Pearson Edexcel

Mark Scheme (Results)

Summer 2023

Pearson Edexcel International Advanced Subsidiary Level In Chemistry (WCH15)
Paper 01
Unit 5: Transition Metals and Organic Nitrogen Chemistry

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Summer 2023
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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 D** ($Pt(s)\,|\,V^{2+}(aq), V^{3+}(aq)\,||\,Cu^{2+}(aq)\,|\,Cu(s)$) ***A*** *is not correct because the $V^{3+}(aq)/V^{2+}(aq)$ half-cell should have a platinum electrode and should show oxidation and the $Cu^{2+}(aq)/Cu(s)$ half-cell should show reduction* ***B*** *is not correct because the $V^{3+}(aq)/V^{2+}(aq)$ half-cell should have a platinum electrode* ***C*** *is not correct because the $V^{3+}(aq)/V^{2+}(aq)$ half-cell should show oxidation and the $Cu^{2+}(aq)/Cu(s)$ half-cell should show reduction*	**(1)** **Computer**

Question Number	Answer	Mark
2	**The only correct answer is D** ($Mg + 2Ce^{4+} \rightarrow Mg^{2+} + 2Ce^{3+}$) ***A*** *is not correct because Ce is a weaker reducing agent than Mg* ***B*** *is not correct because Ce^{3+} is a weaker reducing agent than Ce* ***C*** *is not correct because Mn^{2+} is a weaker reducing agent than Mn*	**(1)** **Computer**

Question Number	Answer	Mark
3	**The only correct answer is D** ($\Delta S^{\ominus}_{total}$) ***A*** *is not correct because $E^{\ominus}_{cell}$ is directly proportional to lnK_c* ***B*** *is not correct because $E^{\ominus}_{cell}$ is directly proportional to $\Delta S^{\ominus}_{total}$ and not $\Delta H^{\ominus}$* ***C*** *is not correct because $E^{\ominus}_{cell}$ is directly proportional to $\Delta S^{\ominus}_{total}$ and not $\Delta S^{\ominus}_{system}$*	**(1)** **Computer**

Question Number	Answer	Mark
4	**The only correct answer is C** (the reactants are thermodynamically unstable with respect to the products) ***A*** *is not correct because the reaction is thermodynamically feasible so will occur under certain conditions* ***B*** *is not correct because the* $E^{\ominus}_{cell}$ *value is a thermodynamic and not a kinetic property* ***D*** *is not correct because the reaction may be kinetically inert and the conditions may be non-standard*	**(1)** **Computer**

Question Number	Answer	Mark
5	**The only correct answer is A** ($H_2 + 2OH^- \rightarrow 2H_2O + 2e^-$) ***B*** *is not correct because hydrogen is consumed and not produced in a hydrogen-oxygen fuel cell* ***C*** *is not correct because oxygen is reduced at the positive electrode in a hydrogen-oxygen fuel cell* ***D*** *is not correct because oxygen is consumed and not produced in a hydrogen-oxygen fuel cell*	**(1)** **Computer**

Question Number	Answer	Mark
6	**The only correct answer is D** (Cu [Ar]$3d^{10}4s^1$) ***A*** *is not correct because the 4s electrons are removed before the 3d electrons* ***B*** *is not correct because the electronic configuration of chromium is* $[Ar]3d^5 4s^1$ ***C*** *is not correct because the 4s electrons are removed before the 3d electrons*	**(1)** **Computer**

Question Number	Answer	Mark
7	**The only correct answer is C** (six) ***A*** *is not correct because it only takes into account water ligands* ***B*** *is not correct because it only takes into account ethanoate ions* ***D*** *is not correct because the coordination numbers of the two chromiums have been added together*	**(1)** **Computer**

Question Number	Answer	Mark
8	**The only correct answer is A** ($[Fe(CN)_6]^{4-}$) ***B*** *is not correct because* $C_2O_4^{2-}$ *is a bidentate ligand* ***C*** *is not correct because* $EDTA^{4-}$ *is a hexadentate ligand* ***D*** *is not correct because* $NH_2CH_2CH_2NH_2$ *is a bidentate ligand*	**(1)** **Computer**

Question Number	Answer	Mark
9	**The only correct answer is A** ($[CuCl_4]^{2-}$) ***B*** *is not correct because this complex is octahedral with a bond angle of 90°* ***C*** *is not correct because this complex is linear with a bond angle of 180°* ***D*** *is not correct because this complex is square planar with a bond angle of 90°*	**(1)** **Computer**

Question Number	Answer	Mark
10	**The only correct answer is B** ($[Co(H_2O)_6]^{2+}$) ***A*** *is not correct because* VO^{2+} *is blue* ***C*** *is not correct because* $[Cr(H_2O)_6]^{2+}$ *is blue* ***D*** *is not correct because* $[Cu(H_2O)_6]^{2+}$ *is blue*	**(1)** **Computer**

Question Number	Answer	Mark
11	**The only correct answer is D** ($2Cr(OH)_3 + 3H_2O_2 + 4KOH \rightarrow 2K_2CrO_4 + 8H_2O$) ***A*** *is not correct because* $FeCl_2$ *forms a green solution* ***B*** *is not correct because this is not a redox reaction* ***C*** *is not correct because this is not a redox reaction*	**(1)** **Computer**

Question Number	Answer	Mark
12	**The only correct answer is C** ($[Cu(H_2O)_6]^{2+} + 4NH_3 \rightarrow [Cu(NH_3)_4(H_2O)_2]^{2+} + 4H_2O$) ***A*** *is not correct because this is the ionic equation describing the deprotonation when ammonia is not in excess* ***B*** *is not correct because four water ligands are exchanged by ammine ligands when ammonia is in excess* ***D*** *is not correct because four water ligands are exchanged by ammine ligands when ammonia is in excess*	**(1)** **Computer**

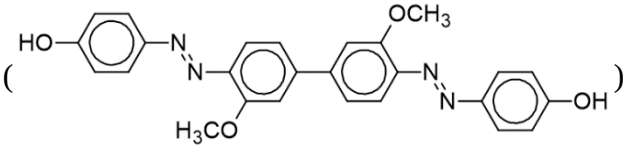
Question Number	Answer	Mark
13	**The only correct answer is A** ($[Zn(OH)_4]^{2-} + 2H_3O^+ \rightarrow [Zn(H_2O)_4(OH)_2]$) ***B*** *is not correct because* $[Zn(OH)_4]^{2-}$ *is a soluble complex ion* ***C*** *is not correct because* $[Cr(H_2O)_6]^{3+}$ *is a soluble complex ion* ***D*** *is not correct because* $[Cr(OH)_6]^{3-}$ *is a soluble complex ion*	**(1)** **Computer**

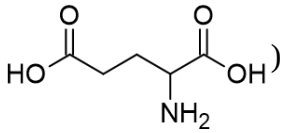
Question Number	Answer	Mark
14	**The only correct answer is C** (+5 $\rightarrow$ +4 $\rightarrow$ +5) ***A*** *is not correct because the oxidation state in* V_2O_5 *is +5 not +2* ***B*** *is not correct because the oxidation state in* V_2O_5 *is +5 not +2* ***D*** *is not correct because the vanadium cannot be oxidised from +5 to +6*	**(1)** **Computer**

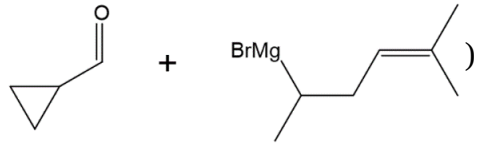
Question Number	Answer	Mark
15	**The only correct answer is C** (14) ***A*** *is not correct because each carbon contributes one electron from a p-orbital* ***B*** *is not correct because each carbon contributes one electron from a p-orbital* ***D*** *is not correct because each carbon contributes one electron from a p-orbital*	**(1)** **Computer**

Question Number	Answer	Mark
16	**The only correct answer is C** (a lone pair of electrons on oxygen in phenol is delocalised into the ring) ***A*** *is not correct because the polarity of the O-H bond does not increase the electron density of the benzene ring* ***B*** *is not correct because the electronegativity of the oxygen atom does not increase the electron density of the benzene ring* ***D*** *is not correct because there is a greater electron density in the ring in phenol than in benzene*	**(1)** **Computer**

Question Number	Answer	Mark
17	**The only correct answer is B** ($C_2H_5NH_2 \xrightarrow{C_2H_5Br}$) ***A*** *is not correct because the reduction of a nitrile forms a primary amine* ***C*** *is not correct because the products would be a tertiary amine and a quaternary ammonium salt* ***D*** *is not correct because the alkaline hydrolysis of this amide forms a primary amine*	**(1)** **Computer**

Question Number	Answer	Mark
18	**The only correct answer is D** () ***A*** *is not correct because this is not an azo dye* ***B*** *is not correct because this is not an azo dye* ***C*** *is not correct because this azo dye could only form if the reagents were not in excess*	**(1)** **Computer**

Question Number	Answer	Mark
19	**The only correct answer is B (**  **)** ***A*** *is not correct because this amino acid contains one acidic group and one basic group* ***C*** *is not correct because this amino acid contains one acidic group and two basic groups* ***D*** *is not correct because this amino acid contains one acidic group and two basic groups*	**(1)** **Computer**

Question Number	Answer	Mark
20	**The only correct answer is A (**  **)** ***B*** *is not correct because these reagents would lead to the formation of compound* ***B*** ***C*** *is not correct because these reagents would lead to the formation of compound* ***B*** ***D*** *is not correct because these reagents would lead to the formation of compound* ***B***	**(1)** **Computer**

Total for Section A = 20 marks

Section B

Question Number	Answer	Additional Guidance	Mark
21(a)	An explanation that makes reference to the following points: • (Hg^{+} is $[Xe]4f^{14}$) $5d^{10}6s^{1}$ **and** (Hg^{2+} is $[Xe]4f^{14}$) $5d^{10}(6s^{0})$ **(1)** • (d-block element as last) electron goes into a (5)d-orbital(s) (when the electronic configuration is written according to the Aufbau principle) **(1)** • (not transition element as) Hg^{+} and Hg^{2+}/(stable) ions do not have incompletely filled (5)d-orbital(s) **(1)**	Accept use of d-subshell for d-orbital(s) Allow use of d-shell for d-subshell Penalise use of just d-block for d-shell once only Penalise use of 3d/4d for 5d once only Allow Hg loses (only) its **6s** electrons (when forming ions/compounds) Do not award answer in terms of the electronic configuration of an ion of mercury Allow Hg^{+} and Hg^{2+}/(stable) ions have completely full (5)d-orbital(s) Ignore any reference to d-d transitions / other transition element properties Do not award answer in terms of the electronic configuration of the element / an Hg atom	**(3)** **Expert**

Question Number	Answer	Additional Guidance	Mark
21(b)(i)	An explanation that makes reference to the following points: • Hg/mercury oxidised **and** from 0 (in Hg) to +2 (in $Hg(NO_3)_2$) **(1)** • N/nitrogen is reduced **and** from +5 (in HNO_3) to +2 (in NO) **(1)**	Allow oxidation numbers from annotation to the equation Ignore any reference to electron loss/gain Do not award reference to oxidation of any other element Do not award HNO_3 is reduced Do not award reference to reduction of any other element If no other mark awarded, Hg/mercury oxidised **and** N/nitrogen reduced OR Hg/mercury from 0 to +2 **and** N/nitrogen from +5 to +2 scores (1)	**(2)** **Expert**

Question Number	Answer	Additional Guidance	Mark
21(b)(ii)	An answer that makes reference to the following points: • ionic half-equation for oxidation of mercury **(1)** • ionic half-equation for reduction of nitrate **(1)**	Allow multiples and ⇌ for → Ignore state symbols, even if incorrect Examples of ionic half-equations: $Hg \rightarrow Hg^{2+} + 2e^{(-)}$ Allow $Hg - 2e^{(-)} \rightarrow Hg^{2+}$ Do not award half-equation including HNO_3/NO_3^- $4H^+ + NO_3^- + 3e^{(-)} \rightarrow NO + 2H_2O$ Allow $3H^+ + HNO_3 + 3e^{(-)} \rightarrow NO + 2H_2O$ Allow $4HNO_3 + 3e^{(-)} \rightarrow NO + 2H_2O + 3NO_3^-$	**(2)** **Expert**

Question Number	Answer	Additional Guidance	Mark
21(b)(iii)	An answer that makes reference to the following point: • balanced equation	Example of completed equation: $\underline{\mathbf{3}}Hg(l) + \underline{\mathbf{8}}HNO_3(aq) \rightarrow \underline{\mathbf{3}}Hg(NO_3)_2(aq) + \underline{\mathbf{2}}NO(g) + \underline{\mathbf{4}}H_2O(l)$ Allow multiples	**(1)** **Clerical**

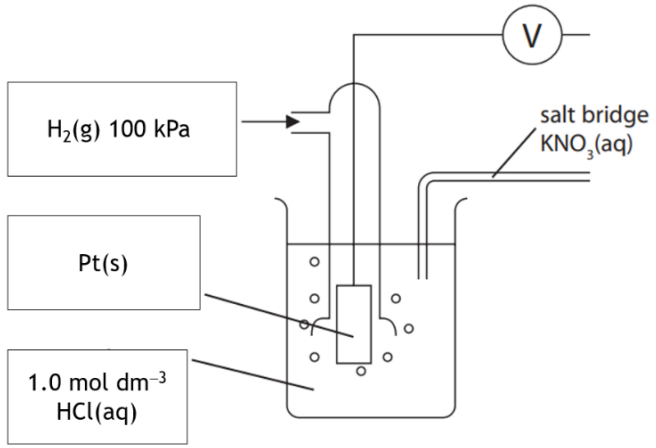
Question Number	Answer	Additional Guidance	Mark
21(c)(i)	An answer that makes reference to the following point: • correct species **(1)** • balanced equation **(1)**	Example of completed equation: $Hg(NO_3)_2 + 3C_2H_5OH \rightarrow Hg(CNO)_2 + 2CH_3CHO + 5H_2O$ Ignore state symbols even if incorrect Do not award molecular formulae eg C_2H_4O for CH_3CHO Do not award CH_3COH for CH_3CHO Allow multiples No TE on M1 except on correct molecular formulae and on CH_3COH	**(2)** **Graduate**

Question Number	Answer	Additional Guidance	Mark
21(c)(ii)	• moles of $Hg(CNO)_2$ **(1)** • moles of gas produced **(1)** • volume of gas produced **(1)**	Correct answer with some working scores (3) Ignore SF except 1SF throughout Example of calculation: $n = \frac{1.00}{284.6} = 0.0035137 / 3.5137 \times 10^{-3}$ $n = 0.0035137 \times 2 = 0.0070274 / 7.0274 \times 10^{-3}$ TE on M1 $v = 0.0070274 \times 24000 = 168.66$ (cm^3) Accept 0.16866 **dm^3** TE on M2	**(3)** **Expert**

Question Number	Answer	Additional Guidance	Mark
21(d)(i)	An answer that makes reference to the following point: • (to provide a) constant concentration (of Cl^-)	Allow KCl for Cl^- throughout Allow to keep the solution / Cl^- saturated Allow to replace Cl^- Ignore just to provide Cl^- Ignore stated concentrations Do not award salt bridge / to complete the circuit Do not award catalyst	**(1)** **Expert**

Question Number	Answer	Additional Guidance	Mark
21(d)(ii)	An answer that makes reference to the following point: • (0.24 – 0.37 =) –0.13 (V)	 Ignore working, even if incorrect	**(1)** **Expert**

Question Number	Answer	Additional Guidance	Mark
21(d)(iii)	An answer that makes reference to the following point: • $Hg_2Cl_2 + Sn \rightarrow 2Hg + Sn^{2+} + 2Cl^-$	Allow $Hg_2Cl_2 + Sn \rightarrow 2Hg + SnCl_2$ Allow multiples Allow $\rightleftharpoons$ for $\rightarrow$ Ignore state symbols even if incorrect Ignore half-equations even if incorrect Ignore use of cell diagrams Do not award uncancelled electrons Do not award $2Hg^+ (+ 2Cl^-)$ for Hg_2Cl_2 **If answer to (d)(ii) is +0.61 (V) / +0.37 (V) / greater than +0.24 (V), equation must be reversed:** $2Hg + Sn^{2+} + 2Cl^- \rightarrow Hg_2Cl_2 + Sn$ OR $2Hg + SnCl_2 \rightarrow Hg_2Cl_2 + Sn$	**(1)** **Expert**

Question Number	Answer	Additional Guidance	Mark
21(d)(iv)	An answer that makes reference to the following points: • hydrogen (gas)/H_2((g)) **and** 100 kPa **(1)** • platinum (solid)/Pt((s)) **and** 298 K / 25°C **(1)** • hydrochloric acid/HCl((aq)) **and** 1 mol dm^{-3} **(1)**	Example of completed diagram:  Allow 101 kPa / 100 000 Pa / 101 000 Pa / 1 atm / 1 bar Accept platinum black for platinum Ignore porous Ignore omission of state symbol 298 K / 25°C may be shown anywhere Allow H^+ / H_3O^+ for hydrochloric acid Allow M for mol dm^{-3} Do not award 0.5 mol dm^{-3} H_2SO_4 If no other mark awarded: hydrogen/H_2 **and** hydrochloric acid/HCl/H^+/H_3O^+ **and** platinum/Pt scores (1)	**(3)** **Graduate**

Question Number	Answer	Additional Guidance	Mark
21(d)(v)	An answer that makes reference to any one of the following points: • (calomel electrode) does not require a (separate) salt bridge OR (calomel electrode) does not require a continuous supply of hydrogen / gas OR platinum/Pt (of hydrogen electrode is) easily poisoned OR difficult to ensure hydrogen electrode is at equilibrium	Ignore calomel electrode is quicker to use / easier to set up / done in the same container / more portable Accept does not require a hydrogen / gas generator Ignore just does not require hydrogen / gas Ignore any reference to pressure Ignore hydrogen is flammable / explosive / difficult to store Ignore (calomel electrode is) safer Ignore platinum is expensive Ignore (calomel electrode) is cheaper Allow (calomel electrode) reaches equilibrium sooner Allow (calomel electrode gives) more stable (reading) Ignore (calomel electrode is) more accurate Ignore calomel electrode potential is more positive	**(1)** **Expert**

(Total for Question 21 = 20 marks)

Question Number	Answer	Additional Guidance	Mark
22	An answer that makes reference to the following points: • moles of $FeSO_4$ **(1)** • moles of excess MnO_4^- **(1)** • initial moles of MnO_4^- **and** moles of MnO_4^- reacted **(1)** • moles of $C_2O_4^{2-}$ **(1)** • mass of CaC_2O_4 **(1)** • percentage by mass of CaC_2O_4 **and** answer to 2SF or 3SF **(1)**	Correct answer to **2SF or 3SF** with some working scores (6) Ignore SF except 1SF Example of calculation: $n = 0.0500 \times \frac{25.95}{1000} = 0.0012975 / 1.2975 \times 10^{-3}$ $n = 0.0012975 \div 5 = 0.0002595 / 2.595 \times 10^{-4}$ TE on moles of $FeSO_4$ $n = 0.0100 \times \frac{50.0}{1000} = 0.0005 / 5 \times 10^{-4}$ (Allow 1 SF) **and** $n = 0.0005 - 0.0002595 = 0.0002405 / 2.405 \times 10^{-4}$ TE on moles of excess MnO_4^- provided answer is positive $n = 0.0002405 \times 2.5 = 0.00060125 / 6.0125 \times 10^{-4}$ TE on moles of MnO_4^- reacted mass = $0.00060125 \times 128.1 = 0.077020$ (g) TE on moles of $C_2O_4^{2-}$ % mass = $\frac{0.077020}{11.4} \times 100 = 0.67562$ (%) = 0.68 / 0.676 (%) TE on mass of CaC_2O_4 provided positive value to 2SF/3SF and < 100% Allow use of 128 for M_r of CaC_2O_4 giving 0.675 (%)	**(6)** **Expert**

(Total for Question 22 = 6 marks)

<table>
<tr><th>Question Number</th><th>Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr>
<td>*23</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).

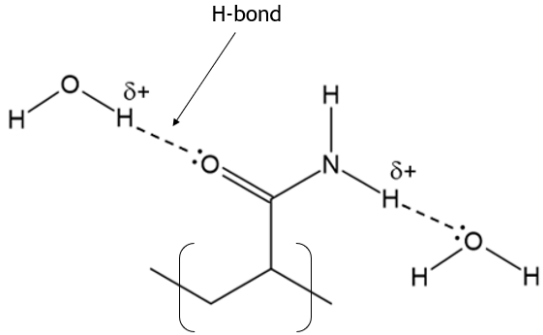
Comment: Look for the indicative marking points first, then consider the mark for the structure of the answer and sustained line of reasoning.
</td>
<td>(6)

Expert</td>
</tr>
</table>

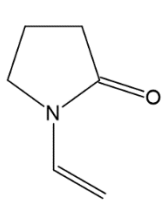
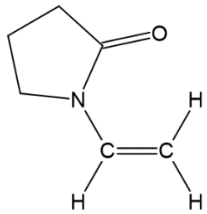
	Indicative points: • **IP1: thermochemical data calculation** (enthalpy of hydrogenation of 1,3,5-cyclohexatriene / benzene is) expected to be –360 (kJ mol^{-1}) • **IP2: thermochemical data comparison** (enthalpy of hydrogenation is) less exothermic / less negative than expected (for 1,3,5-cyclohexatriene) **less exothermic / more stable by 152 (kJ mol^{-1}) scores IP1 and IP2** • **IP3: X-ray diffraction data** (carbon-carbon) bond lengths in benzene are equal **Ignore any reference to bond strength / bond angle in IP3 and IP4** • **IP4: X-ray diffraction data** (carbon-carbon) bond length in benzene is longer than (localised) C=C (in cyclohexene) • **IP5: Bromination data** (product for benzene is formed by electrophilic) substitution • **IP6: Bromination data** (benzene π-bonds less reactive than localised π-bonds and) requires ($FeBr_3$) **catalyst** (and heat)	Allow (enthalpy of hydrogenation is) expected to be three times the value for cyclohexene Allow (enthalpy of hydrogenation is) different by 152 (kJ mol^{-1}) Accept reverse argument Ignore higher/lower for less exothermic Ignore benzene more exothermic than cyclohexene Ignore just benzene more stable than expected Do not award enthalpy required/needed Allow (carbon-carbon) bond lengths are not different Allow cyclohexene (carbon-carbon) bond lengths are different Accept (carbon-carbon) bond length is in between C=C and C–C (in cyclohexene) Allow (carbon-carbon) bond length is shorter than C–C (in cyclohexene) Allow (benzene) does not react by addition Allow cyclohexene/localised π-bonds react by addition Ignore any equations / mechanisms Do not award nucleophilic (substitution / addition) Accept cyclohexene does not require a catalyst Allow halogen carrier for catalyst Ignore just benzene does not decolourise bromine water Do not award Fe catalyst	

(Total for Question 23 = 6 marks)

Question Number	Answer	Additional Guidance	Mark
24(a)(i)	An answer that makes reference to the following point: • prop-2-enamide / 2-propenamide	Allow capital letters and spaces Ignore omission of hyphen Allow propenamide Allow 'ene' for 'en' Allow propyl for prop Do not award propan for prop Do not award N- prefix Do not award cis/trans/E/Z- prefix	**(1)** **Graduate**

Question Number	Answer	Additional Guidance	Mark
24(a)(ii)	An explanation that makes reference to the following points: • (PAM can form many) hydrogen bonds with water **(1)** • H-bonds (with water) can form at NH_2 **and** (C=)O **(1)** • diagram of (at least one) hydrogen bond between a water molecule **and** any amide group **(1)**	Allow M1 from a **labelled** diagram Ignore PAM reacts with water / acts as a base / accepts a proton from water / forms RNH_3^+ M2 can be awarded from a diagram diagram must include: H-bond to lone pair on O or N **and** δ+H atom Ignore bond angle Do not award H-bond shown as coordinate bond / solid line (ie covalent bond) Example of diagram scoring (3):  Allow H-bond between lone pair on N of NH_2 and δ+H of water	**(3)** **Expert**

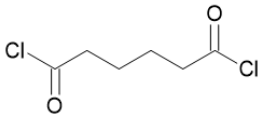
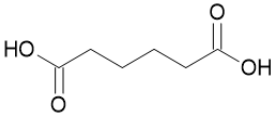
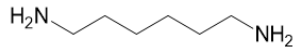
Question Number	Answer	Additional Guidance	Mark
24(a)(iii)	An explanation that makes reference to the following points: • carboxylate / COO^- (above pH 8) **(1)** • repulsion between negative charges (above pH 8) **(1)**	Allow carboxylic acid/COOH/OH groups are deprotonated / donate H^+ / become anions Allow OH^- removes H atoms involved in hydrogen bonds Ignore just PAA is deprotonated / donates H^+ / becomes anion Ignore just salt is formed Do not award zwitterion is formed Allow (COO^-) cannot form (intramolecular) hydrogen bonds Allow (all) hydrogen bonds break Ignore hydrogen bonds weaken Ignore fewer hydrogen bonds Ignore any reference to denaturation Ignore any reference to intermolecular hydrogen bonds	**(2)** **Expert**

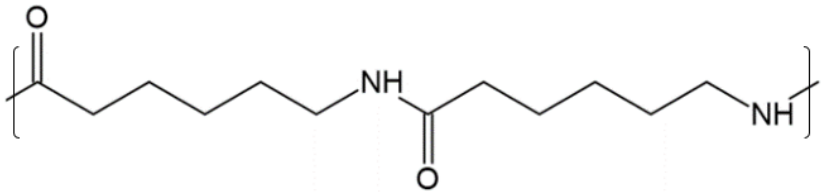
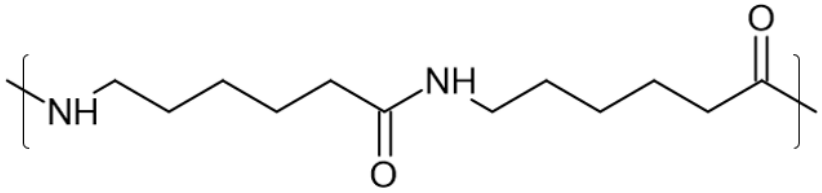
Question Number	Answer	Additional Guidance	Mark
24(b)(i)	An answer that makes reference to the following point: • structure of vinylpyrrolidone monomer	Allow any combination of skeletal, structural or displayed formulae Examples of structure:  	**(1)** **Expert**

Question Number	Answer	Additional Guidance	Mark
24(b)(ii)	An answer that makes reference to the following points: • molar mass of vinylpyrrolidone monomer / PVP repeat unit **(1)** • number of monomers per polymer **and** answer to **nearest whole** number **(1)**	Correct answer with some working scores (2) Example of calculation: $M(C_6H_9NO)$ = 111.0 / 111 (g mol^{-1}) TE on (b)(i) if molar mass is not 111.0 / 111 number = 90000 ÷ 111.0 = 810.81 = 811 TE on M1	**(2)** **Expert**

Question Number	Answer	Additional Guidance	Mark
24(b)(iii)	An answer that makes reference to the following points: • mass of PVP per tablet **(1)** • number of moles of PVP polymer **(1)** • number of molecules of PVP polymer **(1)**	Correct answer with some working scores (3) Example of calculation: mass = $\frac{0.740}{100} \times 4.0 = 0.0296$ (g) Accept 29.6 (mg) Ignore SF except 1 SF moles = $0.0296 \div 90000 = 3.2889 \times 10^{-7}$ Allow 3.2889×10^{-4} **m mol** TE on M1 Ignore SF except 1 SF molecules = $3.2889 \times 10^{-7} \times 6.02 \times 10^{23} = 1.9799 \times 10^{17}$ Accept 2.0×10^{17} / 2×10^{17} TE on M2 (from any M_r value) Ignore SF Do not award multiplication of N_A by mass	**(3)** **Expert**

Question Number	Answer	Additional Guidance	Mark
24(c)(i)	An answer that makes reference to the following points: • (polymer is a very) large molecule OR (polymer is formed from) large number of / many monomers **(1)** • (condensation as) splitting off of a (small) molecule **(1)**	Allow long-chain (molecule) Allow macromolecule Allow repeating for many Ignore 2 or more / several / different for many Ignore (formed by) addition Allow with loss/elimination of H_2O/HCl Ignore forms byproduct	**(2)** **Expert**

Question Number	Answer	Additional Guidance	Mark
24(c)(ii)	An answer that makes reference to the following points: • structure of hexanedioyl dichloride **(1)** • structure of hexane-1,6-diamine **(1)**	Accept monomers in either order Allow any combination of skeletal, structural or displayed formulae If more than one type of formula shown, all must be correct Penalise errors in chain length once only Ignore connectivity in structural formulae eg Allow $COClCH_2$… / $COOHCH_2$… / NH_2CH_2… eg Allow $C{=}OCl{-}CH_2$… / $C{=}OOH{-}CH_2$… / $NH_2{-}CH_2$… Penalise connectivity in skeletal / displayed formulae once only Allow structure of hexanedioic acid Examples of correct structures: $ClOCCH_2CH_2CH_2CH_2COCl$ / $ClOC(CH_2)_4COCl$  $HOOCCH_2CH_2CH_2CH_2COOH$ / $HOOC(CH_2)_4COOH$  $H_2NCH_2CH_2CH_2CH_2CH_2CH_2NH_2$ / $H_2N(CH_2)_6NH_2$  	**(2)** **Expert**

Question Number	Answer	Additional Guidance	Mark
24(c)(iii)	An answer that makes reference to the following points: • amide linkage (within polymer chain) **(1)** • **two** repeat units **(1)**	Allow any combination of skeletal, structural or displayed formulae Allow –NHCO– / –CONH– / –HNCO– / –OCNH– Ignore omission of square brackets Ignore *n* Examples of **two** repeat units:  –$CO(CH_2)_5NHCO(CH_2)_5NH$–  –$NH(CH_2)_5CONH(CH_2)_5CO$–	**(2)** **Expert**

(Total for Question 24 = 18 marks)

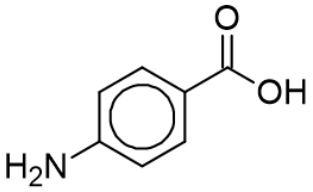
Total for Section B = 50 marks

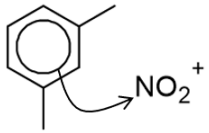
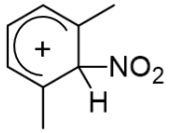
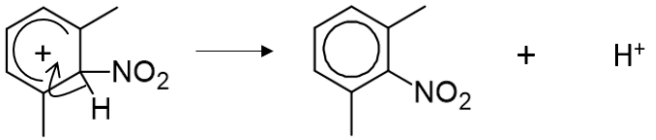
Section C

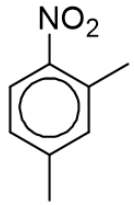
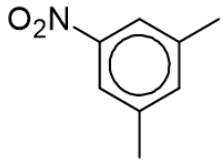
Question Number	Answer	Additional Guidance	Mark
25(a)	An answer that makes reference to the following points: • ester **(1)** • (primary) amine **and** arene/benzene/phenyl OR phenylamine **(1)**	Ignore any structures / formulae Ignore carbonyl Do not award ketone / aldehyde / carboxylic acid Do not award ether Allow amino Allow aryl Ignore alkyl/alkane Do not award alkene Do not award phenol Allow aniline Allow aromatic amine	**(2)** **Graduate**

Question Number	Answer	Additional Guidance	Mark
25(b)(i)	An answer that makes reference to the following points: • molecular formulae of procaine and HCl **(1)** • molecular formula of procaine monohydrochloride **(1)**	**Ignore non-molecular formulae** $C_{13}H_{20}N_2O_2$ + HCl Allow elements in any order $C_{13}H_{21}Cl^{(-)}N_2^{(+)}O_2$ Allow elements in any order TE on molecular formula of procaine Ignore position of charges Do not award separate $C_{13}H_{21}N_2^+O_2$ and Cl^- ions Do not award any additional product(s) Example of equation: $C_{13}H_{20}N_2O_2 + HCl \rightarrow C_{13}H_{21}ClN_2O_2$ scores (2)	**(2)** **Graduate**

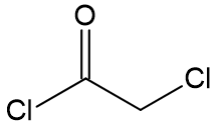
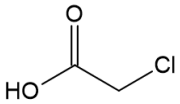
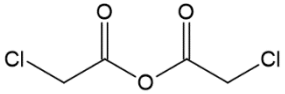
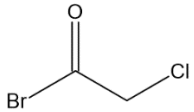
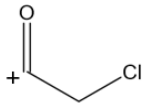
Question Number	Answer	Additional Guidance	Mark
25(b)(ii)	An explanation that makes reference to the following points: • identification of tertiary amine nitrogen **and** effect of ethyl groups OR benzene ring EITHER ethyl / alkyl (groups) are electron donating OR lone pair (on N of NH_2 partially) delocalised into (aromatic) π-bond(s) **(1)** • second effect **(1)**	Ignore just comparison of electron density on N atoms Ignore just comparison of ability of (N) lone pairs to accept H^+ Accept any unambiguous identification Accept ethyl / alkyl has positive inductive effect Allow ethyl / alkyl are electron pushing / electron releasing Allow methyl / R / attached groups for ethyl / alkyl Accept non-bonding pair for lone pair Allow electron pair for lone pair Allow overlaps with / interacts with / released into / drawn into for delocalised into Allow p-orbitals / ring for (aromatic) π-bond(s) Ignore just benzene for (aromatic) π-bond(s) Ignore just ring is electron withdrawing (with no mention of electron pair) If no other mark awarded, tertiary / aliphatic amine is more basic OR aromatic / primary amine is less basic scores (1)	**(2)** **Expert**

Question Number	Answer	Additional Guidance	Mark
25(c)	An answer that makes reference to the following point: • structure of 4-aminobenzoic acid	Allow any combination of skeletal, structural or displayed formulae Example of structure:  Allow Kekulé benzene Allow protonation of $-NH_2$ to $-NH_3^+$ Allow deprotonation of $-COOH$ to $-COO^-$ Allow zwitterion Do not award any other hydrolysis product	**(1)** **Expert**

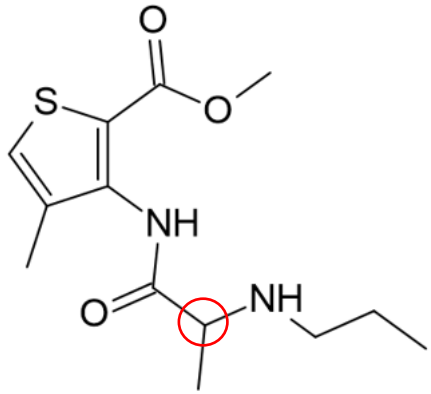
Question Number	Answer	Additional Guidance	Mark
25(d)(i)	An answer that makes reference to the following points:	**Ignore omission or incorrect placement of methyl groups in M2 and M3**	**(4)** **Expert**
	• equation for formation of nitronium ion **(1)**	$HNO_3 + H_2SO_4 \rightarrow NO_2^+ + HSO_4^- + H_2O$ OR $HNO_3 + 2H_2SO_4 \rightarrow NO_2^+ + 2HSO_4^- + H_3O^+$ OR $HNO_3 + H_2SO_4 \rightarrow H_2NO_3^+ + HSO_4^-$ **and** $H_2NO_3^+ \rightarrow NO_2^+ + H_2O$	
	• curly arrow from within hexagon to anywhere on NO_2^+ **(1)**	 TE on electrophile from M1 provided positively charged Do not award lone pair on N of NO_2^+	
	• structure of intermediate ion **(1)**	 Allow any part of gap in 'horseshoe' facing tetrahedral carbon and covering at least three carbons with some part of positive sign within 'horseshoe'. 'Horseshoe' may be dashed TE on electrophile from M2 Do not award NO_2–C connectivity Do not award dashed C–H and C–N bonds unless 3D structure	
	• curly arrow from C–H bond to within ring **and** correct product **and** H^+ **(1)**		

Question Number	Answer	Additional Guidance	Mark
25(d)(ii)	An answer that makes reference to the following points: • structure of 2,4-dimethylnitrobenzene **(1)** • structure of 3,5-dimethylnitrobenzene **(1)**	Allow structures with di-, tri- or tetranitro substitution Ignore connectivity of NO_2 group Penalise omission of delocalised ring once only Examples of structures:   	**(2)** **Graduate**

Question Number	Answer	Additional Guidance	Mark
25(d)(iii)	An answer that makes reference to the following point: • tin and (concentrated) hydrochloric acid	Accept Sn and HCl((aq)) Ignore heat / reflux Ignore NaOH in second step Do not award NaOH with Sn and HCl in the same step Do not award any reference to catalyst	**(1)** **Graduate**

Question Number	Answer	Additional Guidance	Mark
25(d)(iv)	An answer that makes reference to the following point: • skeletal formula of 2-chloroethanoyl chloride	Ignore non-skeletal formulae Ignore bond angles and bond lengths  Allow skeletal formula of 2-chloroethanoic acid  Ignore OH connectivity Allow skeletal formula of 2-chloroethanoic anhydride  Allow skeletal formula of 2-chloroethanoyl bromide  Do not award skeletal formula of 2-chloroethanoyl cation  	**(1)** **Graduate**

Question Number	Answer	Additional Guidance	Mark
25(d)(v)	An answer that makes reference to the following point: • nucleophilic substitution	Allow S_N2 / S_N1 Do not award any other answer	**(1)** **Clerical**

Question Number	Answer	Additional Guidance	Mark
25(e)	An answer that makes reference to the following point: • indication of chiral centre	 articaine Allow any indication Do not award any other answer	**(1)** **Graduate**

Question Number	Answer	Additional Guidance	Mark
25(f)	An answer that makes reference to the following points: • number of half-lives in 4 hours **(1)** • mass of articaine remaining in mg **(1)** • conversion of mg to μg **(1)**	Example of calculation: half-lives = $\frac{(4 \times 60)}{20} = 12$ mass = $100 \times 0.5^{12} = 0.024414$ (mg) TE on M1 Ignore SF except 1SF mass = $0.024414 \times 1000 = 24.414$ (μg) TE on M1 and M2	**(3)** **Expert**

(Total for Question 25 = 20 marks)

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

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