Pearson Edexcel

Mark Scheme (Results)

Summer 2021

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	Answer	Mark
1	**The only correct answer is D**(VO_2^+ and VO^{2+}) ***A****is not correct because both Cr have the oxidation number +6* ***B*** *is not correct because both Cr have the oxidation number +6* ***C*** *is not correct because both V have the oxidation number +5*	**1**

Question number	Answer	Mark
2(a)	**The only correct answer is B**(−1.63 V) ***A*** *is not correct because the electrode potential for the Fe^{3+}/Fe^{2+} electrode system has been added to the E^o_{cell} value instead of being subtracted* ***C*** *is not correct because the value should have a negative sign* ***D*** *is not correct because the value should have a negative sign and the electrode potential for the Fe^{3+}/Fe^{2+} electrode system has been added to the E^o_{cell} value instead of being subtracted*	**1**

Question number	Answer	Mark
2(b)	**The only correct answer is C** (platinum and titanium) ***A*** *is not correct because the $Fe^{3+}\|Fe^{2+}$ electrode system requires a platinum electrode* ***B*** *is not correct because the $Fe^{3+}\|Fe^{2+}$ electrode system requires a platinum electrode and the $Ti^{2+}\|Ti$ electrode system requires a titanium electrode.* ***D*** *is not correct because the $Ti^{2+}\|Ti$electrode system requires a titanium electrode.*	**1**

Question number	Answer	Mark
2(c)	**The only correct answer is C** (2 mol dm^{-3} and 1 mol dm^{-3}) ***A*** *is not correct because the cell solution must be 1 mol dm^{-3} with respect to both Fe^{2+} and Fe^{3+} therefore the dilution on mixing and the two Fe^{3+} ions in each iron(III) sulfate must be taken into account* ***B*** *is not correct because the cell solution must be 1 mol dm^{-3} with respect to both Fe^{2+} and Fe^{3+} therefore the dilution on mixing and the two Fe^{3+} ions in each iron(III) sulfate must be taken into account* ***D*** *is not correct because the cell solution must be 1 mol dm^{-3} with respect to both Fe^{2+} and Fe^{3+} therefore the dilution on mixing and the two Fe^{3+} ions in each iron(III) sulfate must be taken into account*	**1**

Question number	Answer	Mark
3	**The only correct answer is A** (Ar)  ***B*** *is not correct because the most stable electronic configuration is with all six electrons unpaired in two half-filled subshells* ***C****is not correct because the most stable electronic configuration is with all six electrons unpaired in two half-filled subshells* ***D****is not correct because the most stable electronic configuration is with all six electrons unpaired in two half-filled subshells*	**1**

Question number	Answer	Mark
4	**The only correct answer is A** n(electron-pair donor) ***B****is not correct because ligands do not need to be negatively charged* ***C****is not correct because ligands are not electron pair acceptors* ***D****is not correct because ligands are not electron pair acceptors and do not need to be negatively charged*	**1**

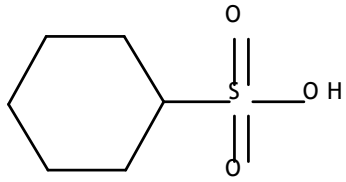
Question number	Answer	Mark
5	**The only correct answer is C** (d—d transitions are not possible because the d orbitals are fully occupied) ***A*** *is not correct because the d orbitals in copper(I) can be split* ***B*** *is not correct because no d—d transitions occur* ***D*** *is not correct because the ease of oxidation of an ion does not affect the colour of its complex*	**1**

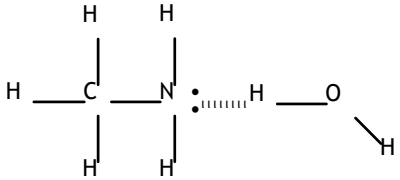
Question number	Answer	Mark
6	**The only correct answer is B**(type of ligand is bidentate; coordination number of copper(II) is 6) ***A*** *is not correct because3 is the number of ligands not the* coordination number ***C*** *is not correct because the ligand is bidentate and 3 is the number of ligands* ***D*** *is not correct because the ligand is bidentate*	**1**

Question number	Answer	Mark
7	**The only correct answer is D**(*green precipitate and precipitate turns brown*) ***A*** *is not correct because* $Fe(OH)_2$ *is green (initially)* ***B*** *is not correct because he precipitate turns brown on standing* ***C*** *is not correct because* $Fe(OH)_2$ *is green (initially)*	**1**

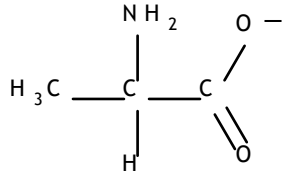
Question number	Answer	Mark
8	**The only correct answer is A** (deprotonation and ligand exchange) ***B*** *is not correct because the formation of the ammine complex involves ligand exchange* ***C*** *is not correct because the formation of the precipitate involves deprotonation of water ligands and the formation of the ammine complex involves ligand exchange* ***D*** *is not correct because the formation of the precipitate involves deprotonation of water ligands*	**1**

Question number	Answer	Mark
9	**The only correct answer is C**(four) ***A*** *is not correct because this omits two isomers* ***B*** *is not correct because in the Kekulé structure1,2-dichlorobenzene has two isomers, one with the carbon atoms carrying the chlorines joined by a single bond and the other with them joined by a double bond* ***D*** *is not correct because this overlooks the fact that the 1,3 and 1,5 structures are identical*	**1**

Question number	Answer	Mark
10	**The only correct answer is D**  ***A*** *is not correct because the substituent is SO_3H* ***B*** *is not correct because the substituent is SO_3H with a C—S bond* ***C*** *is not correct because the substituent is SO_3H*	**1**

Question number	Answer	Mark
11	**The only correct answer is B**  ***A*** *is not correct because the N----H—O bond angle should be 180°* ***C*** *is not correct because hydrogen atoms bonded to carbon atoms cannot form hydrogen bonds* ***D*** *is not correct because hydrogen atoms bonded to carbon atoms cannot form hydrogen bonds*	**1**

Question number	Answer	Mark
12	**The only correct answer is A** (amides) ***B*** *is not correct because amino acids combine to form polypeptides and proteins, which are polyamides* ***C*** *is not correct because diacyl chlorides combine with diamines to form polyamides* ***D*** *is not correct because diamines combine with diacyl chlorides to form polyamides*	**1**

Question number	Answer	Mark
13(a)	**The only correct answer is B**  ***A*** *is not correct because this structure is only possible near neutral pH* ***C*** *is not correct because this structure is formed at low pH* ***D*** *is not correct because this structure dominates at neutral pH*	**1**

Question number	Answer	Mark
13(b)	**The only correct answer is D** (ionic bonds) ***A*** *is not correct because van der Waals forces are the weakest forces broken* ***B*** *is not correct because hydrogen bonds are weaker than ionic bonds* ***C*** *is not correct because* covalent bonds are not broken when amino acids melt	**1**

Question number	Answer	Mark
14	**The only correct answer is D** (P is due to C—H aldehyde and Q is due to C=O aldehyde) ***A*** *is not correct because P is too sharp to be an OH stretch and Q is outside the region of 1725-1700 cm^{-1} for a carboxylic acid C=O stretch* ***B*** *is not correct because P is too sharp to be an OH stretch* ***C*** *is not correct because Q is outside the region of 1725-1700 cm^{-1} for a carboxylic acid C=O stretch*	**1**

Question number	Answer	Mark
15	**The only correct answer is C**(five) **A** *is not correct because the C atoms in methylcyclohexane are not all equivalent* ***B*** *is not correct because there are five types of C atom in methylcyclohexane not three* ***D*** *is not correct because the C atoms in methylcyclohexane are not all different*	**1**

Question number	Answer	Mark
16	**The only correct answer is A**(one singlet, one doublet and a heptet) ***B*** *is not correct because this ignores the fact that the proton environments on C1 and C3 are the same* ***C*** *is not correct because this is the number of protons in each environment, not the splitting pattern* ***D*** *is not correct because this ignores all the splitting except the effect of one methyl on the C2 proton*	**1**

Question number	Answer	Mark
17	**The only correct answer isB** (8.4 dm^3) ***A*** *is not correct because the number of oxygen atoms in the compound has been doubled* ***C*** *is not correct because the oxygen atoms in the compound have been omitted from the calculation* ***D*** *is not correct because the oxygen atoms in the compound have been omitted from the calculation and one oxygen molecule has been allowed for the combustion of each pair of hydrogen atoms*	**1**

Total for Section A = 20 marks

Section B

Question number	Answer	Additional guidance	Mark
18(a)(i)	• selection of the correct half-equations from the table (1) • writing the balanced equation (1)	[1] $MnO_4^- + e^- \rightleftharpoons MnO_4^{2-}$ **and** [7] $MnO_4^{2-} + 4H^+ + 2e^- \rightleftharpoons MnO_2 + 2H_2O$ $3MnO_4^{2-} + 4H^+ \rightleftharpoons 2MnO_4^- + MnO_2 + 2H_2O$ Allow [1] $MnO_4^- + e^- \rightleftharpoons MnO_4^{2-}$ **and** [5] $MnO_4^- + 8H^+ + 5e^- \rightleftharpoons Mn^{2+} + 4H_2O$ which gives $5MnO_4^{2-} + 8H^+ \rightleftharpoons 4MnO_4^- + Mn^{2+} + 4H_2O$ Accept e for e^- in half equations Correct equation scores (2) marks Unbalanced equation with all species correct scores (1) Use of alkaline half-equation to give $3MnO_4^{2-} + 2H_2O \rightleftharpoons 2MnO_4^- + MnO_2 + 4OH^-$ scores (1) mark Ignore state symbols even if incorrect	**2**

Question number	Answer	Additional guidance	Mark
18(a)(ii)	• selection of appropriate values and insertion in the correct equation (1) • completion of calculation **and** evaluation of the feasibility of the reaction (1)	E^{o}_{cell} = 2.26 − 0.56 = (+)1.70 (V) **and** (positive so reaction is) feasible Accept (if second equation given) E^{o}_{cell} = 1.51 − 0.56 = (+)0.95 (V) **and** (positive so reaction is) feasible TE on alkaline disproportionation E^{o}_{cell} = 0.59 − 0.56 = (+)0.03 (V) **and** (positive so reaction is) feasible scores (2) TE on equations used the wrong way round −1.70 / −0.95(V) and not feasible scores (1) Just (+)1.70 (V) / (+)0.95 (V) scores (1) Do not award a non-disproportionation reaction	**2**

Question number	Answer	Additional guidance	Mark
18(a)(iii)	**For M1 and M2Either** • equation for the reaction (1)	$2MnO_4^- + MnO_2 + 4OH^- \rightleftharpoons 3MnO_4^{2-} + 2H_2O$ Allow → for ⇌ Or $E^o_{cell} = 0.56 - 0.59$	**4**
	• calculation of negative E^o_{cell} for the equation (1)	$E^o_{cell} = -0.03$ (V)	
	Or	Reverse reaction **and** $E^o_{cell} = (+)0.03$ (V) (1)	
	• clear identification of the appropriate half-equations from the table (1)	Equations 1 and 2	
	• use of anticlockwise rule or similar to show that required reaction is not favoured (1)	Desired reaction moves 'clockwise' so not (thermodynamically) feasible Allow calculation of E^o_{cell} as above	
	For M3 and M4 • statement that the standard electrode potential values are close (1)	(−)0.03 (V) /$E^o_{cell}$is a (very) small Or equilibrium has significant concentrations of the reactants and products Allow if $E^o_{cell} = (+)0.03$ (V) in M2 Standalone mark	
	• reaction may be shifted in the required direction using **concentrated** alkali (1)	Allow by increasing alkali concentration No TE on incorrect system Ignore just 'by changing concentrations' references to rate and temperature Ignore state symbols even if incorrect	

Question number	Answer	Additional guidance	Mark
18(b)(i)	• colourless **and** to pale pink	Allow pale green for colourless Do not award just ‘green’ for the start colour Accept pink Do not award purple / magenta Ignore ‘clear’ Ignore ‘permanent’	1

Question number	Answer	Additional guidance	Mark
18(b)(ii)	• calculation of moles of manganate(VII) in 27.35 cm^3 (1) • use of 1:5 ratio to calculate mol Fe^{2+} in 25.0 cm^3 (1) • scaling to 250.0 $cm^3$to give mol Fe^{2+} in 250.0 cm^3 (1) • conversion of mol to g of iron (1) • calculation of percentage of iron in the wire **and** gives the final value to 3 SF (1)	Example of calculation 27.35 x 0.0195 x 10^{-3} = 5.33325 x 10^{-4}/ 0.000533325 (mol) 5 x 5.33325 x 10^{-4} = 2.666625 x 10^{-3} /0.002666625 (mol) 10 x 2.666625 x 10^{-3} = 2.666625 x 10^{-2}/ 0.02666625mol) 2.666625 x 10^{-2} x 55.8 = 1.48798 (g) 100 x 1.48798/1.53 = 97.25338 = 97.3% If A_r (Fe) = 56 is used mass = 1.49331 (g) % iron = 97.6% Allow 100 x 1.49/1.53 =97.4% Correct answer to 3 SF and some working scores (5) TE at each stage Ignore premature rounding if final answer correct otherwise allow rounding to at least 3SF	**5**

Question number	Answer	Additional guidance	Mark
18(b)(iii)	An explanation that makes reference to the following • brown suspension formed is manganese(IV) oxide / MnO_2 (1) • $Mn(VII)$ to $Mn(II)$ provides 5 electrons per MnO_4^- but $Mn(VII)$ to $Mn(IV)$ only provides 3 electrons (1) • so more MnO_4^- is needed / titre is greater (1)	Reference to half-equations 6 & 7 in the table Allow manganese(IV) oxide / MnO_2formed (in alkaline conditions) Accept explanation in terms of oxidation numbers Standalone mark If no other mark is scored, allow one mark for the titration is no longer quantitative as another reaction is (also) taking place.	3

Question number	Answer	Additional guidance	Mark
18(c)(i)	(Balance: $\frac{100 \times 0.005 \times 2}{1.53}$ = 0.65) • burette: $\frac{100 \times 0.05 \times 2}{27.35}$ = 0.37(%) • pipette: $\frac{100 \times 0.06}{25}$ = 0.24(%) • volumetric flask: $\frac{100 \times 0.3}{250}$ = 0.12(%) (Total = 1.38) (2)	All three percentages correct scores (2) Any two percentages correct scores (1) IGNORE SF	**2**

Question number	Answer	Additional guidance	Mark
18(c)(ii)	An explanation that makes reference to • total percentage uncertainty is (approximately) 1.38% (1) • because the total percentage uncertainty is much bigger than 0.863, the answer should be to no more than 2 / 3 SF(1)	TE on 18(c)(i) Allow 1.4% / 2 SF Accept % correction of rounding 95.863 to 95.9 = 100 x 0.037 ÷ 95.863 = 0.039 % **and** negligible compared with 1,38% Ignore 'data given to 3SF'	**2**

(Total for Question 18 = 21 marks)

Question number	Answer	Additional guidance	Mark
19(a)(i)	• Amine	Allow amino Ignore classification such as ‘tertiary’ Ignore NH_2 Do not award ammine	1

Question number	Answer	Additional guidance	Mark
19(a)(ii)	Method 1 • rewrite the Ideal Gas Equation in terms of mass and molar mass(1) • change the subject of the equation (1) • change volume to m^3 **and** temperature to K(1) • calculation of molar mass (1)	Example of calculation $PV = \frac{m}{M_r}RT$ $M_r = mRT/PV$ 157 cm^3 = 1.57 x 10^{-4} / 0.000157 m^3 Allow conversion to kPa & vol to dm^3 15°C = 288 K $M_r = \frac{0.493 \times 8.31 \times 288}{103000 \times 1.57 \times 10^{-4}}$ = 72.963 = 73.0 / 73 (g mol^{-1})	**4**

	• Method 2 • Change subject of equation (1) • change volume to m^3 **and** temperature to K (1) • evaluate n (1) • calculation of molar mass (1)		$n = PV/RT$ 157 cm^3 = 1.57 x 10^{-4} / 0.000157 m^3 Allow conversion to kPa & vol to dm^3 n = (103000 x 1.57 x 10^{-4}) ÷ (8.31 x 288) = 6.7568 x 10^{-3} M_r = 0.493 ÷ 6.7568 x 10^{-3} = 72.963 = 73 (g mol^{-1}) Ignore just 'g' do not award 72.9 (g mol^{-1}) if rounded from 72.963 Correct answer with some working scores (4) Correct answer with no working scores zero Use of molar volume = 24000 cm^3 gives n = 6.542 x 10^{-3} from which M_r = 0.493 ÷ 6.542 x 10^{-3} = 75.363 scores M4 Ignore premature rounding if final answer correct otherwise allow rounding to at least 3SF Ignore SF except 1 SF in final answer	

Question number	Answer	Additional guidance	Mark
19(b)(i)	• hydrogen chloride / HCl	Allow hydrochloric acid / HCl(aq)	1

Question number	Answer	Additional guidance	Mark
19(b)(ii)	• N-substituted amide / -CONHR	Accept amide / acid amide / -$CONH_2$ / -CONH- If name and formula are given, both must be correct	1

Question number	Answer	Additional guidance	Mark
19(b)(iii)	• conversion of percentages by mass into moles (1) • evaluation of moles **and**division by the smallest value to give a ratio (1) • conversion of ratio into an empirical formula (1)	Example of calculation C: % 62.6; mol 62.6/12 (=5.2167); Ratio 6.00 H: % 11.3; mol 11.3/1 (=11.3); Ratio 13.01 N: % 12.2; mol 12.2/14 (= 0.8714); Ratio 1.00 O: % 13.9; mol 13.9/16 =0.86875; Ratio 1.00 $C_6H_{13}NO$ Correct answer with no working scores (1) Ignore SF except 1 SF in mol calculation	3

<table>
<tr><th>Question number</th><th>Answer</th><th>Additional guidance</th><th>Mark</th></tr>
<tr>
<td>*19(c)</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><td>Number of indicative marking</td><td>Number of marks awarded for</td></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><td></td><td>Number of marks awarded for structure of answer and sustained lines of reasoning</td></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.

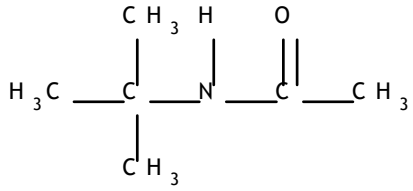
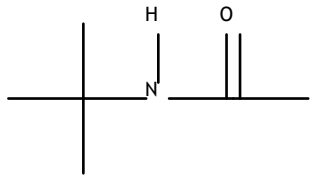
The mark for indicative content should be added to the mark for lines of reasoning. For example, a response with five indicative marking points that is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning).

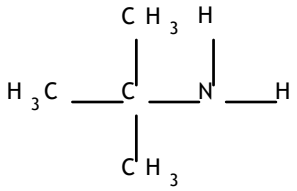
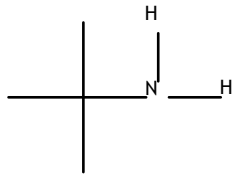
If there were no linkages between the points, then the same indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages).

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 0 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></td>
</tr>
</table>

Question number	Answer	Additional guidance	Mark
***19(c) cont**	Indicative points • **IP1** three peaks indicates three proton environments • **IP2** no splitting shows no proton environment is adjacent to another • **IP3** chemical shift = 7 (ppm) indicates N—**H** proton • **IP4** nine protons in one environment and no coupling indicates $(CH_3)_3C$— • **IP5** chemical shift = 2 (ppm) indicates C**H**$_3$C=O protons • **IP6** structure is 	Marks may be awarded for **IP**s annotated on the NMR or on the structure Allow three types of proton / hydrogen Allow 'peaks have one split' Accept $CH_3C=O$ indicated by amide responsible for the peak at 2 (ppm) Allow $CH_3C=O$ indicated by reaction with ethanoyl chloride Allow displayed, structural or skeletal formulae or any combination of these e.g. 	**6**

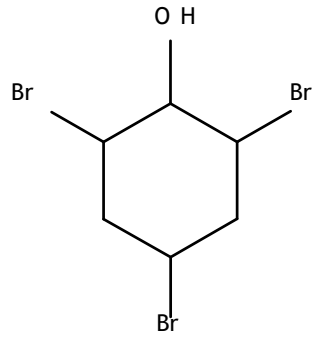
Question number	Answer	Additional guidance	Mark
19(d)		Allow displayed, structural or skeletal formulae or any combination of these e.g.  Allow TE on the amide in 19(c)providing **X** is shown as an amine	1

(Total for Question 19 = 17 marks)

Question number	Answer	Additional guidance	Mark
20(a)(i)	• calculation of the difference between the enthalpies of combustion of cyclohexene and cyclohexa-1,4-diene (1) • subtraction of the calculated difference from the enthalpy of combustion of cyclohexa-1,4-diene to give the enthalpy of combustion of cyclohexa-1,3,5-triene (1)	Example of calculation $-3752 - (-3584) = -168$ (kJ mol^{-1}) Ignore sign of 168 $-3584 - (-168) = -3416$ (kJ mol^{-1}) OR $-3752 - 2 \times (-168) = -3416$ (kJ mol^{-1}) TE on numerical errors in M1 Correct answer with some working scores (2)	**2**

Question number	Answer	Additional guidance	Mark
20(a)(ii)	An explanation that makes reference to • calculation of the difference between the enthalpies of combustion of benzene and cyclohexa-1,3,5-triene (1)	−3416 − (−3267) = −149 (kJ mol^{-1}) TE on value calculated in (a)(i) Ignore omission of negative sign	**3**
	• benzene **more** stable than cyclohexa-1,3,5-triene by 149 (kJ mol^{-1}) (1)	Allow enthalpy of combustion of benzene less negative / less exothermic /lower than that of cyclohexa-1,3,5-triene **and** so benzene is more stable If M1 is scored Allow just 'benzene **more** stable than cyclohexa-1,3,5-triene' Allow reverse arguments Do not award M2 if the enthalpy of combustion of benzene is more negative than that calculated for cyclohexa-1,3,5-triene	
	• (benzene **more** stable)because the π electrons in benzene are delocalised (1)	Allow benzene has delocalisation energy / resonance stability /bonds delocalised Ignore 'bonds all the same length' standalone mark	

Question number	Answer	Additional guidance	Mark
20(b)	An answer that makes reference to **four** of the following: Similarities • **both** reactions involve electrophilic attack (1) • **both** reactions form a carbocation (1) Differences • reaction with benzene is substitution (because the stable benzene ring is retained / restored) (1) • reaction with cyclohexene is addition (because σ bonds stronger than π bonds) (1) • reaction with benzene requires a catalyst (and heat) **and** whereas reaction with cyclohexene occurs under normal laboratory conditions (1)	Allow just electrophilic This may be shown using a **labelled** diagram Allow addition and substitution marks even if incorrectly described e.g. nucleophilic Allow cyclohexene reaction does not require catalyst / heat Allow cyclohexene reacts with bromine water Do not award if conditions are incorrect e.g. cyclohexene reaction requires heat	**4**

Question number	Answer	Additional guidance	Mark
20(c)(i)	• 2,4,6-tribromophenol OR  	If name and formula are given both must be correct Accept Kekulé structure Allow Correct structure and tribromophenol Ignore punctuation errors in the name such as omission of commas or hyphen and inclusion of spaces	**1**

Question number	Answer	Additional guidance	Mark
20(c)(ii)	An explanation that makes reference to • lone pair of electrons on the oxygen (1) • overlap / interact with the π electrons of the ring **and** increasing its electron density / becomes more susceptible to electrophilic attack (1)	Allow lone pair of electrons on the OH Allow (lone pair) donated to the π electrons of the ring Ignore increasing the reactivity of the ring Ignore reference to phenol being a nucleophile	**2**

(Total for Question 20 = 12 marks)

Total for Section B = 50 marks

Section C

Question number	Answer	Additional guidance	Mark
21(a)	An explanation that makes reference to the following points • the electronic structure of Fe(II) is [Ar]$3d^6$ and Fe(III) is [Ar]$3d^5$ (1) • $3d^5$ is more stable than $3d^6$ because the $3d^6$ subshell has two paired electrons which results in repulsion /pairing of electrons is (energetically) less favourable (1)	Ar may be given as $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$ Allow just Fe(II) is $3d^6$ and Fe(III) is $3d^5$ Allow half-filled subshell is more stable Allow 1 electron in each orbital is stable If no other mark is scored, just 'Fe(III) has a half-filled 3d subshell scores (1) Allow use of 'orbital' or '(quantum) shell' for subshell	**2**

Question number	Answer	Additional guidance	Mark
21(b)(i)	• $Fe^{2+}(g) \rightarrow Fe^{3+}(g) + e^{(-)}$	Allow $Fe^{2+}(g) - e^{(-)} \rightarrow Fe^{3+}(g)$ Accepte$^{(-)}$(g)	**1**

Question number	Answer	Additional guidance	Mark
21(b)(ii)	An answer that makes reference to the following points **M1** • conversion of iron(II) / Fe^{2+} to iron(III)/ Fe^{3+} requires 2958 kJ mol^{-1} OR conversion of iron(II) / Fe^{2+} to iron(III)/ Fe^{3+} requires (large amounts of) energy OR conversion of iron(II) / Fe^{2+} to iron(III)/ Fe^{3+} is (very) endothermic (1) **M2** • this energy is recovered by hydration (which is exothermic) (1) **M3** • the hydration of iron(III) / Fe^{3+} is more exothermic than iron(II) / Fe^{2+} **and** because the iron(III) has a greater charge (1)	These marks may be awarded if a labelled Hess cycle is used Accept 'charge density' for charge Ignore smaller ionic radius	**3**

Question number	Answer	Additional guidance	Mark
21(c)	An answer that makes reference to the following points • the energy difference between the two sets of (3)d orbitals is different (1) • because the ligands / ions are different (1) • so radiation / light / quanta absorbed from different regions of the visible spectrum (1)	Allow the different energy levels of the (3)d subshell Do not award orbital for orbitals Do not award (quantum) shell for subshell Ignore just 'complexes are different' Accept different radiation / light frequencies or different radiation / light wavelengths transmitted / reflected Do not award radiation / light emitted	**3**

Question number	Answer	Additional guidance	Mark
21(d)(i)	**Method 1** • conversion of % transmittance into log(% transmittance) (1) • use of the graph to obtain a value for the concentration of iron in mg dm^{-3}(1) • calculation of the mass of iron in 500 cm^3 of iron solution which is also the mass of iron in 20 g of sodium carbonate (1) • conversion of the mass Fe in 20 g to ppm (1) **Method 2** (M1 and M2 as above) • calculation of concentration of sodium carbonate (1) • calculation of the ppm of Fe in 40000 mg of sodium carbonate (1)	Example of calculation log(39.8) = 1.60 [Fe] = 0.44 (mg dm^{-3}) (allow 0.42—0.46) 0.5 x 0.44 = 0.22 mg (in 500 cm^3 / 20g) Accept 0.21-0.23 (mg) OR 0.00022 / 2.2 x 10^{-4} g (in 500 cm^3 / 20g) (10^6 x 2.2 x 10^{-4}) ÷ 20= 11 ppm = 20 x 1000/ 500÷1000 = 40000 mg dm^{-3} ppm = 0.44 x 10^6/40000 = 11 ppm (<20ppm)	**4**

	Method 3 (M1, M2 as above) • Conversion of the maximum permitted mass of iron in 20 g of sodium carbonate • Calculation of the concentration of maximum allowed iron	$20 \times 20 \div 10^6 = 4 \times 10^{-4}$ g = 0.4 mg (>0.22) $0.4 \times 1000 \div 500 = 0.8$ mg dm^{-3} (So Fe is within the stated specification) TE at each stage Correct answer with some working scores (4)	

Question number	Answer	Additional guidance	Mark
21(d)(ii)	• (thioglycolic acid is a) bidentate (ligand) (1) • because there are three ligands per complex ion **and** the coordination number of Fe^{3+} is (usually) six OR can form dative bonds using the lone pairs on the SH **and** the COOH groups (1)	Allow three ligands replace six (monodentate) water ligands Accept S **and** O atoms Ignore just 'forms two dative bonds' / '3 ligands form 6 dative bonds' Do not award two dative covalent bonds from COOH	**2**

Question number	Answer	Additional guidance	Mark
21(e)(i)	• catalyst and reactants are in the same phase	Accept ‘same state’ Allow all species are in aqueous solution Allow ‘It’ is in the same phase / state as the reactants Ignore reference to products	1

Question number	Answer	Additional guidance	Mark
21(e)(ii)	• equation for oxidation of iron(II) by peroxodisulfate (1) • equation for oxidation of iodide ions by iron(III) (1)	Examples of equations $S_2O_8^{2-} + 2Fe^{2+} \rightarrow 2SO_4^{2-} + 2Fe^{3+}$ $2I^- + 2Fe^{3+} \rightarrow I_2 + 2Fe^{2+}$ Allow multiples / equations in any order Ignore state symbols even if incorrect Two unbalanced equations with all species correct scores (1)	**2**

Question number	Answer	Additional guidance	Mark
21(e)(iii)	• uncatalysedreaction involves two negatively charged ions reacting **and** catalysed steps involve oppositely charged ions reacting (which is kinetically more favourable / lowers the activation energy)	Ignore general definitions of catalysts	**1**

Question number	Answer	Additional guidance	Mark
21(f)	• chloride ions are large so steric hindrance is too great for six ligands to coordinate around the central ion	Allow just 'chloride ions are large' Allow chlorine ligands are (too) large Do not award chlorine atoms Ignore reference to repulsion between negative chloride ions	**1**

(Total for Question 21 = 20 marks)

Total for Section C = 20 marks

Total for paper = 90 marks

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