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Cambridge International AS & A Level

CHEMISTRY **9701/41**

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.

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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 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.

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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)	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)	$Na^+{}_2HPO_4^{2-} + H^+ \rightarrow Na^+H_2PO_4^- + Na^+$ **or** $HPO_4^{2-} + H^+ \rightarrow H_2PO_4^-$ [1] $Na^+H_2PO_4^- + NaOH \rightarrow Na^+{}_2HPO_4^{2-} + H_2O$ **or** $H_2PO_4^- + OH^- \rightarrow HPO_4^{2-} + H_2O$ [1]	**2**
1(a)(iv)	HCO_3^- / hydrogen carbonate [1]	**1**
1(b)(i)	either $10^{-13.09}$ or $[H^+] = 8.1 \times 10^{-14}$ seen [1] $8.1x10^{-14} \times [OH^-] = 1 \times 10^{-14}$ seen [1] **OR** $[OH^-] = \frac{1\times10^{-14}}{8.1\times10^{-14}}$ seen **ALLOW** alternative method pOH = 0.91 [1] $[OH^-] = 10^{-0.91}$ seen [1]	**2**
1(b)(ii)	2 moles of OH^- in one mole of **E /** $X(OH)_2$ **OR** there are two hydroxide ions in each formula unit of **E /** $X(OH)_2$ [1]	**1**
1(b)(iii)	$0.0615 \times 0.25 = 0.0154$ moles of **E** RFM = 2.63 / 0.0154 = 170.8 / 171 **OR** RAM = 34 – 2.63 / 0.0154 = 137.1 /137 **AND** barium hydroxide / $Ba(OH)_2$ [1]	**1**

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

Question	Answer	Marks
2(a)	becomes less negative/less exothermic (down the group / from F to I) **AND** due to increase in (ionic) radius / size [1] decreased attraction to **water** **OR** weaker ion-dipole force to water [1]	**2**
2(b)(i)	$CaF_2(aq)$ **OR** $Ca^{2+}(aq) + 2F^-(aq)$ [1]	**1**
2(b)(ii)	• atomisation energy of **Ca** **/** $\Delta H_{at(o)m)}$ • atomisation energy of $\mathbf{F}_{(2)}$ **/** $\Delta H_{at(o)m)}$ **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] from its **gas**eous **ion(s)** [1]	**2**
2(b)(iv)	(ΔH_{latt} =) (change) 3 – (change) 1 [1] **OR** (ΔH_{latt} =) $\Delta H_f(CaF_2(s)) - \Delta H_f(Ca^{2+}(g)) - 2\Delta H_f(F^-(g))$	**1**
2(c)	expression involves four correct numbers (13, 1395, 1214, 1650) **AND** 2 times [1] 1395 – 1650 + 2x = –1214+13 $\Delta H_f(F^-(g))$ × = –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 × ΔS) ΔS = (+)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)	rate = k[A][B] [1] rate = $k[A]^2$ / $k[A]^2[B]^0$ **AND** 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 $mol^{-1}\,dm^3\,s^{-1}$ [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)	$S_2O_8^{2-} + 2Fe^{2+} \rightarrow 2SO_4^{2-} + 2Fe^{3+}$ [1] any multiple $2Fe^{3+} + 2I^- \rightarrow 2Fe^{2+} + I_2$ [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 • $E^{\ominus}_{cell}$ values 1.45 (with ClO^-) • $E^{\ominus}_{cell}$ values 0.96 (with O_2) any two [1] all four [2] **M3:** $2Fe(OH)_2 + ClO^- + H_2O \rightarrow Cl^- + 2Fe(OH)_3$ [1] **M4:** $4Fe(OH)_2 + O_2 + 2H_2O \rightarrow 4Fe(OH)_3$ [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)	$[Co_2O_2NH_2(NH_3)_8]^{3+}$ scores [2] must have Co_2 • $Co_2O_2NH_2$ • 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**

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Question	Answer	Marks
4(c)(i)	$[Cd(NH_3)_4]^{2+} + 4CN^- \rightarrow [Cd(CN)_4]^{2-} + 4NH_3$ **X** **Y** complex formed is $[Cd(CN)_4]^{2-}$ / $Na_2[Cd(CN)_4]$ [1] equation fully correct [1] **ECF**	**2**
4(c)(ii)	$[CdCl_4]^{2-}$ $[Cd(NH_3)_4]^{2+}$ $[Cd(CN)_4]^{2-}$ **OR** **Z** **X** **Y** [1]	**1**
4(d)(i)	$Cr_2O_7^{2-} + 8H^+ + 3HOOCCOOH \rightarrow 2Cr^{3+} + 7H_2O + 6CO_2$ [1]	**1**
4(d)(ii)	• mol $Cr_2O_7^{2-} = 0.0500 \times 16.20 / 1000 = 8.10 \times 10^{-4}$ • mol $HOOCCOOH / C_2O_4^{2-} = 8.10 \times 10^{-4} \times 3 = 2.43 \times 10^{-3}$ ecf • $[C_2O_4^{2-}] = 2.43 \times 10^{-3} \times 40 =$ **0.0972** mol dm^{-3} min 2sf ecf • ✓ ✓ [2]	**2**

Question	Answer	Marks
5(a)	bond angle 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**

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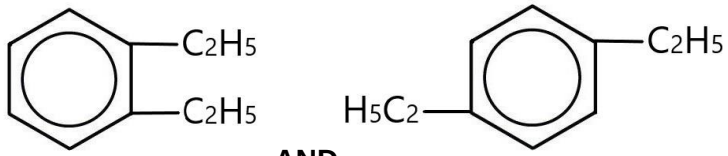
Question	Answer	Marks
6(a)	$C_2H_5Cl + AlCl_3 \rightarrow C_2H_5^+ + AlCl_4^-$ [1] **OR** $C_2H_5Cl + FeCl_3 \rightarrow C_2H_5^+ + FeCl_4^-$	**1**
6(b)(i)	 **AND** **BOTH** [1]	**1**
6(b)(ii)	**alkyl / ethyl** group is 2,4 directing **OR ethyl** group is electron donating / positive inductive effect [1]	**1**
6(c)(i)	hot alkaline $KMnO_4$ / MnO_4^- (followed by acid) [1]	**1**
6(c)(ii)	$C_{10}H_{14}$ / $C_6H_4(C_2H_5)_2 + 12\,[O] \rightarrow C_6H_4(COOH)_2 + 2CO_2 + 4H_2O$ all species correct formulae $C_{10}H_{14} + CO_2 + H_2O$ [1] correct balancing [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 / $C_6H_5C_2H_5$ • triplet • CH_3 • 2H on neighbouring **C** / next to **CH_2** – quartet / quadruplet – CH_2 – 3H on neighbouring **C** / next to **CH_3** / coupling by **CH_3** 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 / $C_6H_4(COOH)_2$ • 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 [1] three components required (acid / aq / heat)	**1**
7(c)	CH_3COCl / ethanoyl chloride [1]	**1**
7(d)	$CH_3COOH + SOCl_2 \rightarrow CH_3COCl + HCl + SO_2$ [1]	**1**
7(e)	C_2H_5Br / C_2H_5Cl / 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**

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Question	Answer	Marks
7(h)	Examiner checks first that each of 1–6 is only used once and **IGNORE**s 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** $C_2H_5NHC_2H_5$ ammonia $C_2H_5NHCOCH_3$ [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 brom**ide** / HBr [1]	**1**

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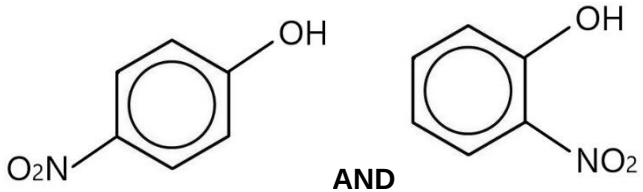
Question	Answer	Marks
8(b)(ii)	 **AND**	**1**
8(b)(iii)	$2C_6H_5OH + 2Na \rightarrow 2C_6H_5ONa + H_2$ [1]	**1**
8(c)	step one: HNO_2 (+ HC*l*) **OR** $NaNO_2$ + HC*l* **AND** T⩽10 °C step two: H_2O **AND** warm / T> 10 °C any two [1] all four [2]	**2**

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