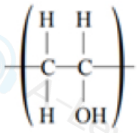
Question Number	Answer
14	**The only correct answer is B**  ***A*** *is incorrect because (poly)ethenol only has one OH in each repeat unit* ***C*** *is incorrect because (poly)ethenol only has one OH in each repeat unit* ***D*** *is incorrect because (poly)ethenol only has one OH in each repeat unit*

Question number	Answer	Mark
14	**The only correct answer is D (**  and  **)** **A** *is incorrect because amines do not react with carboxylic acids* **B** *is incorrect because amides do react to form polyamides* **C** *is incorrect because this pair of monomers will not produce the required polyamide*	**(1)**

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**

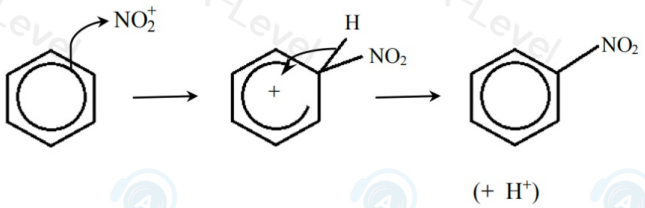
Question Number	Answer	Mark
3	**The only correct answer is B** ($O_2(g) + 2H_2O(l) + 4e^- \rightarrow 4OH^-(aq)$) ***A*** *is incorrect because this is the equation for the overall reaction* ***C*** *is incorrect because this is an equation for a neutralisation reaction* ***D*** *is incorrect because this reaction produces hydrogen and oxygen*	**(1)**

Question number	Answer	Mark
15(a)	**The only correct answer is A** ($NaNO_2$ and HCl at 5 °C) ***B*** *is incorrect because $NaNO_3$ does not react with HCl to form the nitrous acid needed for the formation of benzenediazonium ions* ***C*** *is incorrect because nitrous acid and benzenediazonium ions decompose at 50°C* ***D*** *is incorrect because $NaNO_3$ does not react with HCl to form the nitrous acid needed for the formation of benzenediazonium ions and nitrous acid and benzenediazonium ions decompose at 50°C*	**(1)**

Question number	Answer	Mark
15(b)	**The only correct answer is B** ( in alkaline solution) ***A*** *is incorrect because alkaline conditions are needed to form an azo dye* ***C*** *is incorrect because the OH group is in the wrong position and alkaline conditions are needed to form an azo dye* ***D*** *is incorrect because the OH group is in the wrong position*	**(1)**

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

Question Number	Answer	Additional Guidance	Mark
14(a)(i)	An explanation that makes reference to the following points: • concentrated / conc sulfuric acid concentrated / conc H_2SO_4 **(1)** • nitronium ion / NO_2^+ **(1)**	If name and formula are given both must be correct Do not award (dilute) sulfuric acid Allow balanced or unbalanced equation to form / NO_2^+ Do not award NO_2 without charge If no electrophile is given in (a)(i) allow the mark if NO_2^+ is used in the mechanism in (a)(ii) Allow answers in any order	**(2)**

Question Number	Answer	Additional Guidance	Mark
14(a)(ii)	• arrow from on or within the circle to N of NO_2^+ **(1)** • structure of intermediate ion **(1)** • curly arrow from C–H bond to within ring and correct organic product **(1)**	Example of mechanism  (+ H^+) Allow arrow from within hexagon Allow to anywhere on NO_2 including positive charge Allow TE on incorrect electrophile from (a)(i) 'Horseshoe' facing tetrahedral carbon and covering at least three carbons. Some part of the positive sign within the horseshoe. Do not award dotted/dashed C–H/C–N bonds unless clearly a 3D structure	**(3)**

Question Number	Answer	Additional Guidance	Mark
14(b)(i)	An answer that makes reference to the following points: • tin / Sn **and** (concentrated / conc) hydrochloric acid / HCl(aq)	If name and formula are given both must be correct Allow HCl Do not award other acids Ignore concentration even if incorrect	**(1)**

Question Number	Answer	Additional Guidance	Mark
14(b)(ii)	An answer that makes reference to the following point: • reduction	Accept redox Ignore hydrogenation	**(1)**

<table>
<tr><th>Question Number</th><th>Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td>*14(c)</td><td>This question assesses the student's ability to show a coherent and logically structured answer with linkages and fully sustained reasoning.

Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.

The following table shows how the marks should be awarded for indicative content.
<table>
<tr><td>Number of indicative marking points seen in answer</td><td>Number of marks awarded for indicative marking points</td></tr>
<tr><td>6</td><td>4</td></tr>
<tr><td>5-4</td><td>3</td></tr>
<tr><td>3-2</td><td>2</td></tr>
<tr><td>1</td><td>1</td></tr>
<tr><td>0</td><td>0</td></tr>
</table>
The following table shows how the marks should be awarded for structure and lines of reasoning
<table>
<tr><td></td><td>Number of marks awarded for structure of answer and sustained lines of reasoning</td></tr>
<tr><td>Answer shows a coherent logical structure with linkages and fully sustained lines of reasoning demonstrated throughout</td><td>2</td></tr>
<tr><td>Answer is partially structured with some linkages and lines of reasoning</td><td>1</td></tr>
<tr><td>Answer has no linkages between points and is unstructured</td><td>0</td></tr>
</table></td><td>Guidance on how the mark scheme should be applied.

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

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

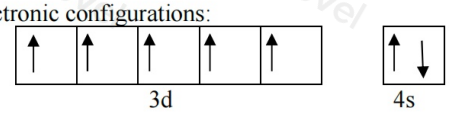
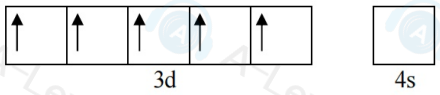
In general it would be expected that
5 or 6 indicative points would get 2 reasoning marks
3 or 4 indicative points would get 1 reasoning mark
0, 1 or 2 indicative points would get zero reasoning marks

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

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

	Indicative content	Allow reverse arguments For IPs 1-5. award IPs if not attributed to an advantage or disadvantage to a maximum of 5 IPs For IPs 1-5, award IPs if attributed incorrectly to advantage or disadvantage, but deduct one reasoning mark	
	IP1 hazard advantage HCl produced by ethanoyl chloride is toxic (but ethanoic acid is not) / ethanoic acid is not toxic / poisonous (but HCl is)	Allow hydrogen chloride may be produced as a corrosive mist (and is hard to handle / control) Allow hydrogen chloride means the reaction must be used in a fume cupboard	
	IP2 hazard disadvantage ethanoic acid (produced by ethanoic anhydride) is flammable (but hydrogen chloride is not)	Allow this is neutral because both ethanoyl chloride (and ethanoic anhydride are) also flammable	
	IP3 hazard disadvantage ethanoic anhydride is toxic / poisonous (but ethanoyl chloride is not)	Ignore comments about other hazards unless incorrect, then penalise in logic mark	
	IP4 reactivity (advantage) ethanoyl chloride might cause further reactions / side reactions / is harder to control or (advantage) ethanoic anhydride is slower so easier to control or (disadvantage) ethanoic anhydride would be slower / be too slow / have a lower rate	Ignore just ethanoyl chloride is more dangerous Accept ethanoyl chloride is too reactive / unsafe	

	IP5 atom economy calculation either calculation of atom economy for ethanoic anhydride and ethanoyl chloride or calculation of the molecular mass of HCl and ethanoic acid and a link to the lower mass giving the higher atom economy	Ignore sale of the other product ethanoic anhydride = 69.231 / 69.2 % and ethanoyl chloride = 78.717 / 78.7 % Or Mr ethanoic acid = 60 and HCl = 36.5 so ethanoyl chloride gives higher atom economy	
	IP6 atom economy statement	Ignore sale of the other product	

Question Number	Answer	Additional Guidance	Mark
20(a)(i)	• both electronic configurations correct	Examples of electronic configurations: Mn atom: [Ar]  3d 4s Mn^{2+} ion: [Ar]  3d 4s Allow half-arrows Allow all arrows pointing downwards in 3d subshell	(1)

Question Number	Answer	Additional Guidance	Mark
20(a)(ii)	An explanation that makes reference to the following points: • there is stability associated with a half-full set of (3)d orbitals **(1)** • Mn^{2+} has five d electrons so is more stable than Mn^{3+} (and has a higher $E^{\ominus}$ value) **(1)** • Fe^{2+} has six d electrons so is less stable than Fe^{3+} (and has a lower $E^{\ominus}$ value) **(1)** If M2 and M3 not awarded then allow 1 rescue mark for two correct electronic configuration from Mn^{3+} = [Ar] $3d^4$ Fe^{2+} = [Ar] $3d^6$ Fe^{3+} = [Ar] $3d^5$ If more than two electronic configurations are given and one is incorrect then do not award the rescue mark	Allow reverse argument Allow 3d subshell with 5 electrons as alternative for half-filled Allow Mn^{2+} has five d electrons so eqm moves to RHS / Mn^{2+} has five d electrons so is energetically more favourable / more energy needed to remove an electron from Mn^{2+} as it has five d electrons Allow Fe^{3+} is more stable as it has a half-filled subshell so Fe^{2+} tends to lose electrons, (making $E^{\ominus}$ less positive) Allow Fe^{2+} has a pair of electrons (in a d orbital) that repel so is less stable than Fe^{3+} (and has a lower $E^{\ominus}$ value)	(3)

Question Number	Answer	Additional Guidance	Mark
20(b)(i)	An explanation that makes reference to the following points: • Mn **reduced** from (+)4 to (+)2 **(1)** • Cl **oxidised** from −1 to 0 **and** in Cl_2 **(1)**	Allow oxidation numbers shown under equation Allow Mn^{4+} and Mn^{2+} Allow Cl^- **Comments:** 0 must be linked to Cl_2 If no other mark is awarded, allow (1) for all oxidation numbers of Mn and Cl correct	(2)

Question Number	Answer	Additional Guidance	Mark
20(b)(ii)	• calculation of mol O_2 **(1)** • calculation of concentration of H_2O_2 **(1)**	Example of calculation: Mol of O_2 = $\frac{86.0}{24000}$ = 0.0035833 / 3.5833 x 10^{-3} (mol) Mol H_2O_2 = 2 x 0.0035833 = 0.0071667 / 7.1667 x 10^{-3} (mol) **and** Conc H_2O_2 = $\frac{0.0071667 \times 1000}{100}$ = 0.071667 / 7.1667 x 10^{-2} (mol dm^{-3}) TE on mol O_2 Ignore SF except 1 SF Comment – if M1 is rounded to 0.00358 and carried through into M1 and M2, this gives a final answer of 0.0716	**(2)**

Question Number	Answer	Additional Guidance	Mark
20(c)	• correct balanced equation	Example of equation: $3MnO_4^{2-} + 4H^+ \rightarrow 2MnO_4^- + MnO_2 + 2H_2O$ Allow multiples Allow reversible arrows provided reactants as shown are still on LHS Allow uncancelled electrons on either side Ignore state symbols even if incorrect Ignore oxidation states above atoms, even if incorrect	**(1)**

Question Number	Answer	Additional Guidance	Mark
20(d)	An explanation that makes reference to the following points: • this reaction is (auto)catalysed by the Mn^{2+} ions formed **(1)** • (the reaction in) experiment 1 starts slowly because there is no Mn^{2+} / catalyst present initially (but speeds up as Mn^{2+} ions are formed) **(1)** • (the reaction in) experiment 2 is fast(est) at the start as Mn^{2+} ions / catalyst (already) present **(1)**	Mn^{2+} can be mentioned at any point Allow experiment 1 starts slowly but speeds up as Mn^{2+} / catalyst forms Allow rate decreases constantly as Mn^{2+} ions / catalyst (already) present	**(3)**

Question Number	Answer	Additional Guidance	Mark
20(e)(i)	• calculation of mol of $KMnO_4$ **(1)** • calculation of mol of $C_6H_5CH_3$ **(1)** • $KMnO_4$ is in excess because there are more than twice as many mol of $KMnO_4$ than mol of $C_6H_5CH_3$ **(1)**	Example of calculation: Mol $KMnO_4 = \frac{7.00}{158} = 0.044304$ (mol) Mol $C_6H_5CH_3 = \frac{1.73}{92} = 0.018804$ (mol) Accept 0.044304 mol $KMnO_4$ would react with 0.022152 mol $C_6H_5CH_3$ or reverse argument TE on M1 and M2 Allow other methods e.g. Mol $C_6H_5CH_3 = \frac{1.73}{92} = 0.018804$ (mol) (1) Minimum mass of $KMnO_4$ needed = 2 x 0.018804 x 158 = 5.9421 (g) (1) This is less than 7 g so $KMnO_4$ is in excess (1) Ignore SF except 1 SF in M1 and M2	**(3)**

Question Number	Answer	Additional Guidance	Mark
20(e)(ii)	• add H^+ ions / acidify the solution / mixture	Allow correct name or formula of any strong acid e.g. HCl, H_2SO_4, HNO_3, H_3PO_4 Do not award carboxylic acids e.g. CH_3COOH Allow $C_6H_5CO_2^- + H^+ \rightarrow C_6H_5COOH$ Ignore references to concentration / heat / reflux Do not award 'acid hydrolysis' / acid catalyst / H^+ ions from water / inclusion of a second incorrect reagent e.g. H^+ and $LiAlH_4$	**(1)**

Question Number	Answer	Additional Guidance	Mark
20(f)(i)	• anode half-equation **(1)** • cathode half-equation **(1)**	Examples of equations: $Zn + 2OH^- \rightarrow ZnO + H_2O + 2e^-$ $2MnO_2 + H_2O + 2e^- \rightarrow Mn_2O_3 + 2OH^-$ Allow multiples / reversible arrows Ignore state symbols even if incorrect If no other mark is awarded allow (1) for anode and cathode half-equations written in wrong places If no other mark awarded allow 1 mark for Zn on the left-hand side of the anode reaction **and** MnO_2 on the left-hand side of the cathode reaction	**(2)**

Question Number	Answer	Additional Guidance	Mark
20(f)(ii)	• $(E^\ominus = +)0.15$ (V)	Do not award – 0.15(V)	**(1)**

(Total for Question 20 = 19 marks)
(Total for Section C = 19 marks)