

Cambridge International AS & A Level

CHEMISTRY**9701/41**

Paper 4 A Level Structured Questions

October/November 2024**MARK SCHEME**Maximum Mark: 100

Published

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This document consists of **14** printed pages.

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GENERIC MARKING PRINCIPLE 1:

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- 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).

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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
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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.

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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.

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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)	conjugate acid conjugate base H_2PO_4^- HPO_4^{2-} [1] BOTH	1
1(a)(ii)	allows only small changes in pH / resists changes in pH [1] when small amounts of acid or alkali/base / H^+ or OH^- are added [1]	2
1(a)(iii)	$\text{Na}^+_2\text{HPO}_4^{2-} + \text{H}^+ \rightarrow \text{Na}^+\text{H}_2\text{PO}_4^- + \text{Na}^+$ or $\text{HPO}_4^{2-} + \text{H}^+ \rightarrow \text{H}_2\text{PO}_4^-$ $\text{Na}^+\text{H}_2\text{PO}_4^- + \text{NaOH} \rightarrow \text{Na}^+_2\text{HPO}_4^{2-} + \text{H}_2\text{O}$ or $\text{H}_2\text{PO}_4^- + \text{OH}^- \rightarrow \text{HPO}_4^{2-} + \text{H}_2\text{O}$ [1] [1]	2
1(a)(iv)	HCO_3^- / hydrogen carbonate [1]	1
1(b)(i)	either $10^{-13.09}$ or $[\text{H}^+] = 8.1 \times 10^{-14}$ seen [1] $8.1 \times 10^{-14} \times [\text{OH}^-] = 1 \times 10^{-14}$ seen [1] OR $[\text{OH}^-] = \frac{1 \times 10^{-14}}{8.1 \times 10^{-14}}$ seen ALLOW alternative method $\text{pOH} = 0.91$ $[\text{OH}^-] = 10^{-0.91}$ seen [1] [1]	2
1(b)(ii)	2 moles of OH^- in one mole of E / $\text{X}(\text{OH})_2$ OR there are two hydroxide ions in each formula unit of E / $\text{X}(\text{OH})_2$ [1]	1
1(b)(iii)	$0.0615 \times 0.25 = 0.0154$ moles of E $\text{RFM} = 2.63 / 0.0154 = 170.8 / 171$ OR $\text{RAM} = 34 - 2.63 / 0.0154 = 137.1 / 137$ AND barium hydroxide / $\text{Ba}(\text{OH})_2$ [1]	1

Question	Answer	Marks
1(c)	$K_{sp} = [\text{Mg}^{2+}][\text{OH}^-]^2$ OR $K_{sp} = 1.4 \times 10^{-4} \times (2 \times 1.4 \times 10^{-4})^2$ [1] $K_{sp} = 1.10 \times 10^{-11}$ [1] min 2sf correct answer [2] $\text{mol}^3 \text{dm}^{-9}$ [1] ecf from M1	3
1(d)	M1: ΔH_{latt} and ΔH_{hyd} less exothermic (down the group) [1] OR $\Delta H_{\text{latt/LE}}$ and ΔH_{hyd} more exothermic/more negative for Mg M2: ΔH_{latt} changes more than ΔH_{hyd} (down the group) [1] OR ΔH_{latt} changes more / faster for Mg M3: ΔH_{sol} becomes more exothermic (down the group) [1] OR ΔH_{sol} becomes less exothermic / less negative for Mg mark independently	3

Question	Answer	Marks
2(a)	becomes less negative/less exothermic (down the group / from F to I) [1] AND due to increase in (ionic) radius / size decreased attraction to water OR weaker ion-dipole force to water [1]	2
2(b)(i)	$\text{CaF}_2(\text{aq})$ OR $\text{Ca}^{2+}(\text{aq}) + 2\text{F}^-(\text{aq})$ [1]	1
2(b)(ii)	- atomisation energy of Ca / $\Delta H_{\text{at(o)m}}$ - atomisation energy of F₍₂₎ / $\Delta H_{\text{at(o)m}}$ OR F-F bond energy / BE of F-F - first ionisation energy / IE_1 of Ca / ΔH_{i1} - second ionisation energy / IE_2 of Ca / ΔH_{i2} (first) electron affinity / EA of F / ΔH_{ea} any three for [1] ALL five [2]	2

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Question	Answer	Marks
2(b)(iii)	energy change / energy released when one mole of an ionic compound is formed [1] <u>from</u> its gaseous ion(s) [1]	2
2(b)(iv)	$(\Delta H_{\text{latt}} =)$ (change) 3 – (change) 1 [1] OR $(\Delta H_{\text{latt}} =) \Delta H_{\text{f}}(\text{CaF}_2(\text{s})) - \Delta H_{\text{f}}(\text{Ca}^{2+}(\text{g})) - 2\Delta H_{\text{f}}(\text{F}^{-}(\text{g}))$	1
2(c)	expression involves four correct numbers (13, 1395, 1214, 1650) AND 2 times [1] $1395 - 1650 + 2x = -1214 + 13$ $\Delta H_{\text{f}}(\text{F}^{-}(\text{g})) \times = -473$ [1] ecf correct answer [2]	2
2(d)	number of possible arrangements of particles / energy in a system [1]	1
2(e)	states or clearly uses $\Delta G = \Delta H - T\Delta S$ [1] OR $6000 = 30\,000 - (298 \times \Delta S)$ $\Delta S = (+)80.5(4)$ [1] min 3sf ecf correct answer [2]	2
2(f)	becomes more soluble AND ΔS is positive / $T\Delta S$ is positive / $-T\Delta S$ is negative (as T inc) [1] (so ΔG becomes more negative)	1

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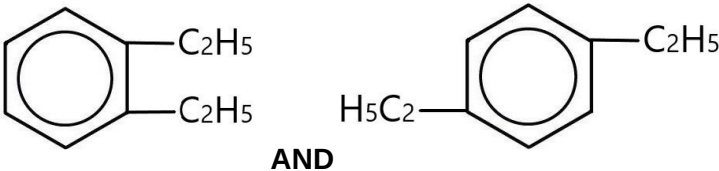
Question	Answer	Marks
3(a)(i)	$\text{rate} = k[A][B]$ [1] $\text{rate} = k[A]^2 / k[A]^2[B]^0$ AND $\text{rate} = k[B]^2 / k[A]^0[B]^2$ [1] BOTH	2
3(a)(ii)	$k = 7.62 / 7.625 / 7.63$ [1] ecf from 3a(i) min 3sf $\text{mol}^{-1} \text{dm}^3 \text{s}^{-1}$ [1] ecf from 3a(i)	2
3(a)(iii)	reaction is 2nd order OR reaction is not 1st order OR reaction does not have constant half-life [1]	1
3(b)(i)	Pt, Pd, Rh any two [1]	1
3(b)(ii)	adsorption (of reactants) / bond forms between the surface/catalyst and reactants - bond weakening (in reactants) desorption (of reactants / products) / bond breaks between the surface/catalyst and products any two [1] all three [2]	2
3(b)(iii)	$\text{S}_2\text{O}_8^{2-} + 2\text{Fe}^{2+} \rightarrow 2\text{SO}_4^{2-} + 2\text{Fe}^{3+}$ [1] any multiple $2\text{Fe}^{3+} + 2\text{I}^- \rightarrow 2\text{Fe}^{2+} + \text{I}_2$ [1] any multiple	2
3(b)(iv)	(heterogeneous) catalyst and reactants in different states / phases AND (homogeneous) catalyst and reactants in same states / phases [1] BOTH	1
3(c)(i)	similar energy of the (3)d and (4)s subshells / orbitals [1]	1

Question	Answer	Marks
3(c)(ii)	M1M2: • ClO^- chosen • O_2 chosen • $E^\ominus_{\text{cell}}$ values 1.45 (with ClO^-) • $E^\ominus_{\text{cell}}$ values 0.96 (with O_2) any two [1] all four [2] M3: $2\text{Fe}(\text{OH})_2 + \text{ClO}^- + \text{H}_2\text{O} \rightarrow \text{Cl}^- + 2\text{Fe}(\text{OH})_3$ [1] M4: $4\text{Fe}(\text{OH})_2 + \text{O}_2 + 2\text{H}_2\text{O} \rightarrow 4\text{Fe}(\text{OH})_3$ [1]	4

Question	Answer	Marks
4(a)	empty (d) orbitals are energetically accessible OR empty (d) orbitals can form dative bonds with ligands OR empty (d) orbitals can accept a lone pair from ligands [1]	1
4(b)(i)	$[\text{Co}_2\text{O}_2\text{NH}_2(\text{NH}_3)_8]^{3+}$ scores [2] must have Co_2 • $\text{Co}_2\text{O}_2\text{NH}_2$ • 8 ammonia so both Co are octahedral (ecf bullet 1) • correct charge based on ligands present (ecf Co and NH_2) any two [1] all three [2]	2
4(b)(ii)	2 3 BOTH [1]	1
4(b)(iii)	ΔE different OR (d–d) energy gap different [1] different frequency/wavelength/energy from visible light absorbed [1]	2

Question	Answer	Marks
4(c)(i)	$\underset{\text{X}}{[\text{Cd}(\text{NH}_3)_4]^{2+}} + 4\text{CN}^- \rightarrow \underset{\text{Y}}{[\text{Cd}(\text{CN})_4]^{2-}} + 4\text{NH}_3$ complex formed is $[\text{Cd}(\text{CN})_4]^{2-} / \text{Na}_2[\text{Cd}(\text{CN})_4]$ [1] equation fully correct [1] ECF	2
4(c)(ii)	OR $[\text{CdCl}_4]^{2-}$ $[\text{Cd}(\text{NH}_3)_4]^{2+}$ $[\text{Cd}(\text{CN})_4]^{2-}$ Z X Y [1]	1
4(d)(i)	$\text{Cr}_2\text{O}_7^{2-} + 8\text{H}^+ + 3\text{HOOC}\text{COOH} \rightarrow 2\text{Cr}^{3+} + 7\text{H}_2\text{O} + 6\text{CO}_2$ [1]	1
4(d)(ii)	- mol $\text{Cr}_2\text{O}_7^{2-} = 0.0500 \times 16.20 / 1000 = 8.10 \times 10^{-4}$ - mol $\text{HOOC}\text{COOH} / \text{C}_2\text{O}_4^{2-} = 8.10 \times 10^{-4} \times 3 = 2.43 \times 10^{-3}$ ecf $[\text{C}_2\text{O}_4^{2-}] = 2.43 \times 10^{-3} \times 40 = \mathbf{0.0972} \text{ mol dm}^{-3}$ min 2sf ecf • ✓ ✓ [2]	2

Question	Answer	Marks
5(a)	<u>bond angle</u> must go from bond to bond P 109 OR 109.5° Q 90° (or 180° if different angle labelled) R 90° (or 180° if different angle labelled) S 180° any two [1] all four [2]	2
5(b)	P tetrahedral Q square planar R octahedral S linear any two [1] all four [2]	2
5(c)	Q AND R [1]	1
5(d)	P AND R [1]	1

Question	Answer	Marks
6(a)	$\text{C}_2\text{H}_5\text{Cl} + \text{AlCl}_3 \rightarrow \text{C}_2\text{H}_5^+ + \text{AlCl}_4^-$ OR $\text{C}_2\text{H}_5\text{Cl} + \text{FeCl}_3 \rightarrow \text{C}_2\text{H}_5^+ + \text{FeCl}_4^-$	[1] 1
6(b)(i)		BOTH [1] 1
6(b)(ii)	alkyl / ethyl group is 2,4 directing OR ethyl group is electron donating / positive inductive effect	[1] 1
6(c)(i)	hot alkaline $\text{KMnO}_4 / \text{MnO}_4^-$ (followed by acid)	[1] 1
6(c)(ii)	$\text{C}_{10}\text{H}_{14} / \text{C}_6\text{H}_4(\text{C}_2\text{H}_5)_2 + 12 [\text{O}] \rightarrow \text{C}_6\text{H}_4(\text{COOH})_2 + 2\text{CO}_2 + 4\text{H}_2\text{O}$ all species correct formulae $\text{C}_{10}\text{H}_{14} + \text{CO}_2 + \text{H}_2\text{O}$ correct balancing	[1] [1] 2
6(c)(iii)	4	[1] 1
6(d)(i)	CDCl_3 does not cause a peak OR does not interfere with spectrum / peaks	[1] 1
6(d)(ii)	- ethylbenzene / $\text{C}_6\text{H}_5\text{C}_2\text{H}_5$ - triplet CH_3 2H on neighbouring C / next to CH₂ - quartet / quadruplet CH_2 3H on neighbouring C / next to CH₃ / coupling by CH₃	any three [1] any five [2] all seven [3] 3

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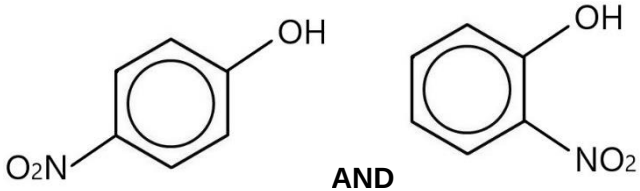
Question	Answer	Marks
6(d)(iii)	- benzene-1,2-dioic acid / $\text{C}_6\text{H}_4(\text{COOH})_2$ - H on the benzene / C_6H_4 – COOH / carboxylic acid ALL three [1]	1
6(d)(iv)	COOH peak disappears OR remove peak at 13.1 (ecf (d)(iii) if δ value used) AND - as proton / hydrogen exchanges with deuterium / D BOTH [1]	1
6(e)	dehydration / elimination / (auto)condensation	[1] 1

Question	Answer	Marks
7(a)	CH_3CN / ethanenitrile	[1] 1
7(b)	dilute acid / HCl (aq) AND hot / heat three components required (acid / aq / heat)	[1] 1
7(c)	CH_3COCl / ethanoyl chloride	[1] 1
7(d)	$\text{CH}_3\text{COOH} + \text{SOCl}_2 \rightarrow \text{CH}_3\text{COCl} + \text{HCl} + \text{SO}_2$	[1] 1
7(e)	$\text{C}_2\text{H}_5\text{Br}$ / $\text{C}_2\text{H}_5\text{Cl}$ / bromoethane / chloroethane	[1] 1
7(f)	heat in ethanol AND under pressure / in sealed tube	[1] 1
7(g)	LiAlH_4 / lithium aluminium hydride	[1] 1

Question	Answer	Marks
7(h)	Examiner checks first that each of 1–6 is only used once and IGNOREs any repeated unless a CON hydrolysis 1 addition 2 reduction 2, 6 substitution 3, 4, 5 two correct [1] four correct [2] five correct [3] six correct [4]	4
7(i)	M1 $\text{C}_2\text{H}_5\text{NHC}_2\text{H}_5$ ammonia $\text{C}_2\text{H}_5\text{NHCOCH}_3$ [1] M2 (basicity linked to) lone pair / p orbital on N AND being able accept / donate to a proton/H⁺ [1] M3 (amine stronger because of) +ve inductive effect / electron donating alkyl / R / ethyl group [1] M4 (amide weaker because) lone pair / p orbital on N is delocalised into C=O group [1]	4

Question	Answer	Marks
8(a)	M1: p orbital / lone pair on the oxygen / O AND is delocalised into the ring / overlaps with delocalised ring [1] M2: O-H weakened (in phenol) OR anion / phenoxide ion / conjugate base is stabilised/more stable [1]	2
8(b)(i)	2,4,6-tribromophenol (name) AND hydrogen bromide / HBr	1

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Question	Answer	Marks
8(b)(ii)		1
8(b)(iii)	$2\text{C}_6\text{H}_5\text{OH} + 2\text{Na} \rightarrow 2\text{C}_6\text{H}_5\text{ONa} + \text{H}_2$	[1] 1
8(c)	step one: HNO_2 (+ HCl) OR NaNO_2 + HCl AND $T \leq 10^\circ\text{C}$ step two: H_2O AND warm / $T > 10^\circ\text{C}$ any two [1] all four [2]	2

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1(a)(ii)	Rate = $k[X]$	[1] 1
1(a)(iii)	$k = 0.693 / t_{1/2} / k = 0.693 / 900 / k = \ln 2 / t_{1/2} / k = \ln 2 / 900 / t_{1/2} = \ln 2 / k$	[1] 1
1(a)(iv)	1.16×10^{-4} $\text{mol dm}^{-3} \text{s}^{-1}$	[1] [1] 2
1(b)(i)	Any two from: - variable oxidation state - vacant / empty / unfilled d orbitals - can form dative bonds / can accept electrons	[1] 1
1(b)(ii)	Iron AND iron is solid, reactants are gases OR catalyst and reactants are in different phases / states	[1] 1
1(b)(iii)	Two for one mark, three for two marks: - adsorption of reactants by Pt - bonds of reactants weaken - desorption of products	[1] [1] 2
1(b)(iv)	$\text{NO}_2 + \text{SO}_2 \rightarrow \text{NO} + \text{SO}_3$ AND $2\text{NO} + \text{O}_2 \rightarrow 2\text{NO}_2$	[1] 1
1(c)	BiO^+ $3\text{H}_2\text{SO}_3 + 2\text{BiO}^+ + \text{H}_2\text{O} \rightarrow 3\text{SO}_4^{2-} + 8\text{H}^+ + 2\text{Bi}$ 0.11 V	[1] [1] [1] 3

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Question	Answer	Marks
2(a)	ΔH_{hyd} increases from left to right due to increase in charge ionic radius decreases from left to right causing increased attractive force to water molecules	[1] [1] [1] 3
2(b)(i)	$\text{Mg}^{2+}(\text{aq}) + 2\text{Cl}^{-}(\text{aq})$	[1] 1
2(b)(ii)	Enthalpy change of hydration of magnesium ions and chloride ions $\Delta H_{\text{hyd}}\text{Mg}^{2+} + 2\Delta H_{\text{hyd}}\text{Cl}^{-}$	[1] [1] 2
2(b)(iii)	Selects 155, 1920 and 364 only 2×364 answer -2493	[1] [1] [1] 3
2(c)	The number of arrangements of the particles and of the energy in the system	[1] 1
2(d)	$\Delta G = \Delta H - T\Delta S$ answer $+10.5$	[1] [1] 2
2(e)(i)	No, ΔG is positive	[1] 1
2(e)(ii)	Becomes more / soluble because ΔG becomes more negative / less positive / smaller / closer to zero	[1] 1

Question	Answer	Marks
3(a)(i)	$[\text{H}^{+}] = 10^{-12.35}$ OR $[\text{H}^{+}] = 4.47 \times 10^{-13}$ $K_w / 4.47 \times 10^{-13}$ OR $\text{pOH} = 1.65$ $[\text{OH}^{-}] = 10^{-1.65}$	[1] [1] [1] [1] 2
3(a)(ii)	$K_{\text{sp}} = (0.0112)(0.0224)^2$ OR $K_{\text{sp}} = [\text{Ca}^{2+}][\text{OH}^{-}]^2$ answer 5.62×10^{-6} $\text{mol}^3 \text{dm}^{-9}$	[1] [1] [1] 3

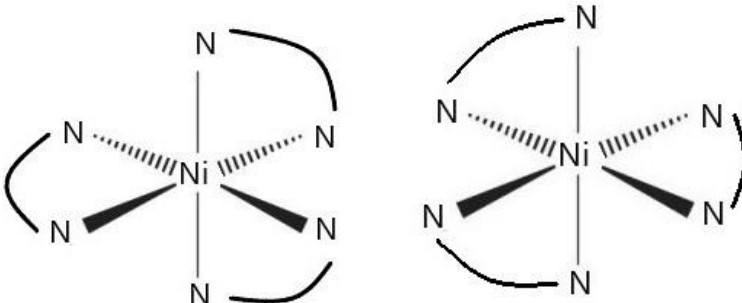
Question	Answer	Marks
3(a)(iii)	white solid / white ppt AND pH between 7.01 and 12.34 common ion effect hydroxide removed by precipitation OR ppt is Ca(OH) ₂	[1] [1] [1] 3
3(a)(iv)	lattice energy and hydration energy greater for CaSO ₄ OR lattice energy and hydration energy decrease down group hydration energy decreases more / is dominant factor enthalpy of solution is more endothermic for BaSO ₄ OR is more endothermic down grp	[1] [1] [1] 3
3(b)(i)	$\text{Ca} + 2\text{CH}_3\text{COOH} \rightarrow \text{Ca}(\text{CH}_3\text{COO})_2 + \text{H}_2$	[1] 1
3(b)(ii)	Pair 1: CH ₃ COOH and CH ₃ COO ⁻ Pair 2: H ₃ O ⁺ and H ₂ O OR H ₂ O and OH ⁻	[1] [1] 2
3(b)(iii)	$\frac{[\text{H}^+][\text{CH}_3\text{COO}^-]}{[\text{CH}_3\text{COOH}]}$	[1] 1
3(b)(iv)	[CH ₃ COO ⁻] = 0.788, [CH ₃ COOH] = 0.270 [H ⁺] = 5.96 × 10 ⁻⁶ pH = 5.22	[1] [1] 2
3(b)(v)	CH ₃ COO ⁻ + H ⁺ → CH ₃ COOH OR Ca(CH ₃ COO) ₂ + 2H ⁺ → 2CH ₃ COOH + Ca ²⁺ CH ₃ COOH + OH ⁻ → CH ₃ COO ⁻ + H ₂ O	[1] [1] 2

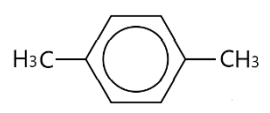
Question	Answer	Marks
4(a)(i)	red/pink blue	[1] 1
4(a)(ii)	$[\text{Co}(\text{H}_2\text{O})_6]^{2+} + 2\text{OH}^- \rightarrow \text{Co}(\text{H}_2\text{O})_4(\text{OH})_2 + 2\text{H}_2\text{O}$	[1] 1
4(a)(iii)	acid-base	[1] 1
4(b)(i)	[CoL ₂] ²⁺	[1] 1

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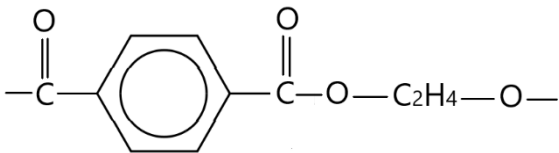
Question	Answer	Marks
4(b)(ii)	+2 [1]	1
4(b)(iii)	2 3 [1]	1
4(b)(iv)	Not of the same energy / have different energy [1]	1
4(c)(i)	$5\text{Fe}^{2+} + \text{MnO}_4^- + 8\text{H}^+ \rightarrow 5\text{Fe}^{3+} + \text{Mn}^{2+} + 4\text{H}_2\text{O}$ [1]	1
4(c)(ii)	$0.02 \times 18.7/1000 = 3.74 \times 10^{-4}$ [1] $3.74 \times 10^{-4} \times 5 = 1.87 \times 10^{-3}$ [1]	2
4(c)(iii)	$1.87 \times 10^{-3} \times 10 = 1.87 \times 10^{-2}$ $4.18/1.87 \times 10^{-2} = 224 / 223.5(294)$ $n = 2$ [1] [1]	2

Question	Answer	Marks
5(a)	$K_{\text{stab}} = \frac{[\text{Ni}(\text{en})_3]^{2+}}{[\text{Ni}^{2+}][\text{en}]^3}$ OR $\frac{[\text{Ni}(\text{en})_3]^{2+}}{[\text{Ni}(\text{H}_2\text{O})_6]^{2+}[\text{en}]^3}$ [1]	1
5(b)(i)	$[\text{Ni}(\text{en})_3]^{2+}$ AND larger K_{stab} OR more stable [1]	1
5(b)(ii)	$[\text{Ni}(\text{H}_2\text{O})_6]^{2+} + 3\text{en} \rightarrow [\text{Ni}(\text{en})_3]^{2+} + 6\text{H}_2\text{O}$ [1]	1

Question	Answer	Marks
5(c)	 octahedral with correct 3D for one $[\text{Ni}(\text{en})_3]^{2+}$ [1] second optical isomer [1] optical isomerism [1]	3

Question	Answer	Marks
6(a)(i)	$\text{ClOCCOC}l$ [1]	1
6(a)(ii)	$\text{PCl}_3 / \text{PCl}_5$ [1]	1
6(b)	oxygen [1] acidified KMnO_4 [1]	2
6(c)	$\text{C}=\text{O}$ are electron withdrawing / electronegative [1] weakens $\text{O}-\text{H}$ bond OR stabilises anion [1]	2
6(d)(i)	 [1]	1
6(d)(ii)	step 1: $\text{CH}_3\text{Cl} + \text{AlCl}_3$ [1] step 2: hot alkaline KMnO_4 [1]	2

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Question	Answer	Marks
6(d)(iii)	 correctly displayed ester linkage [1] rest of structure [1]	2
6(d)(iv)	condensation AND ester [1]	1

Question	Answer	Marks
7(a)	aluminium chloride OR $AlCl_3$ [1]	1
7(b)(i)	delocalised system / delocalised ring / pi system / pi ring C–Cl bond [1]	2
7(b)(ii)	C–H bond delocalised system / delocalised ring / pi system / pi ring [1]	2
7(c)	0, 5, 1 [1]	1
7(d)	$C_6H_6 + Cl_2 \rightarrow C_6H_5Cl + HCl$ [1]	1
7(e)	Cl^+ hydrogen / H chlorine / Cl [1]	1
7(f)(i)	nucleophilic substitution AND ethanol [1]	1
7(f)(ii)	delocalisation of LP of Cl with π system C–Cl bond is stronger in chlorobenzene / partly double [1]	2

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Question	Answer	Marks
8(a)	biological activity [1]	1
8(b)	rotates plane polarised light 5.0° in anticlockwise direction [1]	1
8(c)	enantiomers [1]	1
8(d)	racemic [1]	1
8(e)	use of chiral catalyst [1]	1
8(f)	CH ₂ and CH only in column one [1] CH ₂ gives a doublet, CH gives a triplet [1] doublet due to 1 proton on neighbouring carbons [1] triplet due to 2 protons on neighbouring carbons	3
8(g)	5 [1]	1

Question	Answer	Marks
8(h)	at pH 1 [1] at pH 3 AND [1] or at pH 9 [1] at pH 14 [1]	3

Cambridge International AS & A Level

CHEMISTRY**9701/43**

Paper 4 A Level Structured Questions

October/November 2024

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 2024 series for most Cambridge IGCSE, Cambridge International A and AS Level components, and some Cambridge O Level components.

This document consists of **14** printed pages.

PUBLISHED**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 descriptions 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.

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.

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.

Question	Answer	Marks
1(a)(i)	conjugate acid conjugate base H_2PO_4^- HPO_4^{2-} [1] BOTH	1
1(a)(ii)	allows only small changes in pH / resists changes in pH [1] when small amounts of acid or alkali/base / H^+ or OH^- are added [1]	2
1(a)(iii)	$\text{Na}^+_2\text{HPO}_4^{2-} + \text{H}^+ \rightarrow \text{Na}^+\text{H}_2\text{PO}_4^- + \text{Na}^+$ or $\text{HPO}_4^{2-} + \text{H}^+ \rightarrow \text{H}_2\text{PO}_4^-$ [1] $\text{Na}^+\text{H}_2\text{PO}_4^- + \text{NaOH} \rightarrow \text{Na}^+_2\text{HPO}_4^{2-} + \text{H}_2\text{O}$ or $\text{H}_2\text{PO}_4^- + \text{OH}^- \rightarrow \text{HPO}_4^{2-} + \text{H}_2\text{O}$ [1]	2
1(a)(iv)	HCO_3^- / hydrogen carbonate [1]	1
1(b)(i)	either $10^{-13.09}$ or $[\text{H}^+] = 8.1 \times 10^{-14}$ seen [1] $8.1 \times 10^{-14} \times [\text{OH}^-] = 1 \times 10^{-14}$ seen [1] OR $[\text{OH}^-] = \frac{1 \times 10^{-14}}{8.1 \times 10^{-14}}$ seen ALLOW alternative method $\text{pOH} = 0.91$ [1] $[\text{OH}^-] = 10^{-0.91}$ seen [1]	2
1(b)(ii)	2 moles of OH^- in one mole of E / $\text{X}(\text{OH})_2$ OR there are two hydroxide ions in each formula unit of E / $\text{X}(\text{OH})_2$ [1]	1
1(b)(iii)	$0.0615 \times 0.25 = 0.0154$ moles of E $\text{RFM} = 2.63 / 0.0154 = 170.8 / 171$ OR $\text{RAM} = 34 - 2.63 / 0.0154 = 137.1 / 137$ AND barium hydroxide / $\text{Ba}(\text{OH})_2$ [1]	1

Question	Answer	Marks
1(c)	$K_{sp} = [\text{Mg}^{2+}][\text{OH}^-]^2$ OR $K_{sp} = 1.4 \times 10^{-4} \times (2 \times 1.4 \times 10^{-4})^2$ [1] $K_{sp} = 1.10 \times 10^{-11}$ [1] min 2sf correct answer [2] $\text{mol}^3 \text{dm}^{-9}$ [1] ecf from M1	3
1(d)	M1: ΔH_{latt} and ΔH_{hyd} less exothermic (down the group) [1] OR $\Delta H_{latt/LE}$ and ΔH_{hyd} more exothermic/more negative for Mg M2: ΔH_{latt} changes more than ΔH_{hyd} (down the group) [1] OR ΔH_{latt} changes more / faster for Mg M3: ΔH_{sol} becomes more exothermic (down the group) [1] OR ΔH_{sol} becomes less exothermic / less negative for Mg mark independently	3

Question	Answer	Marks
2(a)	becomes less negative/less exothermic (down the group / from F to I) [1] AND due to increase in (ionic) radius / size decreased attraction to water OR weaker ion-dipole force to water [1]	2
2(b)(i)	$\text{CaF}_2(\text{aq})$ OR $\text{Ca}^{2+}(\text{aq}) + 2\text{F}^-(\text{aq})$ [1]	1
2(b)(ii)	- atomisation energy of Ca / $\Delta H_{at(o)m})$ - atomisation energy of F₍₂₎ / $\Delta H_{at(o)m})$ OR F-F bond energy / BE of F-F - first ionisation energy / IE_1 of Ca / ΔH_{i1} - second ionisation energy / IE_2 of Ca / ΔH_{i2} (first) electron affinity / EA of F / ΔH_{ea} any three for [1] ALL five [2]	2

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Question	Answer	Marks
2(b)(iii)	energy change / energy released when one mole of an ionic compound is formed [1] <u>from</u> its gaseous ion(s) [1]	2
2(b)(iv)	$(\Delta H_{\text{latt}} =)$ (change) 3 – (change) 1 [1] OR $(\Delta H_{\text{latt}} =) \Delta H_{\text{f}}(\text{CaF}_2(\text{s})) - \Delta H_{\text{f}}(\text{Ca}^{2+}(\text{g})) - 2\Delta H_{\text{f}}(\text{F}^{-}(\text{g}))$	1
2(c)	expression involves four correct numbers (13, 1395, 1214, 1650) AND 2 times [1] $1395 - 1650 + 2x = -1214 + 13$ $\Delta H_{\text{f}}(\text{F}^{-}(\text{g})) \times = -473$ [1] ecf correct answer [2]	2
2(d)	number of possible arrangements of particles / energy in a system [1]	1
2(e)	states or clearly uses $\Delta G = \Delta H - T\Delta S$ [1] OR $6000 = 30\,000 - (298 \times \Delta S)$ $\Delta S = (+)80.5(4)$ [1] min 3sf ecf correct answer [2]	2
2(f)	becomes more soluble AND ΔS is positive / $T\Delta S$ is positive / $-T\Delta S$ is negative (as T inc) [1] (so ΔG becomes more negative)	1

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Question	Answer	Marks
3(a)(i)	$\text{rate} = k[A][B]$ [1] $\text{rate} = k[A]^2 / k[A]^2[B]^0$ AND $\text{rate} = k[B]^2 / k[A]^0[B]^2$ [1] BOTH	2
3(a)(ii)	$k = 7.62 / 7.625 / 7.63$ [1] ecf from 3a(i) min 3sf $\text{mol}^{-1} \text{dm}^3 \text{s}^{-1}$ [1] ecf from 3a(i)	2
3(a)(iii)	reaction is 2nd order OR reaction is not 1st order OR reaction does not have constant half-life [1]	1
3(b)(i)	Pt, Pd, Rh any two [1]	1
3(b)(ii)	adsorption (of reactants) / bond forms between the surface/catalyst and reactants - bond weakening (in reactants) desorption (of reactants / products) / bond breaks between the surface/catalyst and products any two [1] all three [2]	2
3(b)(iii)	$\text{S}_2\text{O}_8^{2-} + 2\text{Fe}^{2+} \rightarrow 2\text{SO}_4^{2-} + 2\text{Fe}^{3+}$ [1] any multiple $2\text{Fe}^{3+} + 2\text{I}^- \rightarrow 2\text{Fe}^{2+} + \text{I}_2$ [1] any multiple	2
3(b)(iv)	(heterogeneous) catalyst and reactants in different states / phases AND (homogeneous) catalyst and reactants in same states / phases [1] BOTH	1
3(c)(i)	similar energy of the (3)d and (4)s subshells / orbitals [1]	1

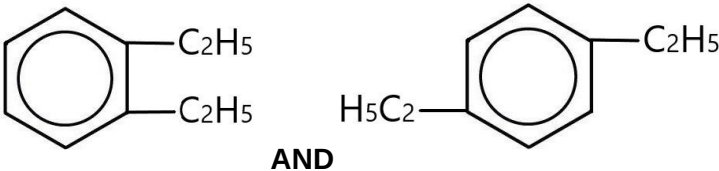
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Question	Answer	Marks
3(c)(ii)	M1M2: • ClO^- chosen • O_2 chosen • $E^\ominus_{\text{cell}}$ values 1.45 (with ClO^-) • $E^\ominus_{\text{cell}}$ values 0.96 (with O_2) any two [1] all four [2] M3: $2\text{Fe}(\text{OH})_2 + \text{ClO}^- + \text{H}_2\text{O} \rightarrow \text{Cl}^- + 2\text{Fe}(\text{OH})_3$ [1] M4: $4\text{Fe}(\text{OH})_2 + \text{O}_2 + 2\text{H}_2\text{O} \rightarrow 4\text{Fe}(\text{OH})_3$ [1]	4

Question	Answer	Marks
4(a)	empty (d) orbitals are energetically accessible OR empty (d) orbitals can form dative bonds with ligands OR empty (d) orbitals can accept a lone pair from ligands [1]	1
4(b)(i)	$[\text{Co}_2\text{O}_2\text{NH}_2(\text{NH}_3)_8]^{3+}$ scores [2] must have Co_2 • $\text{Co}_2\text{O}_2\text{NH}_2$ • 8 ammonia so both Co are octahedral (ecf bullet 1) • correct charge based on ligands present (ecf Co and NH_2) any two [1] all three [2]	2
4(b)(ii)	2 3 BOTH [1]	1
4(b)(iii)	ΔE different OR (d–d) energy gap different [1] different frequency/wavelength/energy from visible light absorbed [1]	2

Question	Answer	Marks
4(c)(i)	$\underset{\text{X}}{[\text{Cd}(\text{NH}_3)_4]^{2+}} + 4\text{CN}^- \rightarrow \underset{\text{Y}}{[\text{Cd}(\text{CN})_4]^{2-}} + 4\text{NH}_3$ complex formed is $[\text{Cd}(\text{CN})_4]^{2-} / \text{Na}_2[\text{Cd}(\text{CN})_4]$ [1] equation fully correct [1] ECF	2
4(c)(ii)	OR $\underset{\text{Z}}{[\text{CdCl}_4]^{2-}} \quad \underset{\text{X}}{[\text{Cd}(\text{NH}_3)_4]^{2+}} \quad \underset{\text{Y}}{[\text{Cd}(\text{CN})_4]^{2-}}$ [1]	1
4(d)(i)	$\text{Cr}_2\text{O}_7^{2-} + 8\text{H}^+ + 3\text{HOOC}\text{COOH} \rightarrow 2\text{Cr}^{3+} + 7\text{H}_2\text{O} + 6\text{CO}_2$ [1]	1
4(d)(ii)	- mol $\text{Cr}_2\text{O}_7^{2-} = 0.0500 \times 16.20 / 1000 = 8.10 \times 10^{-4}$ - mol $\text{HOOC}\text{COOH} / \text{C}_2\text{O}_4^{2-} = 8.10 \times 10^{-4} \times 3 = 2.43 \times 10^{-3}$ ecf $[\text{C}_2\text{O}_4^{2-}] = 2.43 \times 10^{-3} \times 40 = \mathbf{0.0972} \text{ mol dm}^{-3}$ min 2sf ecf • ✓ ✓ [2]	2

Question	Answer	Marks
5(a)	<u>bond angle</u> must go from bond to bond P 109 OR 109.5° Q 90° (or 180° if different angle labelled) R 90° (or 180° if different angle labelled) S 180° any two [1] all four [2]	2
5(b)	P tetrahedral Q square planar R octahedral S linear any two [1] all four [2]	2
5(c)	Q AND R [1]	1
5(d)	P AND R [1]	1

Question	Answer	Marks
6(a)	$\text{C}_2\text{H}_5\text{Cl} + \text{AlCl}_3 \rightarrow \text{C}_2\text{H}_5^+ + \text{AlCl}_4^-$ OR $\text{C}_2\text{H}_5\text{Cl} + \text{FeCl}_3 \rightarrow \text{C}_2\text{H}_5^+ + \text{FeCl}_4^-$	[1] 1
6(b)(i)	 AND	BOTH [1] 1
6(b)(ii)	alkyl / ethyl group is 2,4 directing OR ethyl group is electron donating / positive inductive effect	[1] 1
6(c)(i)	hot alkaline $\text{KMnO}_4 / \text{MnO}_4^-$	(followed by acid) [1] 1
6(c)(ii)	$\text{C}_{10}\text{H}_{14} / \text{C}_6\text{H}_4(\text{C}_2\text{H}_5)_2 + 12 [\text{O}] \rightarrow \text{C}_6\text{H}_4(\text{COOH})_2 + 2\text{CO}_2 + 4\text{H}_2\text{O}$ all species correct formulae $\text{C}_{10}\text{H}_{14} + \text{CO}_2 + \text{H}_2\text{O}$ correct balancing	[1] [1] 2
6(c)(iii)	4	[1] 1
6(d)(i)	CDCl_3 does not cause a peak OR does not interfere with spectrum / peaks	[1] 1
6(d)(ii)	- ethylbenzene / $\text{C}_6\text{H}_5\text{C}_2\text{H}_5$ - triplet CH_3 2H on neighbouring C / next to CH₂ - quartet / quadruplet CH_2 3H on neighbouring C / next to CH₃ / coupling by CH₃	any three [1] any five [2] all seven [3] 3

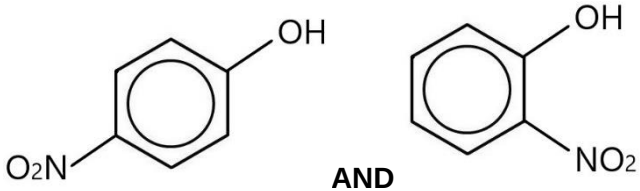
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Question	Answer	Marks
6(d)(iii)	- benzene-1,2-dioic acid / $\text{C}_6\text{H}_4(\text{COOH})_2$ - H on the benzene / C_6H_4 – COOH / carboxylic acid ALL three [1]	1
6(d)(iv)	COOH peak disappears OR remove peak at 13.1 (ecf (d)(iii) if δ value used) AND - as proton / hydrogen exchanges with deuterium / D BOTH [1]	1
6(e)	dehydration / elimination / (auto)condensation [1]	1

Question	Answer	Marks
7(a)	CH_3CN / ethanenitrile [1]	1
7(b)	dilute acid / HCl (aq) AND hot / heat three components required (acid / aq / heat) [1]	1
7(c)	CH_3COCl / ethanoyl chloride [1]	1
7(d)	$\text{CH}_3\text{COOH} + \text{SOCl}_2 \rightarrow \text{CH}_3\text{COCl} + \text{HCl} + \text{SO}_2$ [1]	1
7(e)	$\text{C}_2\text{H}_5\text{Br}$ / $\text{C}_2\text{H}_5\text{Cl}$ / bromoethane / chloroethane [1]	1
7(f)	heat in ethanol AND under pressure / in sealed tube [1]	1
7(g)	LiAlH_4 / lithium aluminium hydride [1]	1

Question	Answer	Marks
7(h)	Examiner checks first that each of 1–6 is only used once and IGNOREs any repeated unless a CON hydrolysis 1 addition 2 reduction 2, 6 substitution 3, 4, 5 two correct [1] four correct [2] five correct [3] six correct [4]	4
7(i)	M1 $\text{C}_2\text{H}_5\text{NHC}_2\text{H}_5$ ammonia $\text{C}_2\text{H}_5\text{NHCOCH}_3$ [1] M2 (basicity linked to) lone pair / p orbital on N AND being able accept / donate to a proton/H⁺ [1] M3 (amine stronger because of) +ve inductive effect / electron donating alkyl / R / ethyl group [1] M4 (amide weaker because) lone pair / p orbital on N is delocalised into C=O group [1]	4

Question	Answer	Marks
8(a)	M1: p orbital / lone pair on the oxygen / O AND is delocalised into the ring / overlaps with delocalised ring [1] M2: O-H weakened (in phenol) OR anion / phenoxide ion / conjugate base is stabilised/more stable [1]	2
8(b)(i)	2,4,6-tribromophenol (name) AND hydrogen bromide / HBr	1

Question	Answer	Marks
8(b)(ii)	 The image shows two chemical structures of nitrophenols. On the left is 4-nitrophenol, consisting of a benzene ring with a hydroxyl group (-OH) at the top position and a nitro group (-NO₂) at the para position (bottom). On the right is 2-nitrophenol, consisting of a benzene ring with a hydroxyl group (-OH) at the top position and a nitro group (-NO₂) at the ortho position (bottom-right). The two structures are separated by the word "AND" in bold capital letters.	1
8(b)(iii)	$2\text{C}_6\text{H}_5\text{OH} + 2\text{Na} \rightarrow 2\text{C}_6\text{H}_5\text{ONa} + \text{H}_2$	[1] 1
8(c)	step one: HNO_2 (+ HCl) OR $\text{NaNO}_2 + \text{HCl}$ AND $T \leq 10^\circ\text{C}$ step two: H_2O AND warm / $T > 10^\circ\text{C}$ any two [1] all four [2]	2