# Mark Scheme (Results)

## October 2020

Pearson International Advanced Level
In Chemistry (WCH15)
Paper 1: 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.

## Using the Mark Scheme

Examiners should look for qualities to reward rather than faults to penalise. This does NOT mean giving credit for incorrect or inadequate answers, but it does mean allowing candidates to be rewarded for answers showing correct application of principles and knowledge. Examiners should therefore read carefully and consider every response: even if it is not what is expected it may be worthy of credit.

The mark scheme gives examiners:
- an idea of the types of response expected
- how individual marks are to be awarded
- the total mark for each question
- examples of responses that should NOT receive credit.

/ means that the responses are alternatives and either answer should receive full credit.
( ) means that a phrase/word is not essential for the award of the mark, but helps the examiner to get the sense of the expected answer.
Phrases/words in **bold** indicate that the meaning of the phrase or the actual word is **essential** to the answer.
ecf/TE/cq (error carried forward) means that a wrong answer given in an earlier part of a question is used correctly in answer to a later part of the same question.

Candidates must make their meaning clear to the examiner to gain the mark. Make sure that the answer makes sense. Do not give credit for correct words/phrases which are put together in a meaningless manner. Answers must be in the correct context.

**Quality of Written Communication**
Questions which involve the writing of continuous prose will expect candidates to:
- write legibly, with accurate use of spelling, grammar and punctuation in order to make the meaning clear
- select and use a form and style of writing appropriate to purpose and to complex subject matter
- organise information clearly and coherently, using specialist vocabulary when appropriate.

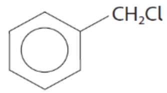
Full marks will be awarded if the candidate has demonstrated the above abilities.
Questions where QWC is likely to be particularly important are indicated (QWC) in the mark scheme, but this does not preclude others.

Section A

| Question number | Answer | Mark |
|---|---|---|
| 1 | **The only correct answer is B** (−210 )<br>*A is incorrect because this is the stabilisation energy of benzene*<br>*C is incorrect because this is the enthalpy change of hydrogenation for three C=C*<br>*D is incorrect because this is 150 kJ mol$^{-1}$ less stable than three C=C* | **(1)** |

| Question number | Answer | Mark |
|---|---|---|
| 2 | **The only correct answer is A** (p orbitals, π bond)<br>*B is incorrect because a σ bond is not present in the ring of delocalised electrons*<br>*C is incorrect because s and p orbitals do not overlap to form the ring of delocalised electrons*<br>*D is incorrect because s and p orbitals do not overlap and a σ bond is not formed in the ring of delocalised electrons* | **(1)** |

| Question number | Answer | Mark |
|---|---|---|
| 3 | **The only correct answer is C** (ethanoyl chloride and aluminium chloride)<br>*A is incorrect because ethanal does not react with benzene*<br>*B is incorrect because ethanal does not react with benzene*<br>*D is incorrect because the catalyst is incorrect* | **(1)** |

| Question number | Answer | Mark |
|---|---|---|
| 4 | **The only correct answer is A**<br><br><br>*B* *is incorrect because chlorine does not substitute into the benzene ring in the presence of ultraviolet light*<br>*C* *is incorrect because chlorine does not substitute into the benzene ring in the presence of ultraviolet light*<br>*D* *is incorrect because chlorine does not substitute into the benzene ring in the presence of ultraviolet light* | **(1)** |

| Question number | Answer | Mark |
|---|---|---|
| 5 | **The only correct answer is C** (6)<br>*A* *is incorrect because the $NO_2$ groups can be on carbon atoms (2,3), (2, 4), (2,5), (2, 6), (3, 4) and (3,5) relative to the OH group*<br>*B* *is incorrect because the $NO_2$ groups can be on carbon atoms (2,3), (2, 4), (2,5), (2, 6), (3, 4) and (3,5) relative to the OH group*<br>*D* *is incorrect because the $NO_2$ groups can be on carbon atoms (2,3), (2, 4), (2,5), (2, 6), (3, 4) and (3,5) relative to the OH group* | **(1)** |

| Question number | Answer | Mark |
|---|---|---|
| 6 | **The only correct answer is C** (2.98 g)<br>*A* *is incorrect because the mass of phenyl ethanoate has been multiplied by 0.85 instead of divided by 0.85*<br>*B* *is incorrect because this is the mass of phenol if the yield is 100% yield*<br>*D* *is incorrect because this is the mass of phenyl ethanoate produced from 3.67 g of phenol* | **(1)** |

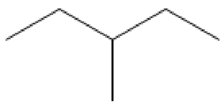
| Question number | Answer | Mark |
|---|---|---|
| 7 | **The only correct answer is B** ($C_7H_8$)<br>*A* *is incorrect because this contains 92.3% carbon*<br>*C* *is incorrect because this contains 90.6% carbon*<br>*D* *is incorrect because this contains 90.0% carbon* | **(1)** |

| Question number | Answer | Mark |
|---|---|---|
| 8 | **The only correct answer is D** ($(C_2H_5)_2NH_2^+Cl^-$)<br>*A* *is incorrect because this compound would not be formed from ethylamine and chloroethane*<br>*B* *is incorrect because this compound is formed when hydrochloric acid is added to ethylamine*<br>*C* *is incorrect because this compound is formed when ethanoyl chloride is added the ethylamine* | **(1)** |

| Question number | Answer | Mark |
|---|---|---|
| 9 | **The only correct answer is D** ($HOOCC_6H_4COOH$ and $HOCH_2CH_2OH$)<br>*A* *is incorrect because the dicarboxylic acid and the dialcohol are the wrong way around*<br>*B* *is incorrect because the dicarboxylic acid and the dialcohol are the wrong way around and there are too many carbon atoms*<br>*C* *is incorrect because each monomer must have the same two functional groups to form this polymer* | **(1)** |

| Question number | Answer | Mark |
|---|---|---|
| 10 | **The only correct answer is B** (4)<br>*A is incorrect because the 1st and 6th amino acids are the same, the 2nd is different, the 3rd and 5th are the same and the 4th is different*<br>*C is incorrect because the 1st and 6th amino acids are the same, the 2nd is different, the 3rd and 5th are the same and the 4th is different*<br>*D is incorrect because the 1st and 6th amino acids are the same, the 2nd is different, the 3rd and 5th are the same and the 4th is different* | **(1)** |

| Question number | Answer | Mark |
|---|---|---|
| 11 | **The only correct answer is B** (ethanal)<br>*A is incorrect because carbon dioxide produces a carboxylic acid*<br>*C is incorrect because methanal produces a primary alcohol*<br>*D is incorrect because propanone produces a tertiary alcohol* | **(1)** |

| Question number | Answer | Mark |
|---|---|---|
| 12 | **The only correct answer is B**<br><br>*A is incorrect because this isomer gives 3 peaks*<br>*C is incorrect because this isomer gives 5 peaks*<br>*D is incorrect because this isomer gives 2 peaks* | **(1)** |

| Question number | Answer | Mark |
|---|---|---|
| 13 | **The only correct answer is C** ($C_{11}H_{14}O$)<br>*A* *is incorrect because there are 6 carbon atoms in the ring, 3 in the side-chain on the left and 2 in the side chain on the right*<br>*B* *is incorrect because there are 6 carbon atoms in the ring, 3 in the side-chain on the left and 2 in the side chain on the right*<br>*D* *is incorrect because there are no hydrogen atoms on the carbon atoms in the ring where there are side-chains* | **(1)** |

| Question number | Answer | Mark |
|---|---|---|
| 14 | **The only correct answer is A** ($N_2O_5$)<br>*B* *is incorrect because Br has oxidation number +5 and Mn has oxidation number +7*<br>*C* *is incorrect because Br has oxidation number +5 and Fe has oxidation number +6*<br>*D* *is incorrect because Br has oxidation number +5 and S has oxidation number +4* | **(1)** |

| Question number | Answer | Mark |
|---|---|---|
| 15 | **The only correct answer is A** ($Cr_2O_7^{2-} + 2C \rightarrow Cr_2O_3 + CO_3^{2-} + CO$)<br>*B* *is incorrect because chromium has oxidation number +6 in the reactant and product and no other atom is changing oxidation number*<br>*C* *is incorrect because chromium has oxidation number +6 in the reactant and product and no other atom is changing oxidation number*<br>*D* *is incorrect because chromium has oxidation number +6 in the reactant and product and no other atom is changing oxidation number* | **(1)** |

| Question number | Answer | Mark |
|---|---|---|
| 16 | **The only correct answer is C** (+6)<br>**A** *is incorrect because the maximum oxidation state occurs when all the 3d and 4s electrons are used in bonding*<br>***B*** *is incorrect because the maximum oxidation state occurs when all the 3d and 4s electrons are used in bonding*<br>***D*** *is incorrect because the maximum oxidation state occurs when all the 3d and 4s electrons are used in bonding* | **(1)** |

| Question number | Answer | Mark |
|---|---|---|
| 17 | **The only correct answer is D** ($NH_4^+$)<br>***A*** *is incorrect because* $CH_3NH_2$ *has a lone pair of electrons that can form a dative covalent bond*<br>***B*** *is incorrect because* $CN^-$ *has a lone pair of electrons that can form a dative covalent bond*<br>***C*** *is incorrect because* $NH_3$ *has a lone pair of electrons that can form a dative covalent bond* | **(1)** |

| Question number | Answer | Mark |
|---|---|---|
| 18 | **The only correct answer is D** (coordination number 6, overall charge 4−)<br>***A*** *is incorrect because the coordination number should be 6 as there are 6 dative covalent bonds and the ions are* $Ni^{2+}$*, two* $Cl^-$ *and two* $C_2O_4^{2-}$*, giving an overall charge of 4−*<br>***B*** *is incorrect because the coordination number should be 6 as there are 6 dative covalent bonds and the ions are* $Ni^{2+}$*, two* $Cl^-$ *and two* $C_2O_4^{2-}$*, giving an overall charge of 4−*<br>***C*** *is incorrect because the coordination number should be 6 as there are 6 dative covalent bonds and the ions are* $Ni^{2+}$*, two* $Cl^-$ *and two* $C_2O_4^{2-}$*, giving an overall charge of 4−* | **(1)** |

| Question number | Answer | Mark |
|---|---|---|
| 19 | **The only correct answer is C** (36.7 $cm^3$ )<br>***A*** *is incorrect because the ratio of oxidation numbers, 4:7, has been used and the mole ratios of* $MnO_4^-:Fe^{2+}$ *should be used*<br>***B*** *is incorrect because the mole ratio of 5:3 has been used the wrong way around*<br>***D*** *is incorrect because the ratio of 7:4 has been used and the mole ratios of* $MnO_4^-:Fe^{2+}$ *should be used* | **(1)** |

| Question number | Answer | Mark |
|---|---|---|
| 20 | **The only correct answer is C** (0.15 (mol $dm^{-3}$)) <br>***A*** *is incorrect because this is the concentration with respect to* $Cr_2(SO_4)_3$<br>***B*** *is incorrect because this is the concentration with respect to chromium ions*<br>***D*** *is incorrect because this is the total concentration of all ions* | **(1)** |

**Total for Section A = 20 marks**

**Section B**

| Question number | Answer | Additional guidance | Mark |
|---|---|---|---|
| **21(a)** | • (**A** Salt bridge containing a solution of) potassium nitrate / $KNO_3$ **(1)**<br>• (**B** Electrode made of ) platinum / Pt **(1)**<br>• (**C** Solution containing) iron(II) **and** iron(III) ions / $Fe^{2+}$ **and** $Fe^{3+}$ (ions) **(1)** | Ignore any conditions, including concentrations<br><br>Allow potassium chloride / KCl / sodium nitrate / $NaNO_3$ / sodium chloride / NaCl<br>Allow ammonium salts<br><br>Do not award iron<br><br>Allow soluble compounds of iron(II) **and** iron(III) e.g. chlorides, nitrates or sulfates<br>Ignore acid | **(3)** |

| Question number | Answer | Additional guidance | Mark |
|---|---|---|---|
| **21(b)** | • half-equation for bismuthate ions **(1)**<br><br>• half-equation for manganate(VII) ions **(1)**<br><br>• overall equation **(1)** | Examples of equations:<br>$BiO_3^- + 6H^+ + 2e^- \rightarrow Bi^{3+} + 3H_2O$<br>Allow half-equation written in reverse<br><br>$Mn^{2+} + 4H_2O \rightarrow MnO_4^- + 8H^+ + 5e^-$<br>Allow $-5e^-$ on left<br>Allow half-equation written in reverse<br><br>Stand alone mark<br>$2Mn^{2+} + 5BiO_3^- + 14H^+ \rightarrow 2MnO_4^- + 5Bi^{3+} + 7H_2O$<br>Overall equation must be written in direction shown<br>Allow multiples<br>Do not award uncancelled electrons / $H^+$ / $H_2O$<br><br>Allow $\rightleftharpoons$ in equations<br><br>Ignore state symbols even if incorrect | **(3)** |

| Question number | Answer | Additional guidance | Mark |
|---|---|---|---|
| **21(c)** | • substitution of values into formula **(1)**<br>• calculation of *E* **(1)** | Example of calculation:<br>$E = -0.74 + \frac{8.31 \times 298}{96500 \times 3} \times \ln 0.0100$<br><br>*E* = −0.77939 / −0.7794 / −0.779 / −0.78 (V)<br><br>TE on incorrect numbers in correct formula<br>e.g. if $[Cr^{3+}]$ = 0.100, *E* = −0.76 (V)<br><br>No TE on incorrect formula<br><br>Ignore SF except 1 SF<br><br>Ignore units, even if incorrect<br>Correct answer with no working scores (2) | **(2)** |

**(Total for Question 21 = 8 marks)**

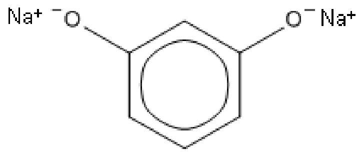
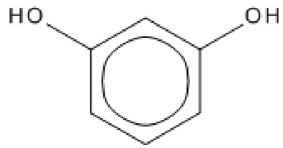
| Question number | Answer | Additional guidance | Mark |
|---|---|---|---|
| **22(a)(i)** | An answer that makes reference to the following points:<br><br>• the curly arrow should go (from the benzene ring/ π bond / delocalised electrons / inside the hexagon and) towards the nitrogen / $NO_2^+$ **(1)**<br><br>• the open end of the 'horseshoe' should be pointing towards the tetrahedral carbon / carbon with 4 bonds **(1)**<br><br>• the curly arrow should start from the (C-H) bond **(1)** | Allow the changes in any order<br>Allow the changes shown in diagrams / amended diagrams in the question<br>Penalise any additional incorrect changes<br><br>Allow first arrow must be reversed<br>Ignore just 'the curly arrow is incorrect'<br><br>Ignore just 'the curly arrow should not start from the hydrogen atom' / ' the curly arrow is incorrect'<br>Ignore use of ion / molecule for hydrogen atom | **(3)** |

| Question number | Answer | Additional guidance | Mark |
|---|---|---|---|
| **22(a)(ii)** | • tin<br>**and**<br>(concentrated) hydrochloric acid / (concentrated) HCl((aq)) | Allow just 'HCl' for hydrochloric acid<br><br>Allow iron **and** (concentrated) hydrochloric acid / (concentrated) HCl((aq))<br><br>Ignore addition of sodium hydroxide / NaOH / alkali added **after** the acid<br><br>Ignore mention of heat / catalyst<br><br>Do not award dilute acid / sulfuric acid / nitric acid | **(1)** |

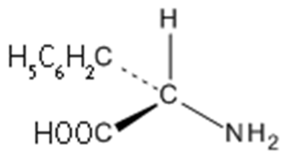
| Question Number | Answer | Additional guidance | Mark |
| --- | --- | --- | --- |
| **22(b)(i)** | An explanation that makes reference to the following points:<br><br>• the lone pair (of electrons) on the nitrogen atom **(1)**<br><br>• overlaps with π cloud / delocalised electrons / delocalised system<br>**or**<br>interacts with (benzene) ring / delocalised electrons / delocalised system **(1)**<br><br>• so the nitrogen atom is less able to accept a hydrogen ion / $H^+$ / proton **(1)** | Allow pair of electrons for lone pair<br>Allow lone pair on the amine / $NH_2$ group<br><br>Allow increases the electron density in the (benzene) ring / feeds into the delocalised electrons<br>**or**<br>decreases the electron density on the nitrogen atom<br><br>Allow the lone pair (of electrons) is less available to accept a hydrogen ion / $H^+$ / proton<br>Allow nitrogen is less able to donate electrons to a hydrogen ion / $H^+$ / proton<br>Allow lone pair is less available to form a dative bond with an acid<br>Allow phenylamine for nitrogen<br>Allow ammonia is more able to accept a hydrogen ion / $H^+$ / proton | **(3)** |

| Question Number | Answer | Additional guidance | Mark |
|---|---|---|---|
| **22(b)(ii)** | A description that makes reference to the following point:<br><br>• a (pale) blue precipitate forms | Allow any shade of blue<br><br>Ignore reference to precipitate dissolving<br>Ignore original colour of solution<br><br>Do not award any other colours with blue e.g. blue-green | **(1)** |

| Question number | Answer | Additional guidance | Mark |
|---|---|---|---|
| **22(c)(i)** | • sodium nitrite / sodium nitrate(III) / $NaNO_2$<br>**and**<br>hydrochloric acid / HCl **(1)**<br><br>• at 5˚C / between 0 and 10˚C **(1)** | Allow nitrous acid / $HNO_2$ / HONO **and** hydrochloric acid / HCl<br><br>Ignore concentration of acid<br><br>Do not award sodium nitrate / $NaNO_3$ / nitric ((V)) acid / $HNO_3$<br><br>Stand alone mark<br><br>Allow any temperature or range of temperatures within the range 0 and 10˚C / less than any temperature within that range<br>Allow ice-bath | **(2)** |

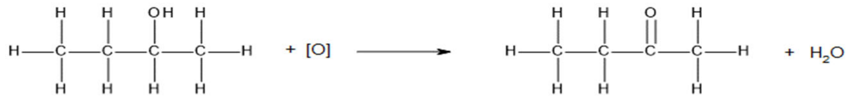
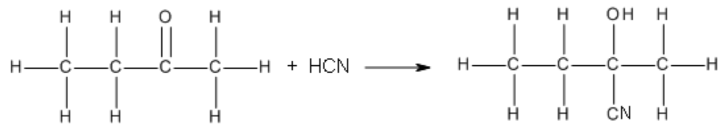
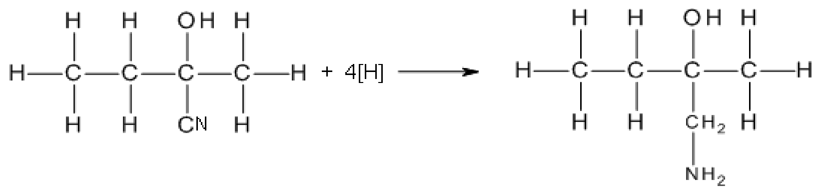
| Question number | Answer | Additional guidance | Mark |
|---|---|---|---|
| 22(c)(ii) | • correct structure | Examples of structure:<br><br><br>or<br><br><br>Allow ONa with no charges<br><br>Allow $O^-$<br><br>Do not award bond between O and Na i.e. O-Na / OH-C / additional atoms bonded to benzene | (1) |

| Question number | Answer | Additional guidance | Mark |
|---|---|---|---|
| 22(c)(iii) | • there is restricted rotation around N=N / the nitrogen bridge / the azo bridge / nitrogen π bond (and the lone pair of electrons on nitrogen) | Allow no rotation around N=N / the double bond<br>Ignore just 'two different groups on N atoms'<br><br>Do not award the molecule does not rotate<br>Do not award restricted / no rotation around C=C | (1) |

| Question number | Answer | Additional guidance | Mark |
|---|---|---|---|
| 22(d) | • other optical isomer | Example of optical isomer:<br><br><br>The groups must be joined in the correct bonds around the central carbon atom but ignore the connectivity of the groups<br><br>Allow the mirror images of the symbols<br><br>Allow subscripts the other side of the symbols e.g. $_5H_6C_2HC$ | (1) |

**(Total for Question 22 = 13 marks)**

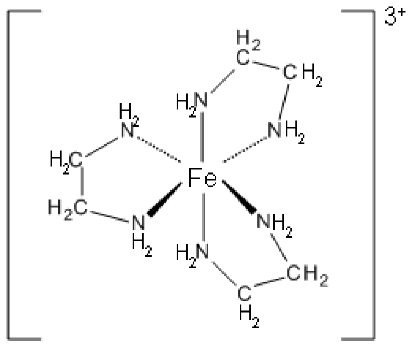
| Question number | Answer | Additional guidance | Mark |
|---|---|---|---|
| **23(a)** | • expression for volume of oxygen reacting with $CH_4$ **(1)**<br><br>• expression for volume of oxygen reacting with $C_2H_6$ **(1)**<br><br>• calculation of volume of methane **(1)**<br><br>• calculation of percentage of methane in mixture **(1)** | Example of calculation:<br>Let x $cm^3$ be the volume of methane<br>$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$<br>x $cm^3$ of $CH_4$ reacts with 2x $cm^3$ of $O_2$<br><br>$C_2H_6 + 3½O_2 \rightarrow 2CO_2 + 3H_2O$<br>(25 – x) $cm^3$ $C_2H_6$ reacts with 3½(25 - x)$cm^3$ $O_2$<br><br>2x + 3½(25 - x) = 65<br>x = 15 $cm^3$<br><br>$\frac{15}{25}$ x 100 = 60%<br>TE on volume of methane<br>Correct answer with no working scores (4)<br>Ignore SF<br>Allow alternative methods<br>**e.g. 1**<br>ratio $CH_4 : O_2$ = 1 : 2 **(1)** / $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$<br>ratio $C_2H_6 : O_2$ = 1 : 3.5 / 2 : 7 **(1)** / $C_2H_6 + 3½O_2 \rightarrow 2CO_2 + 3H_2O$<br>(n = fraction of CH4)<br>2n + 3.5(1 – n) = $\frac{65}{25}$ / 2.6 **(1)**<br>n = $\frac{0.9}{15}$ / 0.6 so 60% methane **(1)**<br>**e.g. 2**<br>mol ($CH_4 + C_2H_6$) = $\frac{25}{24000}$ = 0.0010412/1.0412 x $10^{-3}$ **(1)**<br>mol $O_2$ = $\frac{65}{24000}$ = 0.0027083 / 2.7083 x $10^{-3}$ **(1)**<br>ratio mol ($CH_4 + C_2H_6$) : mol $O_2$ = 1 : 2.6 **(1)**<br>so 60% methane **(1)** | **(4)** |

| Question number | Answer | Additional guidance | Mark |
|---|---|---|---|
| 23(b) | **Step 1**<br>• potassium dichromate((VI)) **and** dilute sulfuric acid / acidified (potassium) dichromate((VI)) (and heat) **(1)**<br><br>• equation **(1)**<br><br>**Step 2**<br>• hydrogen cyanide **and** potassium cyanide / cyanide ions<br>**or**<br>potassium cyanide **and** (sulfuric) acid / hydrogen ions<br>**or**<br>potassium cyanide **and** pH 8-10 / alkali **(1)**<br><br>• equation **(1)**<br><br>**Step 3**<br>• lithium tetrahydridoaluminate((III)) / lithium aluminium hydride **and** dry ether / ethoxyethane (followed by a dilute acid)<br>**or**<br>hydrogen **and** nickel / platinum / palladium<br>**or**<br>sodium **and** ethanol **(1)**<br><br>• equation **(1)** | Allow correct formulae for all reagents<br>Allow any combination of structural and displayed formulae in equations or skeletal formulae<br><br>Example of equation for Step 1:<br><br>Ignore missing $H_2O$ from equation<br><br>Reagents for Step 2 conditional on a carbonyl compound<br><br>Example of equation for Step 2:<br><br><br>Reagents for Step 3 conditional on a nitrile<br><br>Example of equation for Step 3:<br><br>Allow other correct balanced equations / 4[H] on arrow | **(6)** |

**(Total for Question 23 = 10 marks)**

| Question number | Answer | Additional guidance | Mark |
|---|---|---|---|
| **24(a)(i)** | • correct formula of iron(III) hydroxide **(1)**<br><br>• rest of equation correct, conditional on correct precipitate **(1)** | Examples of equation:<br><br>$[Fe(H_2O)_6]^{3+} + 3NH_3 \rightarrow Fe(OH)_3 + 3H_2O + 3NH_4^+$<br>or<br>$[Fe(H_2O)_6]^{3+} + 3NH_3 \rightarrow Fe(OH)_3(H_2O)_3 + 3NH_4^+$<br><br>Allow $Fe(H_2O)_3(OH)_3$<br><br>Ignore state symbols, even if incorrect<br>Ignore square brackets around iron(III) hydroxide formulae | **(2)** |

| Question number | Answer | Additional guidance | Mark |
|---|---|---|---|
| **24(a)(ii)** | • ligand exchange / ligand substitution / ligand displacement | Allow ligand replacement<br><br>Do not award ligand change / change in co-ordination number / redox / deprotonation in addition to correct answer | **(1)** |

| Question number | Answer | Additional guidance | Mark |
|---|---|---|---|
| 24(a)(iii) | • 6 bonds between N in diamines and Fe **(1)**<br><br>• rest of diagram correct **(1)** | Example of diagram:<br><br>Allow $NH_2$– Fe on left of structure<br><br>Conditional on 6 N-Fe bonds<br><br>Allow $C_2H$ for $CH_2$, $H_2N$ for $NH_2$ etc<br>Allow displayed / skeletal formulae for ligands<br><br>Ignore bond lengths and bond angles<br><br>Ignore missing brackets and charge / 3+ on Fe<br><br>Ignore lone pairs on N / arrows added to bonds unless pointing towards the nitrogen atoms<br><br>Do not award two nitrogens from the molecule bonded at 180° to Fe ion | **(2)** |

| Question number | Answer | Additional guidance | Mark |
|---|---|---|---|
| 24(b)(i) | • any 2 colours **(1)**<br><br>• third colour **(1)** | Example of table:<br><table><tr><th>Oxidation state of vanadium</th><th>Colour of aqueous solution</th></tr><tr><td>+3</td><td>green</td></tr><tr><td>+4</td><td>blue</td></tr><tr><td>+5</td><td>yellow or colourless</td></tr></table><br>Ignore any further description of colour e.g. pale yellow<br><br>Do not award combined colours e.g. blue/green | **(2)** |

| Question number | Answer | Additional guidance | Mark |
|---|---|---|---|
| 24(b)(ii) | • it is not a redox reaction because the oxidation number of vanadium is (+)5 in both species | Allow the oxidation number of vanadium remains the same if one oxidation number given – this may be shown by the equation<br><br>Ignore 'there are no electrons in the equation'<br>Ignore just 'the oxidation number of vanadium does not change'<br><br>Do not award reference to any atom oxidised or reduced<br><br>Do not award vanadium oxidation number is (+)5 in both species so it is a redox reaction | **(1)** |

| Question number | Answer | Additional guidance | Mark |
| --- | --- | --- | --- |
| 24(b)(iii) | An answer that makes reference to the following points: | Examples of equations:<br>Allow multiples<br>Ignore state symbols even if incorrect<br>Ignore uncancelled $H^+$ / $H_2O$<br>Penalise uncancelled electrons once only | (5) |
| | • equation for oxidation of $V^{2+}$ to $V^{3+}$ (1) | $NO_3^- + 2H^+ + V^{2+} \rightarrow NO_2 + H_2O + V^{3+}$<br>Allow $Cu^{2+} + V^{2+} \rightarrow Cu^+ + V^{3+}$<br>Allow $\frac{1}{2}Br_2 + V^{2+} \rightarrow Br^- + V^{3+}$ | |
| | • $E^\ominus_{cell}$ for oxidation of $V^{2+}$ to $V^{3+}$ (1) | $E^\ominus_{cell}$ = (+)1.06 (V)<br>TE on $Cu^{2+}$ / $Br_2$ chosen as oxidising agent<br>With $Cu^{2+}$ $E^\ominus_{cell}$ = (+)0.41(0) (V)<br>With $Br_2$ $E^\ominus_{cell}$ = (+)1.35 (V) | |
| | • equation for oxidation of $V^{3+}$ to $VO^{2+}$ (1) | $NO_3^- + V^{3+} \rightarrow NO_2 + VO^{2+}$<br>Allow $\frac{1}{2}Br_2 + V^{3+} + H_2O \rightarrow Br^- + VO^{2+} + 2H^+$ | |
| | • $E^\ominus_{cell}$ for oxidation of $V^{3+}$ to $VO^{2+}$ (1) | $E^\ominus_{cell}$ = (+)0.46 (V)<br>With $Br_2$ $E^\ominus_{cell}$ = (+)0.75 (V) | |
| | • $VO^{2+}$ is not oxidised to $VO_2^+$ / any further as $E^\ominus_{cell}$ is −0.2 (V) / negative (1) | Allow this shown in an equation | |

<table>
<tr><th>Question number</th><th>Answer</th><th>Additional guidance</th><th>Mark</th></tr>
<tr><td>*24(c)</td><td>This question assesses the student's ability to show a coherent and logically structured answer with linkages and fully sustained reasoning.<br><br>Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.<br><br>The following table shows how the marks should be awarded for indicative content.<br><br><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></td><td>Guidance on how the mark scheme should be applied.<br><br>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).<br><br>If there were no linkages between the points, then the same indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages).<br><br>In general it would be expected that 5 or 6 indicative points would get 2 reasoning marks, and</td><td>(6)</td></tr>
</table>

The following table shows how the marks should be awarded for structure and lines of reasoning

| | Number of marks awarded for structure of answer and sustained lines of reasoning |
|---|---|
| Answer shows a coherent logical structure with linkages and fully sustained lines of reasoning demonstrated throughout | 2 |
| Answer is partially structured with some linkages and lines of reasoning | 1 |
| Answer has no linkages between points and is unstructured | 0 |

3 or 4 indicative points would get 1 mark for reasoning, and 0, 1 or 2 indicative points would score zero marks for reasoning.

**Comment:** Look for the indicative marking points first, then consider the mark for the structure of the answer and sustained line of reasoning.

If there is any incorrect chemistry, deduct mark(s) from the reasoning. If no reasoning mark(s) awarded do not deduct mark(s).
e.g. iron catalysing formation of ammonia from nitrogen and hydrogen but naming it the Contact Process / incorrect formula e.g. for persulfate ions

Allow correct formulae for names

Do not award examples that are not transition metals, ions or compounds

**Indicative content**

| | | | |
|---|---|---|---|
| | • **IP1 Comparison - Activation energy**<br>both catalysts increase the rate of reaction by providing an alternative route / mechanism with a lower activation energy<br><br>• **IP2 Phase**<br>a heterogeneous catalyst is in a different phase from the reactants **and** a homogeneous catalyst is in the same phase as the reactants / all solutions / gases<br><br>• **IP3 Example of heterogeneous**<br>example of a heterogeneous catalyst **and** reaction it catalyses e.g. iron and Haber Process, nickel and hydrogenation of alkenes, platinum in a catalytic converter / with CO and NO<br><br>• **IP4 Example of homogeneous**<br>example of a homogeneous catalyst **and** reaction it catalyses e.g. iron(II) / iron(III) ions and reaction between iodide ions and persulfate ions<br><br>• **IP5 Mechanism of heterogeneous**<br>reactant molecules are adsorbed onto the catalyst surface, the bonds are weakened, reaction takes place then the product molecules are desorbed<br><br>• **IP6 Mechanism of homogeneous**<br>the transition metal ion is oxidised / reduced to a different oxidation state then changes back to the original oxidation state | Allow this shown on a Maxwell-Boltzmann distribution / reaction profile diagram<br><br>Allow (physical) state for phase<br>Allow heterogeneous catalysts are easy to separate from the reaction mixture / reactants / products **and** homogeneous catalysts are difficult to separate from the reaction mixture / reactants / products<br><br>Allow e.g. reactant molecules bind to active sites for adsorbed /<br>particles react for bonds weakened /<br>product molecules leave for desorbed<br>Allow vanadium(V) oxide reduced to vanadium(IV) and oxidised back to vanadium(V) for the Contact Process<br><br>Allow this shown in equations, even if unbalanced<br>Allow donate / receive electrons for oxidised / reduced | |

**(Total for Question 24 = 19 marks)**
**Total for Section B = 50 marks**

Section C

| Question number | Answer | Additional guidance | Mark |
|---|---|---|---|
| 25(a) | • correct equation | Example of equation:<br>$2HoF_3 + 3Ca \rightarrow 2Ho + 3CaF_2$<br><br>Allow multiples<br><br>Ignore state symbols, even if incorrect | (1) |

| Question number | Answer | Additional guidance | Mark |
|---|---|---|---|
| 25(b)(i) | • there is extra stability associated with a half-filled (f-)subshell / one electron in each f orbital | Allow $4f^7$ is more stable than $4f^8$<br><br>Allow to reduce the repulsion between paired electrons/ electron-electron repulsion (in orbitals)<br><br>Do not award a half-filled f orbital | (1) |

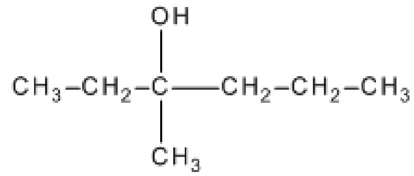
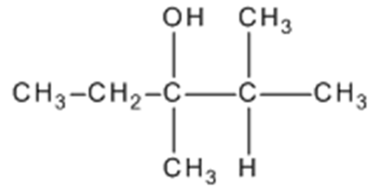
| Question number | Answer | Additional guidance | Mark |
|---|---|---|---|
| 25(b)(ii) | • ([Xe])$4f^5$ | Allow $1s^22s^22p^63s^23p^63d^{10}4s^24p^64d^{10}5s^25p^64f^5$<br>Allow ([Xe])$4f^56s^0$ | (1) |

| Question number | Answer | Additional guidance | Mark |
|---|---|---|---|
| 25(c)(i) | An explanation that makes reference to the following points:<br><br>• thulium (ion)/$Tm^{3+}$ has more protons (in the nucleus than cerium ion / $Ce^{3+}$) **(1)**<br><br>**EITHER**<br>• outer electrons are in the same (sub)shell<br>**OR**<br>so there will be a greater attraction between the nucleus / protons and the (outer) electrons / outer shell **(1)** | Allow $Tm^{3+}$ has a greater nuclear charge (than $Ce^{3+}$)<br>Ignore references to increasing atomic number / charge density<br><br>Allow f sub-shell<br>Allow same / similar shielding | **(2)** |

| Question number | Answer | Additional guidance | Mark |
|---|---|---|---|
| 25(c)(ii) | • the lanthanide ions are larger than the transition metal ions (so there is space for more ligands)<br>**or**<br>there are more orbitals available to accept the lone pairs (from the ligands) | | **(1)** |

| Question number | Answer | Additional guidance | Mark |
|---|---|---|---|
| **25(d)** | An explanation that makes reference to the following points:<br><br>• there are no f electrons in $La^{3+}$ ions **(1)**<br><br>• so no f-f transitions can take place **(1)** | Allow $La^{3+}$ has the same electronic configuration as Xe<br>Allow no occupied f orbitals<br>Allow f subshell / f orbital(s) are empty<br>Ignore reference to numbers of electrons in other orbitals even if incorrect<br>Do not award the difference in energy is outside the visible region<br>Do not award the f-subshell does not split<br><br>Stand alone mark | **(2)** |

| Question number | Answer | Additional guidance | Mark |
|---|---|---|---|
| 25(e)(i) | • calculation of moles of each element **(1)** | Example of calculation:<br><table><tr><td></td><td>Ce</td><td>N</td><td>H</td><td>O</td></tr><tr><td>moles</td><td>23.97 / 140 = 0.171</td><td>19.18 / 14 = 1.37</td><td>2.05 / 1 = 2.05</td><td>54.80 / 16 = 3.425</td></tr><tr><td>divide by smallest</td><td>0.171 / 0.171 = 1</td><td>1.37 / 0.171 = 8</td><td>2.05 / 0.171 = 12</td><td>3.425 / 0.171 = 20</td></tr><tr><td colspan="5">Empirical formula $CeN_8H_{12}O_{20}$</td></tr></table> | **(3)** |
| | • calculation of empirical formula **(1)** | TE on mol ratio from M1 | |
| | • overall formula **(1)** | Example of overall formula:<br>$Ce(NH_4)_2(NO_3)_6.2H_2O$<br>or<br>$Ce(NO_3)_4.(NH_4NO_3)_2.2H_2O$<br>or<br>$Ce(NO_3)_4.2(NH_4NO_3).2H_2O$<br><br>TE on M2<br><br>Allow the ions in any order / charges shown by the ions / missing dot(s) | |

| Question number | Answer | Additional guidance | Mark |
|---|---|---|---|
| **25(e)(ii)** | • identification of **X** **(1)**<br><br>Justification<br>• **X** is an alcohol as it gives a red colour with cerium(IV) ammonium nitrate **(1)**<br><br>• **X** is a tertiary alcohol / not a primary or a secondary alcohol as it does not react with acidified potassium dichromate(VI) **(1)**<br><br>• **X** has 4 different groups attached to one carbon atom / has a chiral centre / carbon (atom) **(1)** | Examples of structure of **X**:<br><br>or<br><br>Allow any unambiguous structure, including $C_2H_5$ /$C_3H_7$ groups, displayed / skeletal formulae<br>Ignore connectivity of OH except OH-C on left<br><br>Allow **X** is an alcohol as it has general formula $C_nH_{2n+1}OH$<br><br>Ignore ketone | **(4)** |

| Question number | Answer | Additional guidance | Mark |
|---|---|---|---|
| 25(f) | • calculation of amount of $Ce^{4+}$ used **(1)**<br><br>• calculation of amount of 4-aminophenol in 25.0 $cm^3$ **(1)**<br><br>• calculation of amount of 4-aminophenol in 100 $cm^3$ **(1)**<br><br>• calculation of mass of paracetamol **(1)**<br><br>• calculation of percentage of paracetamol **and** answer given to 2 or 3SF **(1)** | Example of calculation:<br>Amount of $Ce^{4+}$ used = $\frac{21.70 \times 0.100}{1000}$<br>= 0.00217 / = $2.17 \times 10^{-3}$ (mol)<br><br>Amount of 4-aminophenol in 25 $cm^3$<br>= $\frac{0.00217}{2}$<br>= 0.001085 / = $1.085 \times 10^{-3}$ (mol)<br>TE on amount of $Ce^{4+}$ used<br><br>Amount of 4-aminophenol in 100 $cm^3$ =<br>= 0.001085 x 4<br>= 0.00434 / = $4.34 \times 10^{-3}$ (mol)<br>TE on amount of 4-aminophenol in 25 $cm^3$<br>Allow M3 and M2 in reverse order<br><br>(Amount paracetamol in tablet = amount of 4-aminophenol in 100 $cm^3$)<br>Mass of paracetamol = 0.00434 x 151<br>= 0.65534 (g)<br>TE on amount of 4-aminophenol in 100 $cm^3$<br><br>Percentage of paracetamol = $\frac{0.65534}{0.800} \times 100$<br>= 82 / 81.9%<br>TE on mass of paracetamol provided 0.800 is the denominator and answer < 100%<br>Correct answer given to 2 or 3SF with no working scores (5) | (5) |

**(Total for Question 25 = 20 marks)**
**Total for Section C = 20 marks**
**Total for Paper = 90 marks**

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