18(d)(ii)	An explanation that makes reference to two of the following points: • each nitrogen (atom) has one lone pair (of electrons) **(1)** • so both form dative covalent bonds/two dative bonds can form **(1)** • (and) the lone pairs of electrons being far enough apart **(1)**	Diagrams can give evidence for marking points Allow each ethane-1,2-diamine has two lone pairs (of electrons) Accept coordinate bonds for dative covalent bonds Do not award if carbon/CH_2 group forms dative bonds Allow reference to a four atom chain is the minimum (length) needed for a stable bidentate attachment to the central metal ion	**(2)**

Question Number	Answer	Additional Guidance	Mark
18(d)(iii)	An explanation that makes reference to the following points: • in ethane-1,2-diamine the angles are 107(°) because there are three bond pairs and one lone pair **(1)** • (because) in the complex ion the bond angle is 109.5(°) **(1)** • (the lone pair becomes a bonded pair with reduced repulsion and) therefore there are four pairs of bonded electrons around the nitrogen in the complex ion **(1)**	Standalone mark If no other mark awarded then award (1) for bond angle increases because lone pair now bonded	**(3)**

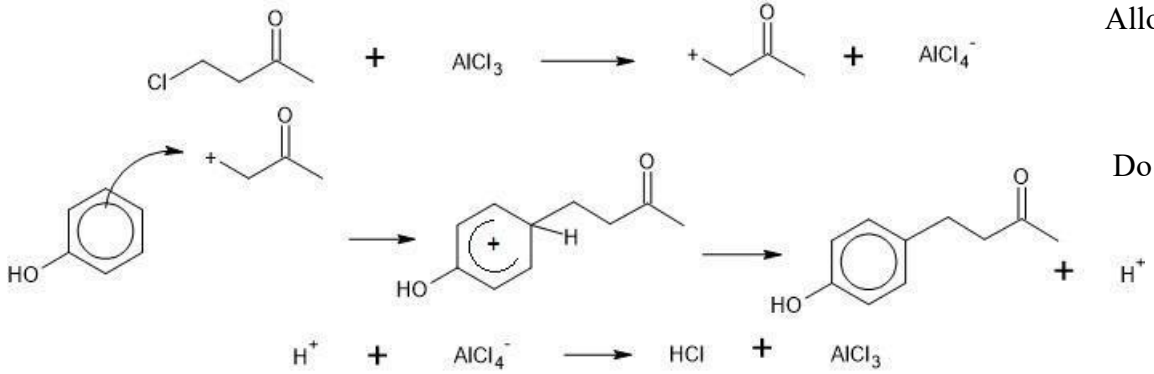
(Total for Question 18 = 22 marks)

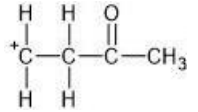
Section C

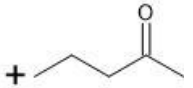
Question Number	Answer	Additional Guidance	Mark
19(a)	• C_5H_6O	Accept elements in any order Ignore $C_{10}H_{12}O_2$	**(1)**

Question Number	Answer	Additional Guidance	Mark
19(b)(i)	An answer that makes reference to the following points: • equation to show formation of electrophile using $AlCl_3$ **(1)** • curly arrow from anywhere on the central ring to positive 'end' carbon **(1)** • structure of intermediate **(1)** • curly arrow from C-H bond to reform the ring **(1)** • equation showing regeneration of catalyst **(1)**	Allow other halogen carriers such as $AlBr_3$ $FeBr_3$/ Fe with excess Br_2 Allow curly arrow from anywhere **within** the hexagon No TE on incorrect neutral species from equation 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 incorrect connectivity of OH Regeneration can be shown by curly arrow to the H being lost from the ring	**(5)**

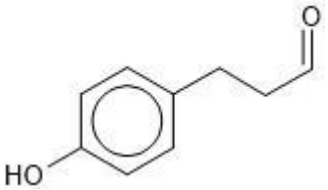
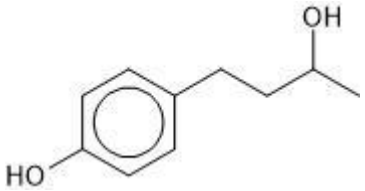
Example of mechanism for 19(b)(i)



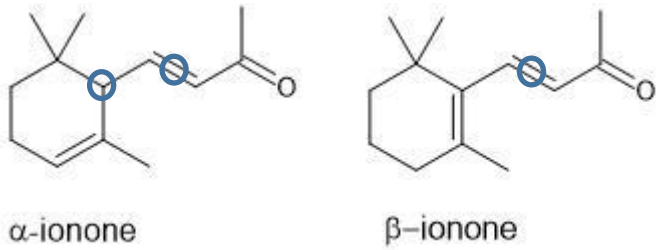
Allow displayed/semi-displayed formulae, e.g. 

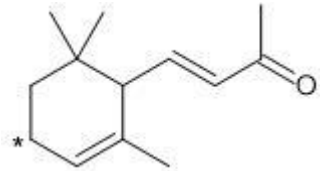
Do not award bond to + of electrophile, e.g. 

Question Number	Answer	Additional Guidance	Mark
19(b)(ii)	An answer that makes reference to the following point • substitution can occur at other positions (of the benzene/aromatic ring)	Allow drawn structures of substitution at other positions of benzene ring Allow multiple/further substitutions Allow other isomers are made Ignore just other substances/side products Do not allow references to addition	**(1)**

Question Number	Answer		Additional Guidance	Mark
19(c)	An answer that makes reference to the following points:		Ignore references to temperature throughout Ignore connectivity of the OH but penalise the positions of the side chains once only in M2 or M6	**(7)**
	• (**M1**) oxidation with $K_2Cr_2O_7$ / $Na_2Cr_2O_7$ with H_2SO_4 **and** a limited amount of oxidising agent	**(1)**	Allow $Cr_2O_7^{2-}/H^+$ here and in M7 Penalise use of HCl once only Allow distillation Do not award reference to reflux	
	• (**M2**) structure of aldehyde intermediate	**(1)**		
	• (**M3**) reaction of bromomethane with magnesium in (dry) ether	**(1)**	Allow use of chloromethane/ iodomethane	
	• (**M4**) structure of Grignard reagent	**(1)**	CH_3MgBr	
	• (**M5**) reaction of aldehyde intermediate with Grignard reagent **and** then hydrolysis using dilute acid	**(1)**	Allow any dilute acid / H^+ which can be shown above an arrow Ignore any structure drawn before hydrolysis even if incorrect Do not award use of concentrated acid	
	• (**M6**) structure of alcohol intermediate	**(1)**		
	• (**M7**) oxidation with $K_2Cr_2O_7$ / $Na_2Cr_2O_7$ with H_2SO_4 (reflux)	**(1)**	Allow use of $KMnO_4$ with acid or base	

Question Number	Answer	Additional Guidance	Mark
19(d)	An answer that makes reference to the following point • avoid reduction of the ketone (functional group)	Allow targets **only** the alkene/C=C group Allow avoid benzene ring/carbonyl reduction Allow benzene ring/carbonyl may be reduced Ignore vague references to other products Do not award if incorrect products stated Do not award incorrect identification e.g. aldehyde	**(1)**

Question Number	Answer	Additional Guidance	Mark
19(e)(i)	An answer that makes reference to the following points: (similarity) • both are the *E*—stereoisomer (of the straight chain C=C) **(1)** (difference) • only the α-ionone exhibits optical isomerism **(1)** • labelling of the chiral carbon on α-ionone and the labelling of carbon-carbon double bond **(1)**	Allow trans for *E* Allow both can form geometric/ *E*−*Z* isomers Do not award if only the ring C=C bonds is indicated Accept has optical isomers or enantiomers Allow has a chiral carbon/centre/asymmetric carbon  α-ionone β–ionone Do not award if the alicyclic ring C=C is circled	**(3)**

Question Number	Answer	Additional Guidance	Mark
19(e)(ii)	An answer that makes reference to the following point • asterisk on the quartet carbon	 Allow any suitable label for the asterisk Do not award if more than one carbon indicated	**(1)**

Question Number	Answer	Additional Guidance	Mark
19(e)(iii)	An answer that makes reference to the following points • 12/twelve **and** because the two methyl group carbon atoms are equivalent	Allow because there are 12 carbon environments/ two carbon (atoms) have the same environment Allow annotations on the structure such as both of the methyl groups given the same number or both circled	**(1)**

(Total for Question 19 = 20 marks)