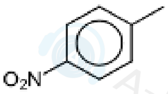
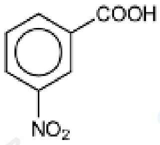
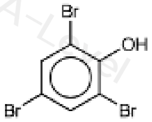
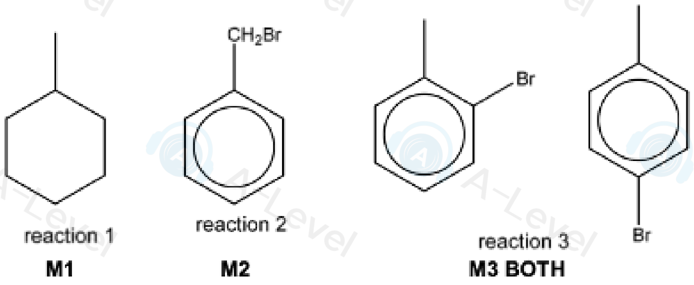
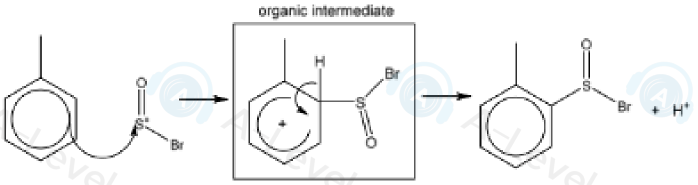
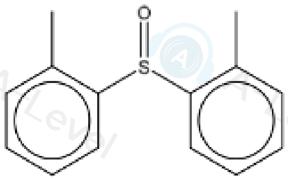
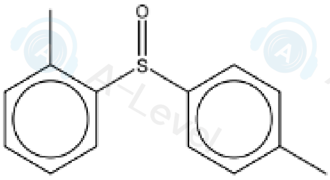
Question	Answer	Marks
1(a)(i)	oxidising agent [1] H_2O_2 + **$2H^+$** + $2I^-$ → $2H_2O$ + I_2 [1]	2
1(a)(ii)	M1: K_{pc} (93.8) = [I_2(cyclohexane)] ÷ [I_2(aq)] 93.8 = (0.390 / 15) ÷ (x / 20) M2: mass of I_2(aq), x = **5.54×10^{-3}** (g) ecf	2
1(a)(iii)	• K_{pc} would be lower • hexan-2-one is **more** polar (than cyclohexane) **OR** hexan-2-one is polar **AND** cyclohexane is non-polar • I_2 is (therefore) less soluble in hexan-2-one *All three correct for two marks*	2
1(b)(i)	enthalpy change when one mole of a solute **AND** dissolves **in water** to form a solution of infinite dilution	1
1(b)(ii)	–(–629) + (–322) + (–293) = **(+)14** (kJ mol^{-1})	1
1(b)(iii)	(cationic) charge density decreases Li^+ to K^+ [1] so lattice energies become less negative / less exothermic **AND** because less **attraction** between ions [1]	2
1(c)(i)	M1: moles of thiosulfate = 0.02230 × 0.150 = 3.345×10^{-3} M2: [Cu^{2+}] = 2 × ½ × 3.345×10^{-3} ÷ 0.0250 = **0.134** (mol dm^{-3}) ecf	2
1(c)(ii)	starch	
1(c)(iii)	 $3d_{xy}$	1
1(d)	*Reduction of Fe^{3+}:* $2Fe^{3+} + 2I^- \rightarrow 2Fe^{2+} + I_2$ [1] *Regeneration of Fe^{3+}:* $2Fe^{2+} + S_2O_8^{2-} \rightarrow 2Fe^{3+} + 2SO_4^{2-}$ [1]	2

Question	Answer	Marks
1(e)	M1: ([Hg^{2+}]) = 1.00×10^{-7} ÷ 454.4 = 2.20×10^{-10} (mol dm^{-3}) M2: K_{sp} = [Hg^{2+}][I^-]^2 = 4[Hg^{2+}]^3 = **4.26×10^{-29}** ecf M3: units = $mol^3\ dm^{-9}$ ecf	3

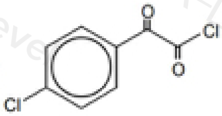
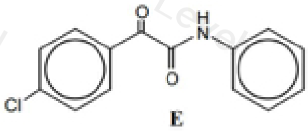
Question	Answer	Marks
4(a)(i)	In **F**: (phenyl)amine **AND** carboxylic acid In **J**: phenol **AND** ester *Any two for one mark* *All four for two marks*	**2**
4(a)(ii)	0 (zero) in **F AND** 2 (two) in **J**	**1**

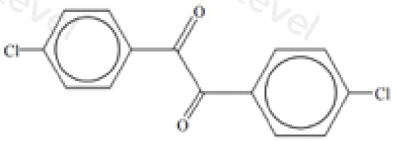
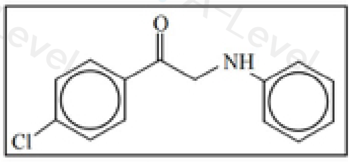
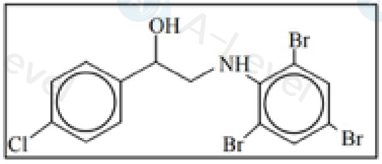
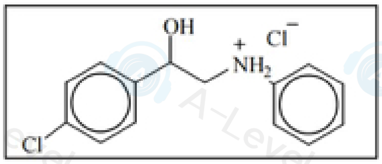
Question	Answer	Marks
4(b)(i)	step 1 CH_3Cl **AND** $AlCl_3$ [1] step 2 **D** =  [1] step 4 (hot) Sn **AND** concentrated **AND** HC*l* [1]	**3**
4(b)(ii)	 [1] COOH group is electron-withdrawing group and 3,5-/meta- directing [1]	**2**
4(c)(i)	$C_9H_{10}O$	**1**
4(c)(ii)	hydrolysis [1] acid–base / neutralisation [1]	**2**
4(d)(i)	$C_6H_5OH + Na \rightarrow C_6H_5O^{(-)}Na^{(+)} + \frac{1}{2}H_2$	**1**
4(d)(ii)		**1**
4(d)(iii)	• (CO)O—H bond **weaker** / more easy to donate H^+ in **K** • owing to negative inductive / electron withdrawing effect of C=O / COOH group • carboxylate anion stabilised / phenoxide anion is less stabilised *All three for two marks*	**2**

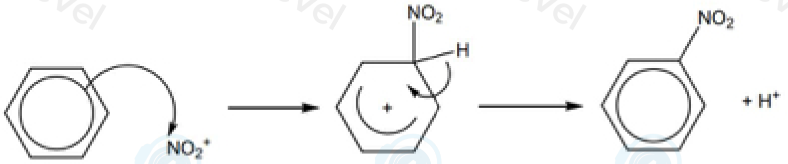
Question	Answer	Marks
5(a)(i)	 	3
5(a)(ii)	**M1** reaction 1: hydrogenation / reduction **M2** mechanism 2: (free) radical substitution	2
5(b)	the substitution product is stabilised by delocalization of π-electrons / by π-electrons in the ring **OR** the addition product is **not** stabilised by delocalisation (of π-)electrons **ALLOW** addition product will remove π-electron delocalised system	1

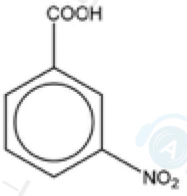
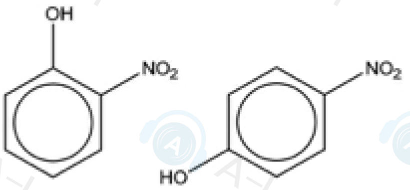
Question	Answer	Marks
5(c)(i)	 **M1** curly arrow from inside the hexagon to S atom **M2** structure of the intermediate **M3** curly arrow from C-H bond into the ring **AND** formation/loss of H$^+$	3
5(c)(ii)	 **OR**  	1
5(d)(i)	$CH_3COOH + SOBr_2 \rightarrow CH_3COBr + HBr + SO_2$	1

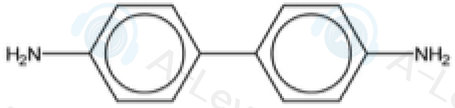
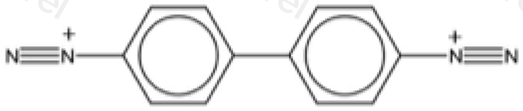
Question	Answer	Marks
5(d)(ii)	**M1** acyl bromides easiest > acyl chlorides > alkyl chlorides hardest **M2 M3** *Any two from:* *Acyl bromides easiest* • in acyl bromides C–Br is much weaker **ORA AND** due to less orbital overlap / Br having a larger atomic radii *Acyl halides easier than alkyl chlorides* • carbon in C–Cl / C–Br / C–X bond is more δ+/electron deficient **OR** C–Cl / C–Br bond is weaker (than C-Cl in alkyl chlorides) **AND** attached to an oxygen atom / two electronegative atoms / electron withdrawing C=O group **ORA** *alkyl chlorides hardest* • in alkyl chlorides C–Cl bond strengthened **AND** by positive inductive effect / electron donating effect of alkyl / R group	3

Question	Answer	Marks
7(a)(i)	$HO_2C–CO_2H$ OR $HO_2C–COCl$	1
7(a)(ii)	$SOCl_2$ OR PCl_5	1
7(b)(i)	**B**  **D**  **C**   **E**	4
7(b)(ii)	**M1** step 1: Cl_2 + $AlCl_3$ **M2** step 3: conc. HNO_3 + H_2SO_4 **M3** step 4: Sn + conc. HCl **M4** step 6: $LiAlH_4$ **M5** *any two of:* heat / $T \geqslant 60$ °C / reflux for step 1 $T \leqslant 60$ °C / warm for step 3 heat / $T \geqslant 60$ °C / reflux for step 4	5

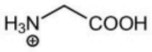
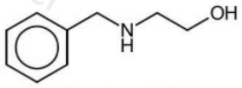
Question	Answer	Marks
7(b)(iii)		1
7(b)(iv)	steps 1, 2 and 3	1
7(c)	 no reaction  	4

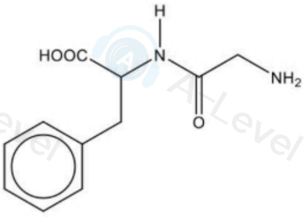
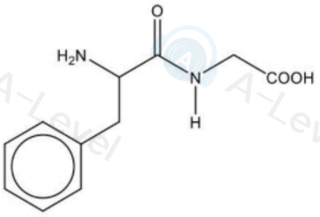
Question	Answer	Marks
6(a)(i)	 **M1** first curly arrow from within hexagon to N of the NO_2^+ **M2** correct intermediate **M3** second curly arrow from C-H bond into the ring **AND** H^+ formed / lost	3
6(a)(ii)	$HSO_4^- + H^+ \rightarrow H_2SO_4$	1

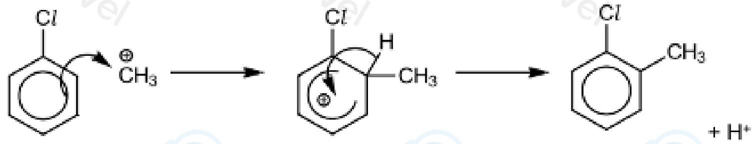
Question	Answer	Marks
6(b)	**M1** *benzoic acid* **M2** *phenol*   **OR**	2
6(c)	**M1** phenol > benzene > benzoic acid **M2** / **M3** phenol: - lone pair / p-orbital on oxygen delocalises into the ring / overlaps with π-delocalised ring - accepts / attracts / polarises NO_2^+ / electrophiles better benzoic acid: - COOH / C=O is an electron-withdrawing / positive inductive effect two for one mark, three for two marks **M4** (phenol-oxygen) increases electron density in the ring *(as compared to benzene as a result of the OH group)* **OR** (benzoic acid–COOH) decreases electron density in the ring *(as compared to benzene as a result of the COOH group)*	4

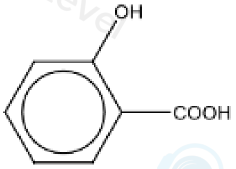
Question	Answer	Marks
6(d)(i)	**X**  **Z**  	3

Question	Answer	Marks
4(a)	chlorine **AND** hydrogen [1]	1
4(b)	$15 \times 60 \times 0.75 = 675$ C [1] $675 / 96\,500 = 7.0 \times 10^{-3}$ moles e^- [1] $7.0 \times 10^{-3} \times 0.25$ gives 1.75×10^{-3} moles O_2 $1.75 \times 10^{-3} \times 24000 = 42$ (41.969) cm^3 O_2 [1] **OR** $15 \times 60 \times 0.75 = 675$ C [1] $675 / 1.60 \times 10^{-19} = 4.22 \times 10^{21}$ e^- $= 7.01 \times 10^{-3}$ moles e^- [1] gives 1.75×10^{-3} moles $O_2 = 42$ (42.047) cm^3 [1]	3
4(c)(i)	1.36 1.07 0.54 [1]	1
4(c)(ii)	all of them [1] (all $E^\ominus$ values) greater than 0.15 / $E^\ominus_{cell}$ greater than zero [1] e.g. $Sn^{2+} + X_2 \rightarrow Sn^{4+} + 2X$ [1]	3
4(c)(iii)	MnO_2 [1]	1
4(d)(i)	1.24 V [1]	1
4(d)(ii)	platinum, platinum [1]	1
4(d)(iii)	increase $[Fe^{2+}]$ or decrease $[Fe^{3+}]$ increase $[S_2O_8^{2-}]$ or decrease $[SO_4^{2-}]$ [1]	1

Question	Answer	Marks
6(a)(i)	**pH** at which a molecule has no overall charge / is neutral/ is a Zwitterion / charges cancel out	1
6(a)(ii)		1
6(b)(i)	ethanol **AND** heat in a sealed tube **OR** ethanol **AND** high pressure	1
6(b)(ii)	C_6H_5COCl / benzoyl chloride / benzoyl anhydride	1
6(b)(iii)	 • carboxylic acid to primary alcohol COOH to CH_2OH • amide to amine CONH to CH_2NH • rest of the molecule is correct (carbons and benzene ring) mark as • ✓ ✓	2

<table>
<tr><th>Question</th><th>Answer</th><th>Marks</th></tr>
<tr><td>6(b)(iv)</td><td> </td><td>2</td></tr>
<tr><td rowspan="2">6(c)(i)</td><td>M1 nitrogen lone pair in amides is delocalised with C=O</td><td>1</td></tr>
<tr><td>M2 lone pair less available for donation / to accept H^+
OR less electron density on N / NH_2 so less able to accept H^+</td><td>1</td></tr>
<tr><td rowspan="2">6(c)(ii)</td><td>chloroethanoic acid is a stronger acid (than ethanoic acid)</td><td>1</td></tr>
<tr><td>because electron-withdrawing (–I / inductive) effect of C<i>l</i> substituent
AND weakens O—H / carboxylate anion stabilised</td><td></td></tr>
<tr><td>6(d)(i)</td><td>
<table>
<tr><td>proton</td><td>a</td><td>b</td><td>c</td><td>d</td><td></td></tr>
<tr><td>δ</td><td>9.0–13.0</td><td>6.0–9.0</td><td>2.3–3.0</td><td>3.2–4.0</td><td>1.0–5.0</td></tr>
<tr><td>splitting</td><td>singlet</td><td>multiplet</td><td>triplet</td><td>triplet</td><td>singlet</td></tr>
<tr><td colspan="6">any three [1] any five [2] any seven [3] all nine [4]</td></tr>
</table>
</td><td>4</td></tr>
<tr><td>6(d)(ii)</td><td>
<table>
<tr><td>proton</td><td>a</td><td>b</td><td>c</td><td>d</td><td>e</td></tr>
<tr><td>present in D_2O</td><td></td><td>✓</td><td>✓</td><td>✓</td><td></td></tr>
</table>
</td><td>1</td></tr>
</table>

Question	Answer	Marks
5(a)(ii)	 curly arrow from inside hexagon to electrophile (CH_3^+)	1
	intermediate	1
	curly arrow from C—H bond into the hexagon **AND** H^+ formed	1
5(a)(iii)	$C_6H_4(Cl)CH_3$ + **2**[O] → $C_6H_4(Cl)CHO$ + H_2O	1
5(a)(iv)	step 3 HCN **AND** KCN (cat) **OR** KCN **AND** H_2SO_4/HC*l*	1
	step 4 H_2SO_4(aq) **OR** HC*l* (aq)	1
5(a)(v)	addition–elimination / condensation	1
5(a)(vi)	(a strong base) it would hydrolyse the **ester**	1
5(a)(vii)	(a substance able to) **rotate** the **plane** of plane-**polarised light**	1
5(a)(viii)	any two of: • reduced / different biological activity of 'other' enantiomer **ORA** • avoids need to separate the optical isomers to form the pure active isomer • lower dosage required **OR** (drug is) more potent • higher yield (of biologically-active molecule) • *no / less* (harmful) side effects **OR** *other isomer* can have side effects	2
5(b)(i)	**M1** [HA] = $(75 \times 10^{-3} / 180) \div 0.100 = 4.17 \times 10^{-3}$ **OR** 1 / 240 (mol dm^{-3})	1
	M2 $[H^+] = (K_a \times [HA])^{½} = (10^{-3.49} \times 4.17 \times 10^{-3})^{½} = 1.16 \times 10^{-3}$ (mol dm^{-3})	1
	M3 pH = –log $[H^+]$ = 2.93 to 2.94 min 2sf	1

Question	Answer	Marks
5(b)(ii)	 CH_3COOH	1 1