Pearson Edexcel

Mark Scheme (Results)

October 2021

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

Section A (Multiple Choice)

Question number	Answer	Mark
1(a)	**The only correct answer is D** (Pt, Pt) ***A*** *is incorrect because both electrodes should be made of platinum* ***B*** *is incorrect because both electrodes should be made of platinum* ***C*** *is incorrect because both electrodes should be made of platinum*	**1**

Question number	Answer	Mark
1(b)	**The only correct answer is C** (1.00 mol dm^{-3} HCl(aq)) ***A*** *is incorrect because* H_3PO_4 *is not completely ionised* ***B*** *is incorrect because* H_2SO_4 *is not completely ionised* ***D*** *is incorrect because* CH_3COOH *is not completely ionised*	**1**

Question number	Answer	Mark
1(c)	**The only correct answer is B** (17.91 g) ***A*** *is incorrect because there should be only one mol of chromium ions per mol of dichromate ions* ***C*** *is incorrect because there should be only one mol of chromium ions per mol of dichromate ions* ***D*** *is incorrect because there should be only one mol of chromium ions per mol of dichromate ions*	**1**

Question number	Answer	Mark
1(d)	**The only correct answer is A** (H_2SO_4) ***B*** *is incorrect because chloride ions could be oxidised* ***C*** *is incorrect because bromide ions would be oxidised* ***D*** *is incorrect because this would introduce additional chromium species into the mixture*	**1**

Question number	Answer	Mark
2	**The only correct answer is C** ($Pt \mid Fe^{2+}, Fe^{3+} \parallel [MnO_4^- + 8H^+], [Mn^{2+} + 4H_2O] \mid Pt$) ***A*** *is incorrect because both electrodes should be made of platinum* ***B*** *is incorrect because both electrodes should be made of platinum and the* MnO_4^-/ Mn^{2+} *half-cell does not show reduction* ***D*** *is incorrect because the* MnO_4^-/ Mn^{2+} *half-cell does not show reduction*	**1**

Question number	Answer	Mark
3	**The only correct answer is D** ($2Ag^{2+} \rightarrow Ag^+ + Ag^{3+}$) ***A*** *is incorrect because the disproportionation is not thermodynamically feasible* ***B*** *is incorrect because the disproportionation is not thermodynamically feasible* ***C*** *is incorrect because the disproportionation is not thermodynamically feasible*	**1**

Question number	Answer	Mark
4	**The only correct answer is A** (the cathode has a more positive potential than the anode) ***B*** *is incorrect because oxidation always occurs at the anode* ***C*** *is incorrect because oxygen is reduced at the positive electrode* ***D*** *is incorrect because the overall reaction is the same under both acidic and alkaline conditions*	**1**

Question number	Answer	Mark
5	**The only correct answer is B** (carbon monoxide forms stronger dative covalent bonds with haemoglobin than does oxygen) ***A*** *is incorrect because carbon monoxide can be displaced from carboxyhaemoglobin* ***C*** *is incorrect because the formation of carboxyhaemoglobin does not lead to an increase in the entropy of the system* ***D*** *is incorrect because the difference in bond type does not fully explain the difference in dative covalent bond strength*	**1**

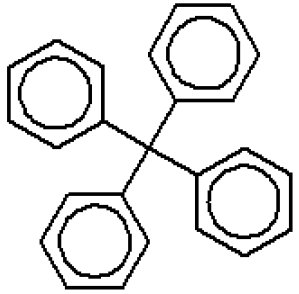
Question number	Answer	Mark
6	**The only correct answer is D** (pink solution → blue precipitate → yellow-brown solution) ***A*** *is incorrect because $CoCl_2(aq)$ is a pink solution* ***B*** *is incorrect because the blue precipitate dissolves in excess aqueous ammonia to form a yellow-brown solution* ***C*** *is incorrect because $CoCl_2(aq)$ is a pink solution*	**1**

Question number	Answer	Mark
7	**The only correct answer is B** ($[Ni(EDTA)]^{2-}$) ***A*** *is incorrect because chloride ions act as monodentate ligands* ***C*** *is incorrect because ethanedioate ions act as bidentate ligands* ***D*** *is incorrect because 1,2-diaminoethane molecules act as bidentate ligands*	**1**

Question number	Answer	Mark
8	**The only correct answer is D** (none of the products are harmful to the environment) ***A*** *is incorrect because the reactions occurring in catalytic converters involve heterogeneous catalysis* ***B*** *is incorrect because carbon monoxide is adsorbed onto the surface of the catalyst* ***C*** *is incorrect because nitrogen is desorbed from the surface of the catalyst*	**1**

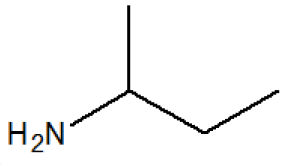
Question number	Answer	Mark
9	**The only correct answer is C** (Mn^{2+}) ***A*** *is incorrect because MnO_4^- ions are neither a product nor a catalyst in this reaction* ***B*** *is incorrect because H^+ ions are neither a product nor a catalyst in this reaction* ***D*** *is incorrect because CO_2 is not a catalyst in this reaction*	**1**

Question number	Answer	Mark
10	**The only correct answer is A** (both $Fe^{2+}(aq)$ and $Fe^{3+}(aq)$ catalyse the reaction) ***B*** *is incorrect because both $Fe^{2+}(aq)$ and $Fe^{3+}(aq)$ catalyse the reaction* ***C*** *is incorrect because both $Fe^{2+}(aq)$ and $Fe^{3+}(aq)$ catalyse the reaction* ***D*** *is incorrect because both $Fe^{2+}(aq)$ and $Fe^{3+}(aq)$ catalyse the reaction*	**1**

Question number	Answer	Mark
11	**The only correct answer is D** () ***A*** *is incorrect because this product is formed by the substitution of one chlorine atom in $CHCl_3$* ***B*** *is incorrect because this product is formed by the substitution of two chlorine atoms in $CHCl_3$* ***C*** *is incorrect because this product is formed by the substitution of all three chlorine atoms in $CHCl_3$*	**1**

Question number	Answer	Mark
12	**The only correct answer is C** (330.7) ***A*** *is incorrect because this is the molar mass of bromobenzene* ***B*** *is incorrect because this is the molar mass of the monosubstituted product* ***D*** *is incorrect because this is the molar mass of the fully substituted product*	**1**

Question number	Answer	Mark
13	**The only correct answer is C** ($CH_3CH_2CH_2NH_2 > NH_3 > C_6H_5NH_2$) ***A*** *is incorrect because* $C_6H_5NH_2$ *is the weakest base in the sequence* ***B*** *is incorrect because* $CH_3CH_2CH_2NH_2$ *is a stronger base than* NH_3 ***D*** *is incorrect because this shows the order of increasing basicity*	**1**

Question number	Answer	Mark
14	**The only correct answer is B** () ***A*** *is incorrect because this amine could be prepared by the reduction of butanenitrile* ***C*** *is incorrect because this amine could be prepared by the reduction of 2-methylpropanenitrile* ***D*** *is incorrect because this amine could be prepared by the reduction of 2,2-dimethylpropanenitrile*	**1**

Question number	Answer	Mark
15	**The only correct answer is B** (4) ***A*** *is incorrect because the repeat unit of the polymer is formed from four different amino acids* ***C*** *is incorrect because the repeat unit of the polymer is formed from four different amino acids* ***D*** *is incorrect because the repeat unit of the polymer is formed from four different amino acids*	**1**

Question number	Answer	Mark
16	**The only correct answer is D** (carbon dioxide giving carboxylic acids) ***A*** *is incorrect because Grignard reagents react with water giving alkanes* ***B*** *is incorrect because Grignard reagents react with methanal giving primary alcohols* ***C*** *is incorrect because Grignard reagents react with ketones giving tertiary alcohols only*	**1**

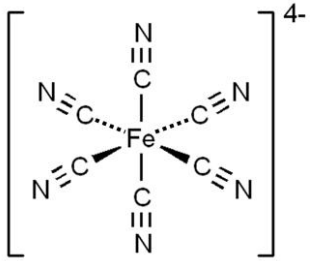
Question number	Answer	Mark
17	**The only correct answer is C** (will be lower than the true value) ***A*** *is incorrect because using a sample that is impure would cause the value to be lower* ***B*** *is incorrect because using a sample that is impure would cause the value to be lower* ***D*** *is incorrect because using a sample that is impure would cause the value to be lower*	**1**

Total for Section A = 20 marks

Section B

Question Number	Answer	Additional guidance	Mark
18(a)	• any indication that **A** contains $FeCl_2$/iron(**II**) chloride (1) • working to show that **A** is a tetrahydrate (1)	Example of calculation: Ignore (**A** contains) Fe^{2+} Ignore $[FeCl_4]^{2-}$ mass of water = 198.8 – (55.8 + 2 × 35.5) = 72.0 (g) moles of water = 72.0 ÷ 18.0 = 4 **A** is $FeCl_2.4H_2O$/iron(**II**) chloride tetrahydrate Allow $FeCl_2(H_2O)_4$	**2**

Question Number	Answer	Additional guidance	Mark
18(b)	• $[Fe(H_2O)_6]^{2+}$	Allow $[Fe(OH)(H_2O)_5]^{+}$ / $[Fe(Cl)(H_2O)_5]^{+}$ Ignore omission of square brackets Ignore name even if incorrect	**1**

Question Number	Answer	Additional guidance	Mark
18(c)	• A diagram showing the octahedral shape	Example of diagram:  Accept arrows for dative covalent bonds Allow CN for C≡N Do not award KCN/HCN for C≡N Do not award M for Fe Ignore connectivity of CN ligands Ignore lone pairs Ignore omission of square brackets Ignore all charges Do not award diagrams with no 3D shape	**1**

Question Number	Answer	Additional guidance	Mark
18(d)	• moles of K, Fe (1) • moles of C and N (1) • calculation of K:Fe:C:N mole ratio **and** empirical formula (1)	Example of calculation: mol K = 35.6 ÷ 39.1 = 0.91049 Allow 0.91282 from A_r value of 39 mol Fe = 17.0 ÷ 55.8 = 0.30466 Allow 0.30357 from A_r value of 56 Ignore SF mol C = 21.9 ÷ 12.0 = 1.8250 mol N = 25.5 ÷ 14.0 = 1.8214 Ignore SF except 1 SF K : Fe : C : N 0.91049 : 0.30466 : 1.825 : 1.8214 3 : 1 : 6 : 6 empirical formula is $K_3FeC_6N_6$ Allow $K_3Fe(CN)_6$ Allow elements in any order TE on moles of K, Fe, C and N provided empirical formula is closest whole number ratio Correct answer with no working scores (3)	**3**

Question Number	Answer	Additional guidance	Mark
18(e)	An equation including: • $[Fe(CN)_6]^{4-}$ reactant **and** $[Fe(CN)_6]^{3-}$ product (1) • rest of equation and balancing (1)	Example of equation: $2[Fe(CN)_6]^{4-} + Cl_2 \rightarrow 2[Fe(CN)_6]^{3-} + 2Cl^-$ Allow $K_4[Fe(CN)_6]$ reactant **and** $K_3[Fe(CN)_6]$ product Ignore omission of square brackets **M2 dependent on M1** Allow multiples Ignore state symbols even if incorrect Do not award uncancelled K^+ spectator ions If no other mark awarded, award (1) for any multiple of the following equation: $2Fe^{2+} + Cl_2 \rightarrow 2Fe^{3+} + 2Cl^-$	**2**

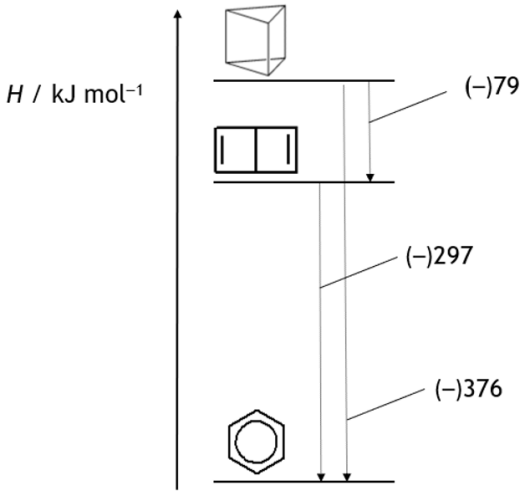
Question Number	Answer	Additional guidance	Mark
18(f)	A completed table showing: • correct identification for reaction 2 (1) • correct identification for reaction 3 (1)	Example of completed table: |	Neutralisation	Ligand exchange	Redox | |---|---|---|---| | Reaction 2 | | ✓ | | | Reaction 3 | | | ✓ | Allow any form of positive identification, including crosses Ignore any form of negative identification Do not award more than 1 box ticked in each row	**2**

(Total for Question 18 = 11 marks)

Question Number	Answer	Additional guidance	Mark
19(a)	• suitable test: bromine water/Br_2(aq) (1) • result of test: decolourises (from orange) with Dewar structure (and no change with benzene) (1)	Allow bromine / Br_2((l)) / Br_2 in organic solvent Do not award Br/Br^- Accept potassium manganate((VII))/$KMnO_4$ **and** acidified/ named acid/H^+ Do not award hydrogenation Do not award combustion Allow does not decolourise with benzene Allow brown/orange/yellow for colour of bromine water Allow red/brown/orange for colour of bromine Allow pink/purple for colour of potassium manganate((VII)) Ignore colour fades for decolourises Ignore reference to addition/substitution Do not award any reference to decolourisation/reaction with benzene	**2**

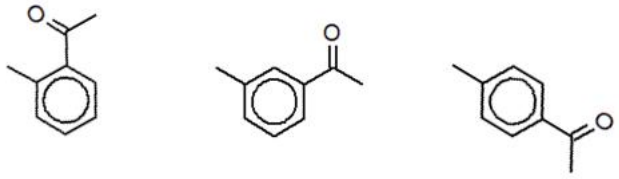
Question Number	Answer	Additional guidance	Mark
19(b)	• similarity: (both compounds have) one (NMR) peak (1) • difference: expected chemical shift values (1)	Ignore any reference to IR and/or ^{13}C NMR Allow (both compounds have) one proton environment Ignore just same number of peaks Ignore references to relative peak area/integration/splitting Do not award any other number of peaks chemical shift for benzene within range of 6.4 to 8.4 ppm (actual value is 7.3 ppm) **and** chemical shift for Ladenburg structure within range of 0 to 2.3 ppm (actual value is 2.3 ppm) Allow any range or value within the above ranges Ignore just benzene would have a higher chemical shift than Ladenburg structure or reverse argument Do not award additional incorrect chemical shifts	**2**

Question Number	Answer	Additional guidance	Mark
19(c)	An explanation that makes reference to the following points: • showed that all C–C bonds are the same length in benzene (1) • in Kekulé structure the C=C bonds would be shorter than the C–C bonds (or reverse argument) (1)	Ignore any reference to: C–H bonds bond strength/bond angle delocalised electrons Dewar/Ladenburg structures Allow showed benzene is a regular hexagon Allow showed benzene contains only one type of carbon-carbon bond Allow benzene bond lengths are in between C=C and C–C Ignore just benzene has no C=C bonds Do not award benzene bond lengths are longer than C–C/ shorter than C=C Allow Kekulé structure would have shown two different lengths/types of carbon-carbon bond Allow Kekulé structure would have alternating carbon-carbon bond lengths Ignore just Kekulé has C=C bonds Do not award C–C bonds would be shorter than the C=C bonds If no other mark awarded, just bond lengths equal in benzene but different in Kekulé scores (1)	**2**

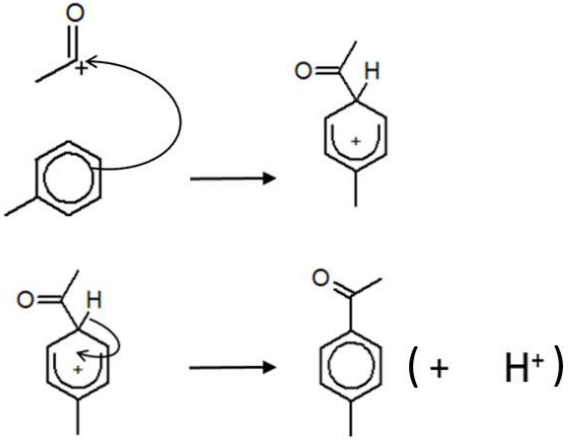
Question Number	Answer	Additional guidance	Mark
19(d)(i)	A diagram showing: • correct relative stabilities (1) • two or three numerical differences in enthalpy with appropriate arrows (1)	Example of diagram:  Allow names for structures If three values and arrows are given they must all be correct to score M2 Allow slight imprecision in start and end of arrows in M2 Ignore any x-axis label Do not award double headed arrows in M2 Do not award incorrect sign in M2	**2**

Question Number	Answer	Additional guidance	Mark
19(d)(ii)	An answer that makes reference to the following: • pi bonds are weaker/more reactive/require less energy to break (than sigma bonds) **or** fewer bonds must break to convert the Dewar structure to benzene	 Ignore just Dewar structure has pi/double bonds/is unsaturated Ignore just Dewar structure has weaker bonds Do not award C=C/double bonds weaker/require less energy to break (than C–C/single bonds) Accept reverse argument Allow any specified numbers to indicate fewer bonds must break Ignore fewer new bonds must form Ignore Dewar structure is more similar to benzene Ignore carbon atoms already in a ring/hexagon Ignore any reference to intermolecular forces Do not award (higher) ring strain in Ladenburg Do not award smaller difference in enthalpy Do not award Ladenburg structure more stable	**1**

Question Number	Answer	Additional guidance	Mark
19(e)	An explanation that makes reference to the following points: ***E*-hexa-1,4-diene** • twice the hydrogenation enthalpy (of hex-3-ene) as two (isolated) C=C bonds (1) ***E*-hexa-1,3-diene** • less exothermic/more stable (by 22 kJ mol^{-1} than *E*-hexa-1,4-diene **and** as some delocalisation of pi-bond(s) (1)	Allow double bond for C=C throughout Accept -118×2 (=–236) as two C=C bonds Allow twice the hydrogenation enthalpy as no delocalisation of pi-bond(s) Accept less negative Allow more positive Allow some delocalisation of double bond(s) Allow double bonds/p-orbitals are conjugated Allow double bonds/p-orbitals are close enough to overlap Ignore just C=C are close Ignore just delocalisation of electrons Ignore electron density more spread out Ignore resonance stabilised	**2**

Question Number	Answer	Additional guidance	Mark
19(f)(i)	• skeletal formula of any one isomer (1) • skeletal formulae of second and third isomers (1)	Example of correct skeletal formulae:  (1,2-isomer) (1,3-isomer) (1,4-isomer) Allow Kekulé benzene ring Allow structural/displayed CH_3 and CH_3CO groups If no other mark awarded, 1,2-, 1,3- and 1,4-isomers with incorrect side chain/cyclohexane ring scores (1)	**2**

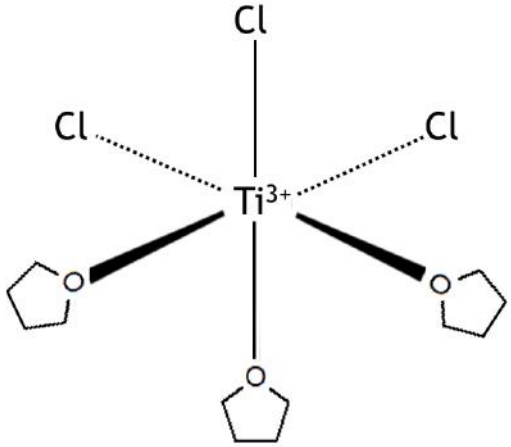
Question Number	Answer	Additional guidance	Mark
19(f)(ii)	• (identification of **X** as) 1,4-isomer (1) • (7 peaks consistent with) 7 carbon environments (1)	Allow any form of identification, including (f)(i) annotation Allow just '1,4' or 'para' **M2 dependent on a structure containing 7 carbon environments** Accept 1,2-isomer and/or 1,3-isomer have 9 carbon environments/would have 9 peaks Allow (4 arene peaks consistent with) 4 arene carbon environments Allow 1,2-isomer and/or 1,3-isomer have 6 arene carbon environments/would have 6 arene peaks	**2**

Question Number	Answer	Additional guidance	Mark
19(f)(iii)	A mechanism including: • curly arrow from on or within circle to C^+ of CH_3CO^+ (1) • structure of intermediate ion (1) • curly arrow from C–H bond to within ring **and** correct product (1) • balanced equation for regeneration of catalyst (1)	Example of mechanism:  Allow Kekulé benzene ring 'Horseshoe' facing tetrahedral carbon and covering at least three carbons with some part of positive sign within 'horseshoe' Allow methyl at 1,2- or 1,3-positions Ignore missing methyl substituent Do not award dotted/dashed C–H/C–C bonds unless 3D structure Allow 1,2- or 1,3-product from corresponding intermediate Do not award missing methyl substituent $AlCl_4^- + H^+ \rightarrow AlCl_3 + HCl$	**4**

(Total for Question 19 = 19 marks)

Question Number	Answer	Additional guidance	Mark
20(a)	An answer that makes reference to one of the following points: • variable oxidation state/oxidation number **or** • (easily) oxidised **and** reduced (back to original oxidation state) **or** • (easily) donate **and** accept electrons (from other molecules/species)	Ignore references to ionisation energy Ignore partially full d orbital(s)/d subshell Ignore more than one stable ion Ignore references to heterogeneous catalysis/adsorption Ignore references to alternative reaction pathways/activation energy Allow can change oxidation state/oxidation number Allow have different oxidation state(s)/oxidation number(s) Ignore variable valency Allow just lose and gain electrons (easily)	**1**

Question Number	Answer	Additional guidance	Mark
20(b)(i)	An answer that makes reference to the following points: • monodentate: forms a single/one dative (covalent) bond (1) • ligand: (a species with a) lone pair (of electrons) that can form a dative (covalent) bond to a (central transition) metal (ion) (1)	Accept coordinate for dative throughout Accept donates a single/one lone pair Allow occupies a single/one coordination site	**2**

Question Number	Answer	Additional guidance	Mark
20(b)(ii)	A completed diagram showing: • three adjacent THF/Cl ligands	Expected diagram:  Ignore lone pairs Ignore 1– charge on Cl ligands	**1**

Question Number	Answer	Additional guidance	Mark
20(c)(i)	• yellow to (permanent pale) green	Ignore qualifiers, eg pale Ignore precipitate Do not award green to yellow Do not award any combination of yellow and green, eg yellowy-green Do not award any other colour	**1**

Question Number	Answer	Additional guidance	Mark
20(c)(ii)	A calculation including: • moles of Ti^{3+} in titre (1) • moles of $Mg(NO_3)_2.6H_2O$ in 100 cm^3 (1) • moles of NO_3^- in 10.00 cm^3 (1) • Ti^{3+} : NO_3^- mol ratio (1) • final oxidation state of nitrogen (1)	Example of calculation: moles of $Ti^{3+} = 0.085 \times \frac{20.70}{1000} = 0.0017595 / 1.7595 \times 10^{-3}$ moles of $Mg(NO_3)_2.6H_2O = \frac{0.75}{256.3} = 0.0029263 / 2.9263 \times 10^{-3}$ moles of $NO_3^- = \frac{0.0029263}{10} \times 2 = 0.00058525 / 5.8525 \times 10^{-4}$ TE on moles $Mg(NO_3)_2.6H_2O$ Ignore SF except 1 SF in M1, M2 and M3 Ignore truncation of moles in M1, M2 and M3, eg 0.0005852 Ti^{3+} : NO_3^- mol ratio = 0.0017595 : 0.00058525 = 3 : 1 TE on moles Ti^{3+} and moles NO_3^- final oxidation state of nitrogen = (+)2 TE on mol ratio provided final oxidation state of nitrogen is between –3 and +4, eg Ti^{3+} : NO_3^- mol ratio = 0.0017595 : 0.00029263 = 6 : 1 final oxidation state of nitrogen = –1 Do not award incorrect oxidation state of N in NO_3^- Correct answer with no working scores (1)	**5**

Question Number	Answer	Additional guidance	Mark
20(c)(iii)	An equation including: • selection of correct nitrogen half-equation (1) • balanced ionic equation from chosen half-equations (1)	Example of equation: $3Ti^{3+} + H_2O + NO_3^- \rightarrow 3TiO^{2+} + 2H^+ + NO$ TE on (c)(ii) provided +3 or +4 oxidation state Allow multiples Allow reversible arrow Ignore state symbols even if incorrect	**2**

Question Number	Answer	Additional guidance	Mark
20(c)(iv)	An answer that makes reference to the following point: • (calculation of) $E^{\ominus}_{cell}$ value	Example of calculation: ($E^{\ominus}_{cell}$ = 0.96 – 0.10 =) (+)0.86 (V) TE on ionic equation from (c)(iii): (+)0.7(0) (V) for $Ti^{3+} + NO_3^- \rightarrow TiO^{2+} + NO_2$ (+)0.84 (V) for $2Ti^{3+} + H_2O + NO_3^- \rightarrow 2TiO^{2+} + H^+ + HNO_2$	**1**

Question Number	Answer	Additional guidance	Mark
20(c)(v)	An answer that makes reference to the following point: • (heat is to) speed up/increase rate of reaction	 Allow to ensure fast oxidation of Ti^{3+} Allow to provide activation energy/E_a Allow (reaction has a) high activation energy/E_a Ignore just to provide (more) energy Ignore to increase collision frequency Ignore to ensure complete reaction Ignore any reference to thermodynamic feasibility	**1**

<table>
<tr><th>Question Number</th><th>Answer</th><th>Additional guidance</th><th>Mark</th></tr>
<tr><td>20(c)(vi)</td><td>
This question assesses a 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 and sustained lines of reasoning</th></tr>
<tr><td>Answer shows a coherent and 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>
The mark for indicative content should be added to the mark for lines of reasoning. For example, an answer 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 are no linkages between points, the same five indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages).

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

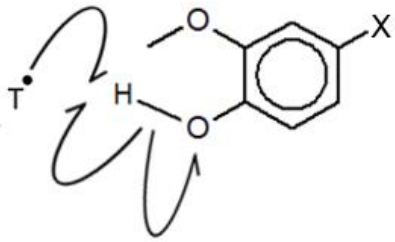
Comment: Look for the indicative marking points first, then consider the mark for the structure of the answer and sustained line of reasoning.
</td><td>6</td></tr>
</table>

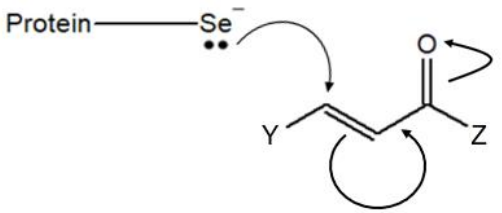
	Indicative points: • IP1: identification of $[Ti(H_2O)_6]^{3+}$ complex ion • IP2: partially filled d-subshell/d-orbital(s) (in Ti^{3+}) • IP3: splitting in energy of d-subshell/d-orbitals by water/ligands • IP4: absorption of light/photon/(electromagnetic) radiation **and** electronic transition • IP5: origin of observed colour of complex ion • IP6: clearer colour change at end-point with indicator	Allow $[Ti(H_2O)_5Cl]^{2+}$ / $[Ti(H_2O)_4Cl_2]^{+}$ Accept incomplete for partially filled Accept (Ti^{3+} is) $1s^2 2s^2 2p^6 3s^2 3p^6 3d^1 (4s^0)$ Allow (Ti^{3+} is) $(3)d^1$ water/ligands **and** split the energy of the d-subshell/d-orbitals Allow ligands cause d-d splitting Do not award d-orbital (singular) (visible) light/photon/(electromagnetic) radiation is absorbed **and** promoting electrons from lower to higher energy Allow light etc causes d-d transitions colour due to reflected/transmitted light Allow colour due to wavelengths/frequencies of light that are not absorbed Allow complementary colour observed Do not award any reference to emission of light Accept reverse argument Allow colours are more intense/distinct/sharp/strong Allow concentration (of $[Ti(H_2O)_6]^{3+}$/$TiCl_3$) too low to accurately determine end-point in absence of indicator Ignore just easier to determine end-point Ignore just more accurate/precise Ignore mention of specific colours, even if incorrect Do not award reference to acid-base colour change	

(Total for Question 20 = 20 marks)

TOTAL FOR SECTION B = 50 MARKS

Section C

Question Number	Answer	Additional guidance	Mark
21(a)	A completed mechanism showing: • curly half-arrows to show homolytic fission of O–H bond	Example of completed mechanism:  Accept curly half-arrows originating from opposite sides of the O–H bond Left-hand curly half-arrow must terminate between T• and H Right hand curly half-arrow must terminate on or near to O atom of H–O	**1**

Question Number	Answer	Additional guidance	Mark
21(b)	A completed mechanism showing: • curly arrow from lone pair on Se^- to correct C of C=C (1) • curly arrow from C=C bond to C–C bond **and** curly arrow from C=O bond to O (1)	Example of completed mechanism:  Penalise curly half-arrows once only Do not award curly arrow from negative charge on Se^- Ignore (δ+)C=C(δ–) dipole Do not award (δ-)C=C(δ+) dipole Do not award full charge on either carbon of C=C bond Do not award incorrect (δ-)C=O(δ+) dipole	**2**

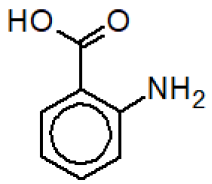
<table>
<tr><th>Question Number</th><th>Answer</th><th>Additional guidance</th><th>Mark</th></tr>
<tr><td>21(c)</td><td>A completed table showing:

• two or three correct answers (1)

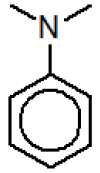
• four correct answers (2)</td><td>Example of completed table:

<table>
<tr><td></td><td>$[Au(Curc)_2]^+$</td><td>$[Al(Curc)(C_2H_5OH)_2(NO_3)_2]$</td></tr>
<tr><td>Coordination number</td><td>4</td><td><u>6</u></td></tr>
<tr><td>O–M–O bond angle</td><td>90°</td><td><u>90°</u>
Ignore 180°</td></tr>
<tr><td>Shape</td><td><u>square planar</u></td><td>octahedral</td></tr>
<tr><td>Charge on metal ion</td><td><u>+3</u></td><td>+3</td></tr>
</table>
</td><td>2</td></tr>
</table>

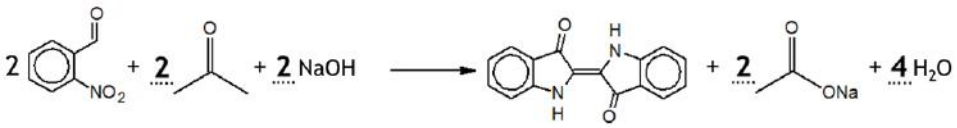
Question Number	Answer	Additional guidance	Mark
21(d)(i)	• $K_2Cr_2O_7$ **and** H_2SO_4 (1) • heat/reflux (1)	**If name and formula given, both must be correct to score M1** Accept names (eg sodium dichromate((VI)) and sulfuric acid) Allow $Cr_2O_7^{2-}$ **and** H^+ / acidified dichromate Ignore concentration of acid Do not award $KMnO_4$ for $K_2Cr_2O_7$ Do not award HCl for H_2SO_4 **M2 dependent on some mention of dichromate (or manganate) oxidising agent** Ignore distillation	**2**

Question Number	Answer	Additional guidance	Mark
21(d)(ii)	• correct structure for 2-aminobenzoic acid	Example of correct structure:  Accept hydrochloride salt ($-NH_3Cl$) Allow protonated amine group ($-NH_3^+$) Allow any correct combination of skeletal, structural or displayed formulae Allow Kekulé benzene Ignore connectivity Ignore name, even if incorrect	1

Question Number	Answer	Additional guidance	Mark
21(d)(iii)	• $NaNO_2$/sodium nitrite/sodium nitrate(III) **and** HCl/hydrochloric acid	Allow HNO_2/nitrous acid Allow H^+ **and** NO_2^- Ignore conditions, including concentration of HCl Ignore H_2O Do not award $NaNO_3$/sodium nitrate	1

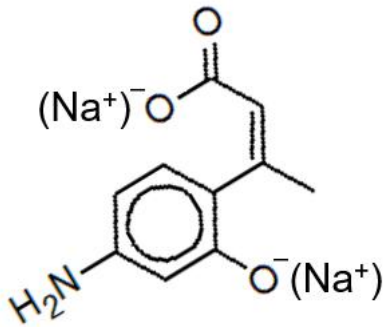
Question Number	Answer	Additional guidance	Mark
21(d)(iv)	• correct structure for *N*,*N*-dimethylphenylamine	Example of correct structure:  Allow any correct combination of skeletal, structural or displayed formulae Allow Kekulé benzene Ignore quaternary salt ($-N(CH_3)_3^+$) Ignore name, even if incorrect	**1**

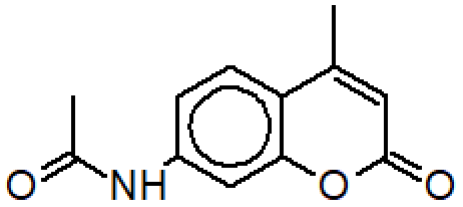
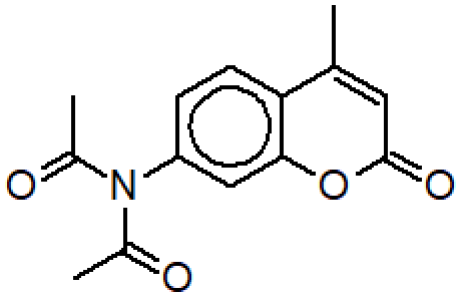
Question Number	Answer	Additional guidance	Mark
21(d)(v)	An explanation including: • effect of temperature higher than 5°C (1) • effect of temperature lower than 5°C (1)	 (diazonium/it) decomposes / reacts with water / forms a phenol / undergoes nucleophilic substitution (above 5°C) Ignore byproducts form / side reactions occur / yield too low (above 5°C) (rate of reaction) too slow (below 5°C) Allow just slows down (below 5°C) Ignore insufficient energy for reaction to occur (below 5°C) Ignore any reference to activation energy/collision frequency Ignore freezes (at 0°C and below)	**2**

Question Number	Answer	Additional guidance	Mark
21(e)(i)	A completed equation showing: • correct balancing of propanone and sodium ethanoate (1) • correct balancing of sodium hydroxide and water (1)	Example of equation:  **M2 dependent on M1**	**2**

Question Number	Answer	Additional guidance	Mark
21(e)(ii)	**M1: molar masses** • M(2-nitrobenzaldehyde) **and** M(indigotin) (1) Then, for M2 and M3, either: **Method 1 (M2 and M3)** • moles indigotin in 10.0 g **and** indigotin:2-nitrobenzaldehyde mol ratio (1) • moles 2-nitrobenzaldehyde required **and** mass 2-nitrobenzaldehyde required (1)	Correct answer with no working scores (3) Example of calculation: M(2-nitrobenzaldehyde) = 7 × 12.0 + 5 × 1.0 + 1 × 14.0 + 3 × 16.0 = 151(.0 g mol^{-1}) M(indigotin) = 16 × 12.0 + 10 × 1.0 + 2 × 14.0 + 2 × 16.0 = 262(.0 g mol^{-1}) Allow truncation of mass/moles throughout, eg 0.03816 for 0.038168 Ignore SF except 1 SF in M2 and M3 moles indigotin in 10.0 g = $\frac{10.0}{262}$ = 0.038168 TE on M(indigotin) moles 2-nitrobenzaldehyde = 2 × 0.038168 (= 0.076336) TE on moles indigotin moles 2-nitrobenzaldehyde required = $\frac{100}{85}$ × 0.076336 = 0.089807 mass 2-nitrobenzaldehyde required = 0.089807 × 151 = 13.561 = 14 (g) TE on moles 2-nitrobenzaldehyde TE on M(2-nitrobenzaldehyde)	**3**

	OR **Method 2 (M2 and M3)** • mass indigotin if 100% yield **and** moles indigotin if 100% yield • indigotin:2-nitrobenzaldehyde mol ratio **and** mass 2-nitrobenzaldehyde	 (1) (1)	 mass indigotin if 100% yield = $\frac{100}{85} \times 10.0$ = 11.765 (g) moles indigotin if 100% yield = $\frac{11.765}{262}$ = 0.044903 TE on *M*(indigotin) moles 2-nitrobenzaldehyde = 2 × 0.044903 (= 0.089807) TE on moles indigotin mass 2-nitrobenzaldehyde = 0.089807 × 151 = 13.561 = 14 (g) TE on moles 2-nitrobenzaldehyde TE on *M*(2-nitrobenzaldehyde)	

Question Number	Answer	Additional guidance	Mark
21(f)(i)	A drawing showing: • hydrolysed ester linkage **and** correct carbon frame and amine group (1) • deprotonated carboxylic acid **and** phenol groups (1)	Example of drawing:  Allow –ONa Do not award –O–Na Allow *E* isomer Allow Kekulé benzene Allow any correct combination of skeletal, structural or displayed formulae	**2**

Question Number	Answer	Additional guidance	Mark
21(f)(ii)	A drawing showing: • correct condensation product	Example of drawing:  Allow Kekulé benzene Allow any correct combination of skeletal, structural or displayed formulae Allow diacylated product, ie  	**1**

Total for Section C = 20 marks
Total for Paper = 90 marks