Cambridge Assessment International Education

Cambridge International AS & A Level

CHEMISTRY **9701/41**

Paper 4 A Level Structured Questions **October/November 2023**

MARK SCHEME

Maximum Mark: 100

Published

This mark scheme is published as an aid to teachers and candidates, to indicate the requirements of the examination. It shows the basis on which Examiners were instructed to award marks. It does not indicate the details of the discussions that took place at an Examiners' meeting before marking began, which would have considered the acceptability of alternative answers.

Mark schemes should be read in conjunction with the question paper and the Principal Examiner Report for Teachers.

Cambridge International will not enter into discussions about these mark schemes.

Cambridge International is publishing the mark schemes for the October/November 2023 series for most Cambridge IGCSE, Cambridge International A and AS Level components, and some Cambridge O Level components.

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Generic Marking Principles

These general marking principles must be applied by all examiners when marking candidate answers. They should be applied alongside the specific content of the mark scheme or generic level descriptors for a question. Each question paper and mark scheme will also comply with these marking principles.

GENERIC MARKING PRINCIPLE 1:

Marks must be awarded in line with:

- the specific content of the mark scheme or the generic level descriptors for the question
- the specific skills defined in the mark scheme or in the generic level descriptors for the question
- the standard of response required by a candidate as exemplified by the standardisation scripts.

GENERIC MARKING PRINCIPLE 2:

Marks awarded are always **whole marks** (not half marks, or other fractions).

GENERIC MARKING PRINCIPLE 3:

Marks must be awarded **positively**:

- marks are awarded for correct/valid answers, as defined in the mark scheme. However, credit is given for valid answers which go beyond the scope of the syllabus and mark scheme, referring to your Team Leader as appropriate
- marks are awarded when candidates clearly demonstrate what they know and can do
- marks are not deducted for errors
- marks are not deducted for omissions
- answers should only be judged on the quality of spelling, punctuation and grammar when these features are specifically assessed by the question as indicated by the mark scheme. The meaning, however, should be unambiguous.

GENERIC MARKING PRINCIPLE 4:

Rules must be applied consistently, e.g. in situations where candidates have not followed instructions or in the application of generic level descriptors.

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GENERIC MARKING PRINCIPLE 5: Marks should be awarded using the full range of marks defined in the mark scheme for the question (however; the use of the full mark range may be limited according to the quality of the candidate responses seen).
GENERIC MARKING PRINCIPLE 6: Marks awarded are based solely on the requirements as defined in the mark scheme. Marks should not be awarded with grade thresholds or grade descriptors in mind.

Science-Specific Marking Principles

1	Examiners should consider the context and scientific use of any keywords when awarding marks. Although keywords may be present, marks should not be awarded if the keywords are used incorrectly.
2	The examiner should not choose between contradictory statements given in the same question part, and credit should not be awarded for any correct statement that is contradicted within the same question part. Wrong science that is irrelevant to the question should be ignored.
3	Although spellings do not have to be correct, spellings of syllabus terms must allow for clear and unambiguous separation from other syllabus terms with which they may be confused (e.g. ethane / ethene, glucagon / glycogen, refraction / reflection).
4	The error carried forward (ecf) principle should be applied, where appropriate. If an incorrect answer is subsequently used in a scientifically correct way, the candidate should be awarded these subsequent marking points. Further guidance will be included in the mark scheme where necessary and any exceptions to this general principle will be noted.
5	‘List rule’ guidance For questions that require ***n*** responses (e.g. State **two** reasons …): • The response should be read as continuous prose, even when numbered answer spaces are provided. • Any response marked *ignore* in the mark scheme should not count towards ***n***. • Incorrect responses should not be awarded credit but will still count towards ***n***. • Read the entire response to check for any responses that contradict those that would otherwise be credited. Credit should **not** be awarded for any responses that are contradicted within the rest of the response. Where two responses contradict one another, this should be treated as a single incorrect response. • Non-contradictory responses after the first ***n*** responses may be ignored even if they include incorrect science.

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6 Calculation specific guidance

Correct answers to calculations should be given full credit even if there is no working or incorrect working, **unless** the question states 'show your working'.

For questions in which the number of significant figures required is not stated, credit should be awarded for correct answers when rounded by the examiner to the number of significant figures given in the mark scheme. This may not apply to measured values.

For answers given in standard form (e.g. $a \times 10^n$) in which the convention of restricting the value of the coefficient (a) to a value between 1 and 10 is not followed, credit may still be awarded if the answer can be converted to the answer given in the mark scheme.

Unless a separate mark is given for a unit, a missing or incorrect unit will normally mean that the final calculation mark is not awarded. Exceptions to this general principle will be noted in the mark scheme.

7 Guidance for chemical equations

Multiples / fractions of coefficients used in chemical equations are acceptable unless stated otherwise in the mark scheme.

State symbols given in an equation should be ignored unless asked for in the question or stated otherwise in the mark scheme.

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Question	Answer	Marks
1(a)(i)	M1:$F_2 + ClO_2 \rightarrow FClO_2 + F$ [1] M2:$ClO_2 + F \rightarrow FClO_2$ [1] OR M1: $F_2 + ClO_2 \rightarrow F_2ClO_2$ M2: $F_2ClO_2 + ClO_2 \rightarrow 2FClO_2$ two balanced equations MUST add to give the overall equation	**2**
1(a)(ii)	first step AND has one mole / molecule of F_2 and ClO_2 [1] OR same moles of reactants as orders in rate equation	**1**
1(b)(i)	rate = k $[F_2][ClO_2]$ / rate = 1.22 $[F_2][ClO_2]$ AND second / 2 BOTH[1]	**1**
1(b)(ii)	rate = $1.22 \times 2 \times 10^{-3} \times 2 \times 10^{-3} = 4.88 \times 10^{-6}$ [1] min 2sfecf **1(b)(i)**	**1**
1(c)(i)	$k_1 = (0.693 / 4) = 0.173$ OR 1.73×10^{-1}[1] MUST BE 3SF s^{-1} [1]	**2**
1(c)(ii)	at 4 s = 0.001 at 8 s = 0.0005 at 12 s = 0.00025 smooth curve ALL correct [1]	**1**
1(c)(iii)	tangent drawn at 0.00100 mol dm^{-3} AND gradient dependent on their rate = Y / X in the range = $1.5–2.0 \times 10^{-4}$ [1] IGNORE sign	**1**

Question	Answer	Marks
2(a)	(K_w =)[H+][OH–] OR (K_w =)[H3O+][OH–] [1]	**1**
2(b)(i)	M1: pH values 1.5 AND 12.5 [1] M2: conc of HC*l* = 10–1.5 = 0.0316 ecf [1] min 2sf	**2**
2(b)(ii)	sodium chloride / NaC*l* AND 7 [1]	**1**
2(b)(iii)	(mixture Y) 1 to 3 AND (mixture Z) 11 to 13 [1]	**1**
2(c)(i)	H_2SO_4 > CH_3CCl_2COOH > CH_3CH_2COOH [1] u / c explanation • H_2SO_4 is fully dissociated / strong acid • CH_3CH_2COOH / CH_3CCl_2COOH are partly dissociated / weak acids • C*l* / chlorine is electron-withdrawing / electronegative • alkyl group (in CH3CH2COOH) is electron donating • stabilises / destabilises anion OR weakens / strengthens O-H bond (linked correctly) • correct reference to release of / donation of / form H+ / proton any two [1] any four [2]	**3**
2(c)(ii)	• H_3O^+ and H_2O • H_2SO_4 and HSO_4^- • HSO_4^- and SO_4^{2-} any one correct pair [1] all three correct pairs [2]	**2**
2(d)(i)	(the) ratio of the concentrations (of a solute between) two solvents / two liquids (at) equilibrium [1]	**1**
2(d)(ii)	mass = 5-x / x = 7.84 OR mass = x / 5-x = 7.84 mass = 0.5656 g mass = 4.43 g [1] min 2sf	**1**

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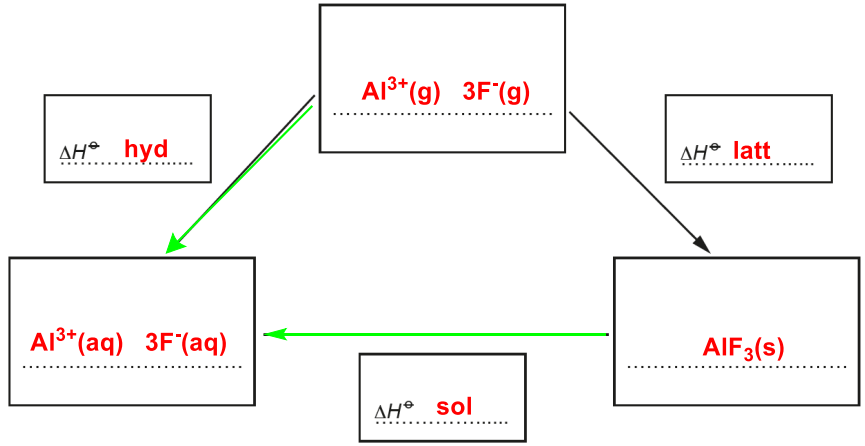
Question	Answer	Marks
2(d)(iii)	Any numbers in which volume of water is 7.84 times volume of hexane e.g. 78.4 cm^3 water 10 cm^3 hexane [1] u / c e.g mass = 0.566 g 177.4 cm^3 water 22.6 cm^3 hexane ALLOW reverse ratio volume of hexane is 7.84 times volume of water when consistent with d(ii)	**1**
2(d)(iv)	Q is $CH_3(CH_2)_4OH$ AND it is least polar / contains a large non-polar hydrocarbon chain / stronger id-id forces with hexane in Q OWTTE [1]	**1**

Question	Answer	Marks
3(a)(i)	(number of possible) arrangements of particles / energy in a system OR measure / degree of disorder in / of a system [1]	**1**
3(a)(ii)	positive / + AND more gas molecules / particles in products OR more moles / molecules in products / RHS [1]	**1**
3(b)	ΔH = (2 × 150) – (1 × 496) (= –196) [1] OR ΔH = (2 × 150) + (4 × 460) – (1 × 496) – (4 × 460) (= –196)	**1**
3(c)	$\Delta G = \Delta H - T\Delta S$ seen or used with correct signs[1] –238 = –196 – 298ΔS ΔS = 42 / 298 ΔS = (+)0.141 / 0.1409 (kJ K–1 mol–1) OR (+)141 / 140.9 (J K–1 mol–1) [1] ecf from $\Delta G = \Delta H + T\Delta S$ 141 = (2 × 70) + S(O2(g)) – (2 × 102) S, O2(g) = 205 / 204.94 (J K^{-1} mol^{-1}) [1] ecf	**3**

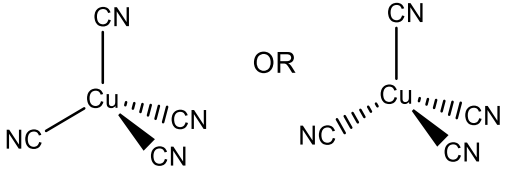
Question	Answer	Marks
3(d)	iron(III) chloride / $FeCl_3$ AND same state / phase as reactants / H_2O_2 [1]	**1**
3(e)(i)	hydrogen peroxide / H_2O_2 AND +2.18 [1]	**1**
3(e)(ii)	$\Delta G = -nE^{\ominus}_{cell}F$ [1] $\Delta G = (-2 \times 2.18 \times 96500) = -420.7$ (kJ mol–1) [1] ecf	**2**
3(f)(i)	Nernst: (E =) $E^{\ominus}$ + (0.059 / z)log[ox] / [red] [1] u / c OR (E =) $E^{\ominus}$ + (RT / zF)ln[ox] / [red] OR (E =) 1.82 + (0.059 / 1)log(0.02 / 2) E = 1.82 + (0.059 / 1)log(0.02 / 2) = (+)1.702 (V) [1] min 2sf OR E = 1.82 + [(8.314 × 298 / 1) × (96 500)] ln(0.02 / 2) = (+)1.702	**2**
3(f)(ii)	$H_2O_2 + 2H+ + 2Co^{2+} \rightarrow 2H_2O + 2Co^{3+}$ [1] ECF for reverse equation from **(f)(i)** if E > 1.77 V	**1**
3(g)(i)	enthalpy change when one mole of gaseous ions forms an aqueous solution / dissolves in water [1]	**1**

Question	Answer	Marks
3(g)(ii)	Substances with state symbols: • $AlF_3(s)$ • $AlF_3(aq)$ OR $Al^{3+}(aq) + (3)F^-(aq)$ • $Al^{3+}(g)$ $(3)F^-(g)$ [1] changes identified and three correct arrow directions (one given) [1]  	**2**
3(g)(iii)	ΔH_{latt} = –4690 + (3 × – 506) – (–209) = –5999 (kJ mol–1)	**1**

Question	Answer	Marks
4(a)(i)	• $Co(OH)_2$ OR $Co(OH)_2(H_2O)_4$ • $[Co(NH_3)_6]^{2+}$ OR $[Co(NH_3)_6]^{3+}$ • $[CoCl_4]^{2-}$ any two [1] all three [2]	**2**
4(a)(ii)	pink to blue [1]	**1**
4(b)(i)	$2Ca(NO_3)_2 \rightarrow 2CaO + 4NO_2 + O_2$ OR $Ca(NO_3)_2 \rightarrow CaO + 2NO_2 + ½O_2$ [1]	**1**

Question	Answer	Marks
4(b)(ii)	M1: $Mg(NO_3)_2$ below 480 °C, $Ba(NO_3)_2$ above 520 °C BOTH [1] u / c M2: ionic radii of M^{2+} increases down the group OR radii of Ba^{2+} is greater (than Mg^{2+}) OR charge density of M^{2+} decreases down the group OR charge density of Ba^{2+} is smaller (than Mg^{2+}) [1] ORA u / c M3: (larger cations) polarise / distort anion / NO_3^- less OR (larger ions) weaken N-O / N=O (bond) less [1] ORA	**3**

Question	Answer	Marks
5(a)	more than one (stable) oxidation state [1] empty / vacant (d) orbitals are energetically accessible OR empty / vacant (d) orbitals can form dative bonds with ligands [1]	**2**
5(b)(i)	oxid. no. = + 4 AND coord. no. = 8 [1]	**1**

Question	Answer	Marks
5(b)(ii)	bond angle must go from bond to bond OR CN group to CN group diagram • for Ag: NC—Ag—CN • angle = labelled 180° • for Cu:  • angle = labelled 109–110° any two [1] all four [2]	**2**
5(c)(i)	K_{stab} = $[[Cu(CN)_4]^{3-}] / [Cu^+] [CN^-]^4$ [1] ALLOW use of $[[Cu(H_2O)_6]^+]$	**1**
5(c)(ii)	[Cu+] = 5.0×10^{-19} (mol dm^{-3}) [1] min 1sf ECF from reversed ratio **5(c)(i)**	**1**
5(d)(i)	mol of I_2 = $0.5 \times 0.02 \times 20.1 / 1000 = 2.01 \times 10^{-4}$ [1] min 2sf	**1**
5(d)(ii)	mol of Cu = $2.01 \times 10^{-4} \times 2 \times 4 = 1.608 / 1.61 \times 10^{-3}$ [1] ecf min 2sf	**1**
5(d)(iii)	% of Cu = $100 \times (1.608 \times 10^{-3} \times 63.5) / 0.567 = 18.0$ [1] ecf	**1**
5(d)(iv)	Cu^{2+} is d^9 / d shell / sub-shell / orbitals is / are not full AND Cu^+ is d^{10} / d shell / sub-shell / orbitals is / are full [1] d-d* transitions / d electron promotion not possible / possible (linked correctly) [1]	**2**

Question	Answer	Marks
6(a)(i)	NH_3 = monodentate $EDTA^{4-}$ = polydentate / hexadentate CN^- = monodentate $C_2O_4^{2-}$ = bidentate any two [1] all four [2]	**2**
6(a)(ii)	(ligand that) donates 3 lone pairs to central metal atom / ion OR (ligand that) forms 3 dative bonds to central metal atom / ion [1]	**1**
6(a)(iii)	ref to using the electrons / lone pair on (each) N / amine group [1]	**1**
6(b)(i)	trans = non-polar cis isomer 1 = polar cis isomer 2 = polar ALL [1]	**1**
6(b)(ii)	optical isomers / non-superimposable mirror images [1] ALLOW enantiomers / they rotate polarised light differently	**1**

Question	Answer	Marks
7(a)	$C_{16}H_{10}N_2O_7S_2^{2-}$ OR $C_{16}H_{10}N_2O_7S_2$ [1]	**1**

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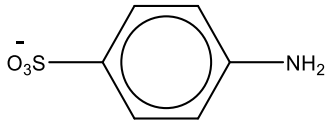
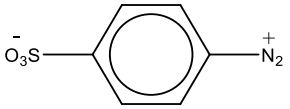
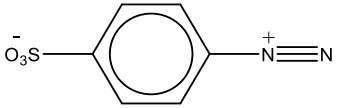
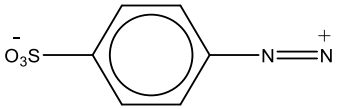
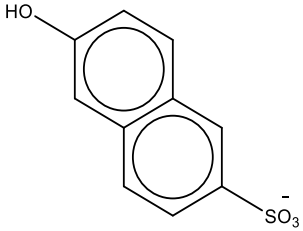
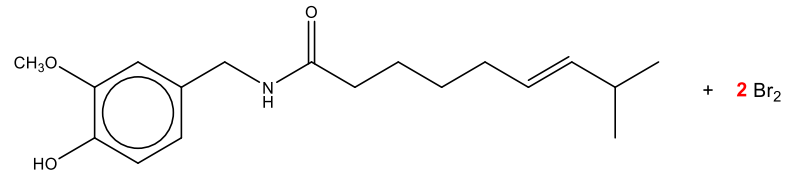
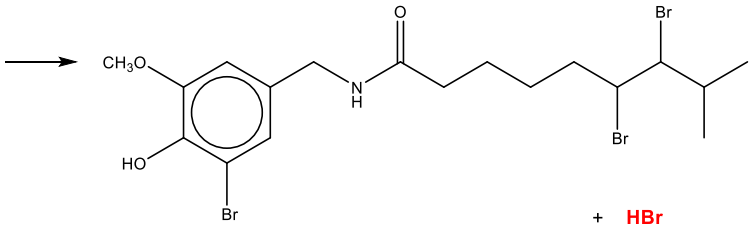
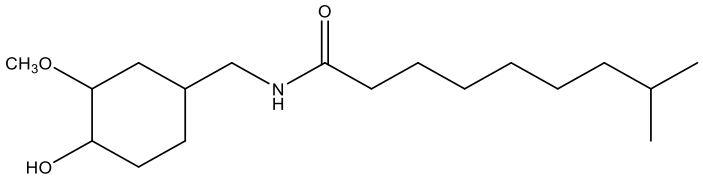
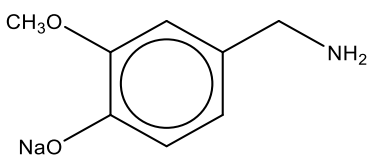
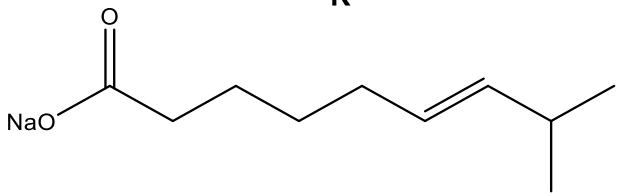
Question	Answer	Marks
7(b)	**E:**  [1] **F:**  OR   [1] ECF from E **G**  [1]	**3**
7(c)	M1 step 1: HNO_2 OR $NaNO_2$ + HCl [1] M2 step 1: T ⩽ 10 °C [1] M3 step 2: NaOH(aq) / alkaline conditions [1]	**3**
7(d)	14 / fourteen [1]	**1**

Question	Answer	Marks
8(a)	phenol, amide AND alkene / C=C all three needed [1]	**1**
8(b)	 + 2 Br_2  + HBr M1: HBr [1] u / c M2: structure of the organic product[1] M3: correct balanced equation [1] ecf	**3**
8(c)	 M1: ring reduced [1] M2: alkene reduced [1]	**2**
8(d)(i)	hot AND concentrated acidified AND MnO_4^- / $KMnO_4$ all [1]	**1**

<table>
<tr><th>Question</th><th>Answer</th><th>Marks</th></tr>
<tr><td>8(d)(ii)</td><td>
<table>
<tr><th>environment</th><th>δ</th><th>splitting pattern</th><th>explanation for SP</th></tr>
<tr><td>CH_3</td><td>0.9-1.7</td><td>doublet</td><td>1H on neighbouring C / next to CH / one vicinal proton</td></tr>
<tr><td>CH</td><td>2.2-3.0</td><td>multiplet / heptet / septet</td><td>6H on neighbouring C / next to 2 x (CH_3) / six vicinal protons</td></tr>
<tr><td>COOH</td><td>9.0-13.0</td><td>singlet</td><td></td></tr>
</table>
[1] for δ values
[1] for splitting
[1] for explanations
</td><td>3</td></tr>
<tr><td>8(e)(i)</td><td>
H

[1]
K

[1]
</td><td>2</td></tr>
<tr><td>8(e)(ii)</td><td>hydrolysis AND neutralisation / acid-base[1]</td><td>1</td></tr>
</table>

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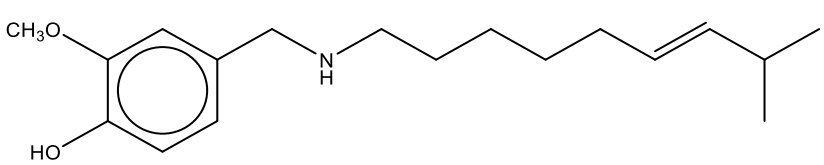
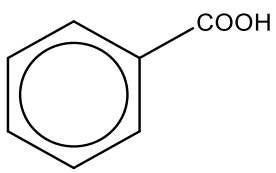
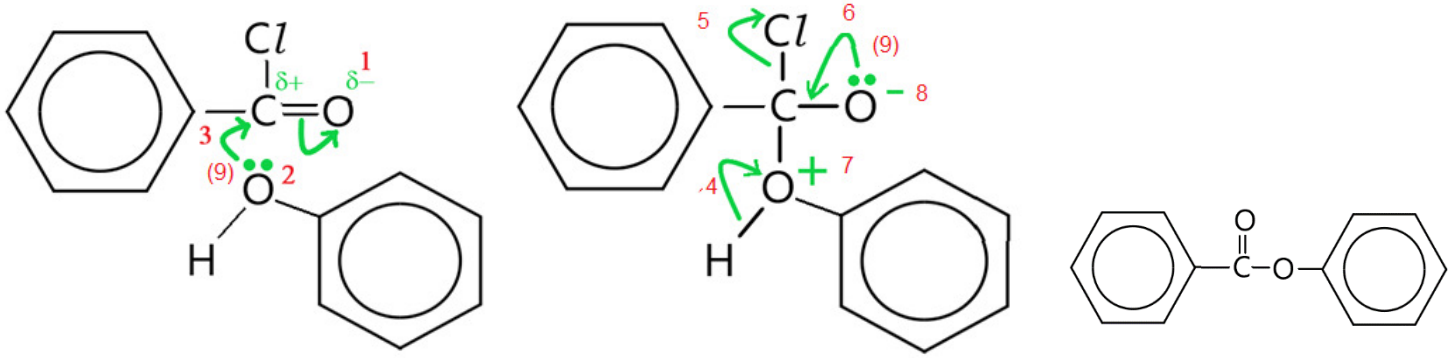
Question	Answer	Marks
8(f)	**L**  [1]	**1**

Question	Answer	Marks
9(a)(i)	**M**  [1]	**1**
9(a)(ii)	hot (alkaline) $KMnO_4$ / MnO_4^- [1] $SOCl_2$ OR PCl_5 OR PCl_3 + heat[1]	**2**
9(a)(iii)	oxidation [1] (nucleophilic) substitution	**2**

Question	Answer	Marks
9(b)(i)	 and HCl [10] The red numbers refer to points 1 to 10 in the verbal MS that follows.	
	box one: • 1 dipole on C=O • 2 curly arrow from O of phenol to C of acyl chloride • 3 curly arrow from bond of C=O to O of acyl chloride box two: • 4 curly arrow from O-H bond to what was O of phenol • 5 curly arrow from C-Cl bond to what was Cl of acyl chloride • 6 curly arrow from O to reform C=O • 7 + charge on what was O of phenol • 8 – charge on what was O of acyl chloride • 9 curly arrow start close to LP for bullet 3 OR 6 (from LP on O) box three: • 10 HCl / H^+Cl^- any two [1] any five [2] any eight [3] all ten [4]	**4**
9(b)(ii)	(nucleophilic) addition-elimination [1]	**1**

Question	Answer	Marks
9(c)	chlorobenzene, chloroethane, benzoyl chloride [1] u / c explanation linked to their order • correct link to: strengthening (ArC*l* / RC*l*) C-C*l* bond OR weakening (RCOC*l*) C-C*l* bond OR C-C*l* bond has partially double bond character (ArC*l*) OR C-C*l* is more difficult to break (linked correctly) chlorobenzene: • lone pair / p-orbital on C*l* overlaps / delocalised / incorporated with ring benzoyl chloride: • C of C-C*l* has most electron deficient OR has an electronegative oxygen atom / two electronegative atoms / electron withdrawing C=O group chloroethane • electron donating effect / positive inductive effect of alkyl / R group any two [1] any three [2]	**3**