

Practice paper – Set 2

A Level Chemistry A

H432/01 Periodic table, elements and physical chemistry

MARK SCHEME

Duration: 2 hour 15 minutes

MAXIMUM MARK 100

Final

MARKING INSTRUCTIONS**PREPARATION FOR MARKING****RM ASSESSOR**

1. Make sure that you have accessed and completed the relevant training packages for on-screen marking: *RM Assessor Online Training*; *OCR Essential Guide to Marking*.
2. Make sure that you have read and understood the mark scheme and the question paper for this unit.
3. Log-in to RM Assessor and mark the **required number** of practice responses ("scripts") and the **required number** of standardisation responses.

MARKING

1. Mark strictly to the mark scheme.
2. Marks awarded must relate directly to the marking criteria.
3. The schedule of dates is very important. It is essential that you meet the RM Assessor 50% and 100% (traditional 50% Batch 1 and 100% Batch 2) deadlines. If you experience problems, you must contact your Team Leader (Supervisor) without delay.
4. If you are in any doubt about applying the mark scheme, consult your Team Leader by telephone, email or via the RM Assessor messaging system.

5. Work crossed out:
 - a. where a candidate crosses out an answer and provides an alternative response, the crossed out response is not marked and gains no marks
 - b. if a candidate crosses out an answer to a whole question and makes no second attempt, and if the inclusion of the answer does not cause a rubric infringement, the assessor should attempt to mark the crossed out answer and award marks appropriately.
6. Always check the pages (and additional objects if present) at the end of the response in case any answers have been continued there. If the candidate has continued an answer there then add a tick to confirm that the work has been seen.
7. There is a NR (No Response) option. Award NR (No Response)
 - if there is nothing written at all in the answer space
 - OR if there is a comment which does not in any way relate to the question (e.g. 'can't do', 'don't know')
 - OR if there is a mark (e.g. a dash, a question mark) which isn't an attempt at the question.

Note: Award 0 marks – for an attempt that earns no credit (including copying out the question).
8. The RM Assessor **comments box** is used by your Team Leader to explain the marking of the practice responses. Please refer to these comments when checking your practice responses. **Do not use the comments box for any other reason.**

If you have any questions or comments for your Team Leader, use the phone, the RM Assessor messaging system, or email.
9. Assistant Examiners will send a brief report on the performance of candidates to their Team Leader (Supervisor) via email by the end of the marking period. The report should contain notes on particular strengths displayed as well as common errors or weaknesses. Constructive criticism of the question paper/mark scheme is also appreciated.

10. For answers marked by levels of response:

Read through the whole answer from start to finish, concentrating on features that make it a stronger or weaker answer using the indicative scientific content as guidance. The indicative scientific content indicates the expected parameters for candidates' answers, but be prepared to recognise and credit unexpected approaches where they show relevance.

Using a 'best-fit' approach based on the science content of the answer, first decide which set of level descriptors, Level 1, Level 2 or Level 3, **best** describes the overall quality of the answer using the guidelines described in the level descriptors in the mark scheme.

Once the level is located, award the higher or lower mark.

The higher mark should be awarded where the level descriptor has been evidenced and all aspects of the communication statement (in *italics*) have been met.

The lower mark should be awarded where the level descriptor has been evidenced but aspects of the communication statement (in *italics*) are missing.

In summary:

- **The science content determines the level.**
- **The communication statement determines the mark within a level.**

Level of response questions on this paper are **17(a)** and **20(a)**.

11. Annotations

Annotation	Meaning
DO NOT ALLOW	Answers which are not worthy of credit
IGNORE	Statements which are irrelevant
ALLOW	Answers that can be accepted
()	Words which are not essential to gain credit
—	Underlined words must be present in answer to score a mark
ECF	Error carried forward
AW	Alternative wording
ORA	Or reverse argument

12. Subject-specific Marking Instructions

INTRODUCTION

Your first task as an Examiner is to become thoroughly familiar with the material on which the examination depends. This material includes:

- the specification, especially the assessment objectives
- the question paper
- the mark scheme.

You should ensure that you have copies of these materials.

You should ensure also that you are familiar with the administrative procedures related to the marking process. These are set out in the OCR booklet **Instructions for Examiners**. If you are examining for the first time, please read carefully **Appendix 5 Introduction to Script Marking: Notes for New Examiners**.

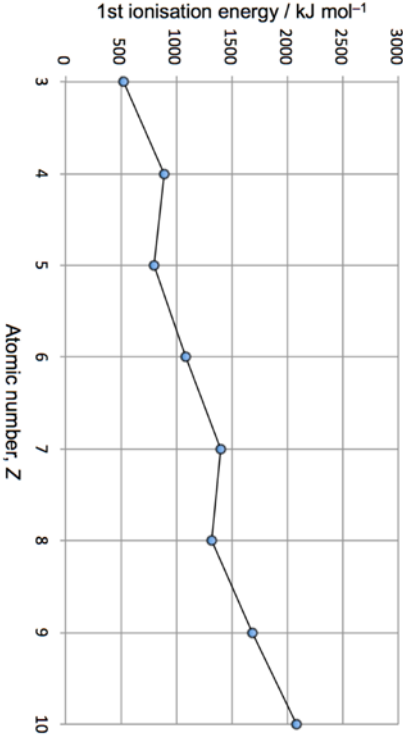
Please ask for help or guidance whenever you need it. Your first point of contact is your Team Leader.

SECTION A

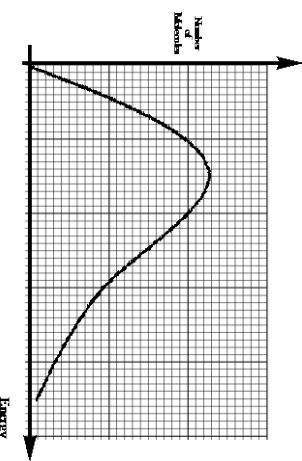
Question	Answer	Marks	Guidance
1	C	1	
2	D	1	
3	C	1	
4	C	1	
5	C	1	
6	B	1	
7	C	1	
8	B	1	
9	B	1	
10	D	1	
11	A	1	
12	B	1	
13	D	1	
14	B	1	
15	C	1	
Total		15	

SECTION B

Question	Answer	Marks	Guidance												
16 (a) (i)	<table border="1"> <thead> <tr> <th>Isotope</th><th>Protons</th><th>Neutrons</th><th>Electrons</th></tr> </thead> <tbody> <tr> <td>^{48}Tl</td><td>...22...</td><td>...26....</td><td>...22....</td></tr> <tr> <td>$^{46}\text{Tl}^{3+}$</td><td>...22....</td><td>24</td><td>19</td></tr> </tbody> </table>	Isotope	Protons	Neutrons	Electrons	^{48}Tl	...22...	...26....	...22....	$^{46}\text{Tl}^{3+}$...22....	24	19	2	Mark by row
Isotope	Protons	Neutrons	Electrons												
^{48}Tl	...22...	...26....	...22....												
$^{46}\text{Tl}^{3+}$...22....	24	19												
(b) (i)	<p>FIRST CHECK THE ANSWER ON ANSWER LINE</p> <p>If answer = 79.915 award 2 marks</p> <p>-----</p> <p>$(78.9183361 \times 50.69) + (80.9162896 \times 49.31)$</p> <p>100</p> <p>OR 79.90352697 ✓</p> <p>= 79.904 (to 3 DP) ✓</p>	2													
(ii)	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^5$ ✓	1	<p>ALLOW 4s before 3d, i.e. $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^5$</p> <p>ALLOW upper case D, etc and subscripts, e.g.$4S_2 3D_{10}$</p> <p>DO NOT ALLOW [Ar] as shorthand for $1s^2 2s^2 2p^6 3s^2 3p^6$</p> <p>Look carefully at $1s^2 2s^2 2p^6 3s^2 3p^6$ – there may be a mistake</p>												

Question	Answer	Marks	Guidance
(c) (i)	 <p>1st ionisation energy / kJ mol⁻¹</p> <p>Atomic number, Z</p> <p>Increase from 5–7 (B→N) AND 5 below 4 but above 3 ✓</p> <p>8(O) below 7 and 9 AND above 6 ✓</p>	2	<p>ALLOW if points correct but straight lines not drawn</p>
(ii)	<p>Trend described down group</p> <p><i>Atomic radius</i> larger atomic radius OR more shells ✓</p> <p><i>Effect of nuclear charge/shielding</i> Increased nuclear charge is outweighed by increased distance/shielding OR more/increased shielding ✓</p> <p><i>Reactivity AND Nuclear attraction</i></p>	3	<p>FULL ANNOTATIONS MUST BE USED</p> <p>-----</p> <p>ALLOW ORA but comparison should be used for each mark.</p> <p>ALLOW 'more/higher energy levels'</p> <p>ALLOW 'electrons further from nucleus'</p> <p>ALLOW 'different shell' OR 'new shell'</p> <p>IGNORE more orbitals OR more sub-shells</p> <p>ALLOW more electron repulsion from inner shells</p> <p>IGNORE responses with no comparison e.g. 'is shielding'</p> <p>Mark requires statement that reactivity</p>

Question		Answer	Marks	Guidance
		Reactivity increases AND less nuclear attraction OR less attraction on electrons ✓		increases AND reason IGNORE nuclear charge/effective nuclear charge ALLOW 'less nuclear pull' OR 'electrons held less tightly'
		Total	10	

Question	Answer	Marks	Guidance
17 (a)*	<p>Please refer to the marking instructions on page 4 of this mark scheme for guidance on how to mark this question.</p> <p>Level 3 (5–6 marks) All three scientific points are covered in detail and explained thoroughly.</p> <p><i>There is a well-developed explanation which is clear and logically structured, with correct labels for the distribution, E_a in distribution linked to areas and benefits clearly linked to energy demand and the environment.</i></p> <p>Level 2 (3–4 marks) All three scientific points are covered but explanations may be incomplete. OR Two of the scientific points are described thoroughly with no omissions.</p> <p><i>The explanation has a line of reasoning presented with some structure, and linked to the distribution; attempts to link benefits for energy demand or the environment.</i></p> <p>Level 1 (1–2 marks) There is a description based on at least two of the main scientific points OR One scientific point explained thoroughly with few omissions.</p> <p><i>Explanation is communicated in an unstructured way with some links to the Boltzmann distribution or energy demand/the environment.</i></p> <p>0 marks No response worthy of credit.</p>	6	<p>Indicative scientific points may include: BOLTZMANN DISTRIBUTION</p>  <p>Curve</p> <ul style="list-style-type: none"> • Curve starts at origin (ALLOW some leeway) • Curve does not touch the x axis at high energy <p>Axes labels</p> <ul style="list-style-type: none"> • y axis: Number of molecules/particles • x axis: Energy (IGNORE enthalpy) <p>ACTIVATION ENERGY Catalyst on distribution</p> <ul style="list-style-type: none"> • Two activation energies labelled • Activation energy with catalyst at lower energy <p>Explanation</p> <ul style="list-style-type: none"> • More molecules have more energy than E_a • Greater area under curve above E_a <p>CATALYST Lower energy demand</p> <ul style="list-style-type: none"> • Reactions take place at lower temperatures <p>Environment</p> <ul style="list-style-type: none"> • Reduced CO_2 emissions/burning fossil fuel • Different reactions possible with better atom economy/less waste/less hazardous chemicals (IGNORE 'less global warming')
(b)	FIRST CHECK THE ANSWER ON THE ANSWER LINE	7	Final answer must be correct and have the correct

Question	Answer	Marks	Guidance
	<p>IF answer = 5184/5180 atm² award 7 marks IF answer = 5184/5180 with incorrect units award 6 marks</p> <p>Equilibrium amounts in mol 2 MARKS</p> <p>3 correct ✓✓ 2 correct ✓</p> <p>$n(\text{H}_2\text{O}) = 0.600 \text{ mol}$ $n(\text{H}_2) = 2.40 \text{ mol}$ $n(\text{CO}) = 0.800 \text{ mol}$</p> <p>Partial pressures</p> <p>Total moles = 4.00 (mol) ✓</p> <p>$p(\text{CH}_4) = \frac{0.200}{4.00} \times 30.0 = 1.50 \text{ atm}$ AND</p> <p>$p(\text{H}_2\text{O}) = \frac{0.600}{4.00} \times 30.0 = 4.50 \text{ atm}$ AND</p> <p>$p(\text{H}_2) = \frac{2.40}{4.00} \times 30.0 = 18.0 \text{ atm}$ AND</p> <p>$p(\text{CO}) = \frac{0.800}{4.00} \times 30.0 = 6.00 \text{ atm}$ ✓</p> <p>K_p calculation</p> <p>$K_p = \frac{p(\text{H}_2)^3 \times p(\text{CO})}{p(\text{CH}_4) \times p(\text{H}_2\text{O})}$ OR $\frac{18.0^3 \times 6.00}{1.50 \times 4.50}$ ✓</p> <p>$K_p = 5184$ OR 5180 atm² ✓</p> <p>units = atm² ✓</p>		<p>units to score all seven marks</p> <p>If there is an alternative answer, check to see if there is any ECF credit possible using working below</p> <p>ALLOW ECF from equilibrium amounts OR/AND incorrect total number of moles</p> <p>Correct values substituted into correct expression for K_p gains first four marks.</p> <p>ALLOW ECF with answer 3 or more SF up to calculator value, correctly rounded</p>
	Total	13	

Question	Answer	Marks	Guidance
18 (a) (i)	(enthalpy change for) the formation of 1 mole H ₂ O ✓ from reaction of an acid/H ⁺ with an alkali/base/OH ⁻ ✓	2	ALLOW (enthalpy change for) the reaction of 1 mol H ⁺ with 1 mol of OH ⁻ ALLOW formation of 1 mol of water from neutralisation if no definition in words, award 1st mark if 1 mol is written under species in the equation, in line with marking criteria DO NOT ALLOW formation of 1 mol H ₂ O from 1 mole of acid and/or 1 mol of alkali DO NOT ALLOW formation of 1 mol H ₂ O from an acid and its conjugate base
	H ⁺ (aq) + OH ⁻ (aq) → H ₂ O(l) ✓		
(ii)	2NaOH + H ₂ SO ₄ → Na ₂ SO ₄ + 2H ₂ O ✓	1	IGNORE state symbols (even if wrong) <i>not required</i>
(iii)	FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = -56.43 OR -56.4 (kJ mol⁻¹) award 3 marks ----- Energy change energy change = 75.0 × 4.18 × 13.5 = 4232.25 (J) OR 4.23225 (kJ) ✓ Moles $n(\text{NaOH}) = 1.5(0) \times \frac{50.0}{1000} = 0.075(0) \text{ (mol)}$ OR $n(\text{H}_2\text{SO}_4) = 1.5(0) \times \frac{25.0}{1000} = 0.0375(0) \text{ (mol)}$ OR $n(\text{H}_2\text{O}) \text{ formed} = 0.075(0) \text{ (mol)} \checkmark$ $\Delta H_{\text{neut}} = -\frac{4.23225}{0.075} = -56.43 \text{ OR } -56.4 \text{ (kJ mol}^{-1}\text{)} \checkmark$ – sign required	3	FULL ANNOTATIONS MUST BE USED ----- IF there is an alternative answer, check to see if there is any ECF credit possible using working below ----- IGNORE any sign shown ALLOW 4230 (J) AND 4.23 (kJ) up to calculator value correctly rounded ALLOW ECF from $\frac{\text{calculated energy change}}{\text{calculated moles H}_2\text{O}}$ ALLOW 3 significant figures up to calculator value correctly rounded

Question	Answer	Marks	Guidance
(b)	(i) $2\text{H}_2\text{S}(\text{g}) + \text{O}_2(\text{g}) \rightarrow 2\text{S}(\text{s}) + 2\text{H}_2\text{O}(\text{g}) \checkmark$	1	ALLOW multiples, e.g. $6\text{H}_2\text{S}(\text{g}) + 3\text{O}_2(\text{g}) \rightarrow 6\text{S}(\text{s}) + 6\text{H}_2\text{O}(\text{g})$
(ii)	FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = 3.05×10^7 (g) award 3 marks ----- volume of H_2S $= 1.50 \times 10^8 \times 16/100 = 2.4 \times 10^7 \text{ dm}^3$ of $\text{H}_2\text{S} \checkmark$ $n(\text{H}_2\text{S}) (= n(\text{S}))$ $= 2.4 \times 10^7/24.0 \text{ mol} = 1 \times 10^6 \text{ mol} \checkmark$ Mass S = $1 \times 10^6 \times 95/100 \times 32.1 = 3.05 \times 10^7 \text{ (g)} \checkmark$	3	ALLOW ECF from incorrect volume of H_2S 3 SF AND standard form required
(c)	(i) FIRST, CHECK FOR A VALUE OF ΔG. IF answer = $-89.96(34) \text{ (kJ mol}^{-1}\text{)}$ award 3 marks ----- ΔS calculation (2 marks) $\Delta S = (3 \times 31.8) + (2 \times 188.7) - [(2 \times 205.7) + (248.1)]$ OR $\Delta S = 472.8 - 659.5 \checkmark$ $\Delta S = -186.7 \text{ J mol}^{-1} \text{ K}^{-1}$ OR $-0.1867 \text{ kJ mol}^{-1} \text{ K}^{-1} \checkmark$ ΔG calculation (1 mark) $\Delta G = \Delta H - T\Delta S = -145.6 - (298 \times -0.1867)$ $= -89.96(34) \text{ (kJ mol}^{-1}\text{)} \checkmark$ Comment (1 mark) – sign shows the (forward) reaction is feasible \checkmark Temperature at which feasibility changes (1 mark)	5	ALLOW (–) 187 OR 0.187 ALLOW ECF from incorrect ΔH ALLOW –90 up to calculator value of –89.9634 correctly rounded ORA for comment about – sign required for feasibility

Question	Answer	Marks	Guidance
	$T = \frac{\Delta H}{\Delta S} = \frac{-145.6}{-0.1867} = 780 \text{ K}$ <p>AND comment that ΔG OR $\Delta H - T\Delta S = 0$ ✓</p>		
(ii)	<p>FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = -296.8 (kJ mol⁻¹) award 2 marks -----</p> <p>Correct expression $-145.6 = (2 \times -241.8) - (2 \times -20.6 + \Delta_f H(\text{SO}_2))$ ✓</p> <p>Calculation of $\Delta_f H(\text{SO}_2)$ formation $\Delta_f H(\text{SO}_2) = (2 \times -241.8) - (2 \times -20.6) + 145.6$ $= -296.8 \text{ (kJ mol}^{-1}\text{)}$ ✓</p>	2	<p>ALLOW ECF ALLOW 1 mark for (+)296.8 <i>Subtraction the wrong way around</i></p>
	Total	17	

Question	Answer	Marks	Guidance
19 (a) (i)	$(K_a =) \frac{[\text{H}^+][\text{C}_6\text{H}_7\text{O}_6^-]}{[\text{C}_6\text{H}_8\text{O}_6]} \checkmark$ ALL species MUST have square brackets State symbols not required TAKE CARE that 'H' is different on top and bottom of expression	1	ALLOW $[\text{H}_3\text{O}^+]$ for $[\text{H}^+]$ IGNORE state symbols, even if wrong IGNORE $\frac{[\text{H}^+]^2}{[\text{C}_6\text{H}_8\text{O}_6]}$ OR $\frac{[\text{H}^+]^2[\text{A}^-]}{[\text{HA}]}$
(ii)	$\text{p}K_a = -\log K_a = -\log (6.76 \times 10^{-5}) = 4.17 \checkmark$	1	Answer required to two DP
(iii)	FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = 2.82 award 4 marks <hr/> $n(\text{vitamin C}) = \frac{3 \times 0.500}{176}$ $= 8.52(2) \times 10^{-3} \text{ (mol)} \checkmark$ $[\text{vitamin C}] = 8.52 \times 10^{-3} \times \frac{1000}{250}$ $= 0.0341 \text{ (mol dm}^{-3}\text{)} \checkmark$ $[\text{H}^+] = \sqrt{(K_a \times [\text{C}_6\text{H}_8\text{O}_6])}$ OR $\sqrt{(6.76 \times 10^{-5} \times 0.0341)}$ OR $1.52 \times 10^{-3} \text{ mol dm}^{-3} \checkmark$ pH $= -\log(1.52 \times 10^{-3}) = 2.82 \checkmark$ Answer required to two DP	4	ALLOW ECF from incorrect $n(\text{vitamin C})$ ALLOW ECF from incorrect $[\text{vitamin C}]$ must be derived from $\sqrt{(K_a \times [\text{C}_6\text{H}_8\text{O}_6])}$ ALLOW ECF from incorrect $[\text{H}^+]$ but ONLY if derived from $\sqrt{(K_a \times [\text{C}_6\text{H}_8\text{O}_6])}$
(b) (i)	FIRST, CHECK THE ANSWER ON ANSWER LINE IF ratio = 0.708 award 3 marks <hr/>	3	IF there is an alternative answer, check to see if there is any ECF credit possible using working below ANNOTATIONS MUST BE USED ALLOW ALTERNATIVE using Henderson–

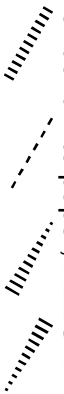
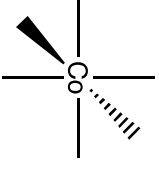
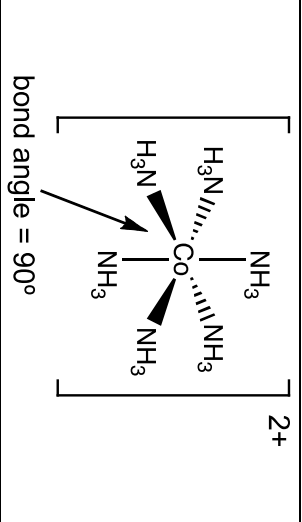
Question	Answer	Marks	Guidance
	$[H^+] = 10^{-pH} = 10^{-4.02} = 9.55 \times 10^{-5} \text{ (mol dm}^{-3}\text{)} \checkmark$ $\frac{[C_6H_7O_6^-]}{[C_6H_8O_6]} = \frac{K_a}{[H^+]} = \frac{6.76 \times 10^{-5}}{9.55 \times 10^{-5}} \checkmark$ $= \frac{0.708}{1} \checkmark$		Hasselbalch equation ----- ALLOW 9.55×10^{-5} up to calculator value of $9.54992586 \times 10^{-5}$ correctly rounded ALLOW ECF from incorrect $[H^+]$ ALLOW 0.71 (2 SF) up to calculator value correctly rounded
	(ii) mass of $C_6H_7O_6Na = 0.708 \times \frac{300}{176} \times 198.0$ $= 239 \text{ OR } 240 \text{ (mg)} \checkmark$	1	ALLOW ECF from answer to (i)
(c)	FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = 0.0524 (mol dm⁻³) award 2 marks ----- $[H^+(\text{aq})] = 10^{-pH} = 10^{-12.72}$ $= 1.91/1.9 \times 10^{-13} \text{ (mol dm}^{-3}\text{)} \checkmark$ $[NaOH] / [OH^-(\text{aq})] = \frac{K_w}{[H^+(\text{aq})]} = \frac{1.0 \times 10^{-14}}{1.91 \times 10^{-13}}$ $= 0.0524 \text{ (mol dm}^{-3}\text{)} \checkmark$	2	ALLOW alternative approach via pOH $pOH = 14 - 12.72 = 1.28 \checkmark$ $[NaOH] / [OH^-(\text{aq})] = 10^{-pOH}$ $= 0.0524 \text{ (mol dm}^{-3}\text{)} \checkmark$ ALLOW any value between 0.052 and 0.053 <i>answer depends on degree of rounding for H^+ but 2 SF minimum</i> calculator: 0.052480746
	Total	12	

Question	Answer	Marks	Guidance
20 (a)	<p>Please refer to the marking instructions on page 4 of this mark scheme for guidance on how to mark this question.</p> <p>Level 3 (5–6 marks) A comprehensive conclusion which outlines control of concentrations for each experiment with all volumes shown AND uses quantitative results for determination of orders and rate equation AND calculates a value for the rate constant with units.</p> <p><i>There is a well-developed conclusion showing a line of reasoning which is clear and logically structured. The working for control of variables, determination of orders/rate equation and rate constant are clearly linked to the experimental evidence.</i></p> <p>Level 2 (3–4 marks) Reaches a sound, but not comprehensive, conclusion based on the quantitative results AND outlines control of all concentrations, diluting each solution at a time OR correctly identifies the orders supported by results and calculates a value for the rate constant.</p> <p><i>The conclusion has a line of reasoning with some structure. The working for control of variables OR orders/rate equation AND rate constant are linked to the experimental evidence.</i></p> <p>Level 1 (1–2 marks) Attempts to controls concentrations by diluting each solution in turn AND reaches a simple conclusion for orders to obtain a rate equation</p>	6	<p>Indicative scientific points may include: <u>Control of variables</u> <i>Initial concentrations throughout</i></p> <ul style="list-style-type: none"> • mix 10 cm³ of Br⁻, BrO₃⁻ and H⁺ • dilute each solution in turn with water • only one solution changed at a time • total volume kept the same <p>NOTE: Volumes of each mixture could be shown and illustrates all points above, e.g. Expt 1: 10 / 10 / 10 Expt 2: 2.5 + 7.5 H₂O / 10 / 10 Expt 3: 10 / 5 + 5 H₂O / 10 Expt 4: 10 / 5 + 5 H₂O / 5 + 5 H₂O</p> <hr/> <p><u>Orders/rate equation</u></p> <ul style="list-style-type: none"> • Br⁻ 1st order • BrO₃⁻ 1st order • H⁺ 2nd order <p>OR rate = $k[\text{Br}^-][\text{BrO}_3^-][\text{H}^+]^2$</p> <ul style="list-style-type: none"> • Supported by reasoning from the experimental results <p><u>Calculation of k, including units</u></p> <ul style="list-style-type: none"> • Value of k correctly calculated: $k = 12$ • Units: dm⁹ mol⁻³ s⁻¹ OR mol⁻³ dm⁹ s⁻¹

Question	Answer	Marks	Guidance
	with few errors. <i>The working for orders, and rate equation are linked to the experimental data, but the evidence may not be clearly shown.</i> 0 marks – No response or no response worthy of credit.		
(b)	(i) $3 \text{MnO}_4^{2-} + 4 \text{H}^+ \rightarrow 2 \text{MnO}_4^- + \text{MnO}_2 + 2 \text{H}_2\text{O}$ ✓	1	ALLOW 1 in front of MnO_2
(ii)	In acidic conditions (Concentration of) H^+ increases AND equilibrium (position) shifts to the right to reduce concentration of H^+ /remove H^+ ✓ In alkaline conditions OH^- reacts with H^+ AND equilibrium (position) shifts to the left to increase concentration of H^+ /add H^+ ✓	2	ALLOW $\text{H}^+ + \text{OH}^- \rightarrow \text{H}_2\text{O}$
(c)	In acid: $\text{H}_2(\text{g}) \rightarrow 2\text{H}^+(\text{aq}) + 2\text{e}^-$ AND $\text{O}_2(\text{g}) + 4\text{H}^+(\text{aq}) + 4\text{e}^- \rightarrow 2\text{H}_2\text{O}(\text{l})$ ✓ $2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$ AND Cell potential = $1.23 - 0.00 = 1.23$ (V) ✓ In alkali: $2\text{OH}^-(\text{aq}) + \text{H}_2(\text{g}) \rightarrow 2\text{H}_2\text{O}(\text{l}) + 2\text{e}^-$ AND $\text{O}_2(\text{g}) + 2\text{H}_2\text{O}(\text{l}) + 4\text{e}^- \rightarrow 4\text{OH}^-(\text{aq})$ ✓ $2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$	4	ALLOW $\text{H}_2 + \frac{1}{2}\text{O}_2 \rightarrow \text{H}_2\text{O}$

Question		Answer	Marks	Guidance
		AND Cell potential = $0.40 - (-0.83) = 1.23 \text{ (V)}$ ✓		ALLOW $\text{H}_2 + \frac{1}{2}\text{O}_2 \rightarrow \text{H}_2\text{O}$
		Total	13	

Question	Answer	Marks	Guidance
21 (a)	(i) $1s^2 2s^2 2p^6 3s^2 3p^6 3d^6$ ✓ Look carefully at $1s^2 2s^2 2p^6 3s^2 3p^6$ – there may be a mistake	1	ALLOW $4s^0$ before or after $3d$, i.e. $1s^2 2s^2 2p^6 3s^2 3p^6 4s^0 3d^6$ DO NOT ALLOW [Ar] as shorthand for $1s^2 2s^2 2p^6 3s^2 3p^6$ ALLOW upper case D, etc and subscripts, e.g. $3D_{10}$ IGNORE an extra $1s^2$ after prompt on answer line
(ii)	<div style="border: 1px solid black; padding: 5px; margin: 10px auto; width: fit-content;"> FeCl_4^- ✓ </div> <p style="text-align: center;">↓ Conc HCl(aq)</p> <p style="text-align: center;">$[\text{Fe}(\text{H}_2\text{O})_6]^{3+}$ pale yellow solution</p> <p style="text-align: center;">↓ KI/I^- ✓</p> <p style="text-align: center;">$[\text{Fe}(\text{H}_2\text{O})_6]^{2+}$ pale green solution</p> <p style="text-align: center;">↓ NaOH(aq)</p> <div style="border: 1px solid black; padding: 5px; margin: 10px auto; width: fit-content;"> $\text{Fe}(\text{OH})_2$ AND green precipitate ✓ </div>	4	<p>Check correct 1 – charge ALLOW brackets, e.g. $[\text{FeCl}_4]^-$</p> <p>For I^-, ALLOW SO_2, $(\text{H}^+)/\text{Zn}$</p> <p>For MnO_4^-, ALLOW H_2O_2, $(\text{H}^+)/\text{Cr}_2\text{O}_7^{2-}$, Cl_2</p> <p>For $\text{Fe}(\text{OH})_2$ ALLOW $\text{Fe}(\text{OH})_2(\text{H}_2\text{O})_4$ For colour, ALLOW any colour that describes green</p>
(b)	$n(\text{H}_2) = \frac{150}{24000} = 0.00625 \text{ (mol)}$ ✓	4	

Question	Answer	Marks	Guidance
	<p>If Equation 1, $M = \frac{0.188}{0.00625} = 30.08 \text{ (g mol}^{-1}\text{)}$ ✓</p> <p>If Equation 2, $M = 0.188/0.00625 \times 1.5 = 45.18 \text{ (g mol}^{-1}\text{)}$ ✓</p> <p>Element M = scandium/Sc ✓</p>		<p>DO NOT ALLOW ECF based on 30</p> <p>NOTE: Only 45 matches Ar values of d-block element/Sc–Zn</p>
(c) (i)	<p>$[\text{Co}(\text{H}_2\text{O})_6]^{2+} + 6\text{NH}_3 \rightarrow [\text{Co}(\text{NH}_3)_6]^{2+} + 6\text{H}_2\text{O}$ ✓</p> <p>ligand substitution ✓</p>	2	<p>ALLOW ligand exchange</p> <p>IGNORE charges (anywhere) and labels (even if wrong)</p> <p>Square brackets NOT required</p> <p>Must contain 2 ‘out wedges’, 2 ‘in wedges’ and 2 lines in plane of paper OR 4 lines, 1 ‘out wedge’ and 1 ‘in wedge’:</p> <p>For bond into paper, ALLOW:</p>  <p>ALLOW following geometry throughout:</p> 
(ii)	 <p>3-D Shape ✓</p> <p>bond angle 90° ✓</p> <p>Bonds must be to N of NH_3 ligands</p>	2	
(iii)	Empirical formula of complex D	4	

Question	Answer	Marks	Guidance
	<p>Co : N : H : Cl $\frac{22.03}{58.9} : \frac{31.41}{14.0} : \frac{6.73}{1.00} : \frac{39.83}{35.5}$ OR 0.374 : 2.24 : 6.73 : 1.12 ✓</p> <p>= 1 : 6 : 18 : 3 = $\text{CoN}_6\text{H}_{18}\text{Cl}_3$ ✓</p> <p>complex ion C $[\text{Co}(\text{NH}_3)_6]^{3+}$ ✓</p> <p>complex D $[\text{Co}(\text{NH}_3)_6]^{3+}[\text{Cl}]_3$ ✓</p>		<p>Correct empirical formula subsumes previous mark</p>
(iv)	<p>Half equations $[\text{Co}(\text{NH}_3)_6]^{2+} \rightarrow [\text{Co}(\text{NH}_3)_6]^{3+} + \text{e}^-$ ✓</p> <p>$\text{H}_2\text{O}_2 + 2\text{e}^- \rightarrow 2\text{OH}^-$ ✓</p> <p>Overall equation $2[\text{Co}(\text{NH}_3)_6]^{2+} + \text{H}_2\text{O}_2 \rightarrow 2[\text{Co}(\text{NH}_3)_6]^{3+} + 2\text{OH}^-$ ✓</p>	3	<p>ALLOW multiples throughout</p> <p>ALLOW $\text{H}_2\text{O}_2 + 2\text{H}^+ + 2\text{e}^- \rightarrow 2\text{H}_2\text{O}$</p> <p>ALLOW $2[\text{Co}(\text{NH}_3)_6]^{2+} + \text{H}_2\text{O}_2 + 2\text{H}^+ \rightarrow 2[\text{Co}(\text{NH}_3)_6]^{3+} + 2\text{H}_2\text{O}$</p>
	Total	20	