OCR
Oxford Cambridge and RSA

A Level Chemistry A
H432/01 - **Periodic table, elements and physical chemistry**

MARK SCHEME

Duration: 2 hour 15 minutes

MAXIMUM MARK 100

This document consists of 25 pages

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. **Crossed Out Responses**

Where a candidate has crossed out a response and provided a clear alternative then the crossed out response is not marked. Where no alternative response has been provided, examiners may give candidates the benefit of the doubt and mark the crossed out response where legible.

Rubric Error Responses – Optional Questions
Where candidates have a choice of question across a whole paper or a whole section and have provided more answers than required, then all responses are marked and the highest mark allowable within the rubric is given. Enter a mark for each question answered into RM assessor, which will select the highest mark from those awarded. *(The underlying assumption is that the candidate has penalised themselves by attempting more questions than necessary in the time allowed.)*

Multiple Choice Question Responses
When a multiple choice question has only a single, correct response and a candidate provides two responses (even if one of these responses is correct), then no mark should be awarded (as it is not possible to determine which was the first response selected by the candidate).
When a question requires candidates to select more than one option/multiple options, then local marking arrangements need to ensure consistency of approach.

Contradictory Responses
When a candidate provides contradictory responses, then no mark should be awarded, even if one of the answers is correct.

Short Answer Questions (requiring only a list by way of a response, usually worth only **one mark per response**)
Where candidates are required to provide a set number of short answer responses then only the set number of responses should be marked. The response space should be marked from left to right on each line and then line by line until the required number of responses have been considered. The remaining responses should not then be marked. Examiners will have to apply judgement as to whether a 'second response' on a line is a development of the 'first response', rather than a separate, discrete response. *(The underlying assumption is that the candidate is attempting to hedge their bets and therefore getting undue benefit rather than engaging with the question and giving the most relevant/correct responses.)*

Short Answer Questions (requiring a more developed response, worth **two or more marks**)
If the candidates are required to provide a description of, say, three items or factors and four items or factors are provided, then mark on a similar basis – that is downwards (as it is unlikely in this situation that a candidate will provide more than one response in each section of the response space.)

Longer Answer Questions (requiring a developed response)
Where candidates have provided two (or more) responses to a medium or high tariff question which only required a single (developed) response and not crossed out the first response, then only the first response should be marked. Examiners will need to apply professional judgement as to whether the second (or a subsequent) response is a 'new start' or simply a poorly expressed continuation of the first response.

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. Award No Response (NR) if:

    - there is nothing written in the answer space.

    Award Zero '0' if:

    - anything is written in the answer space and is not worthy of credit (this includes text and symbols).

    Team Leaders must confirm the correct use of the NR button with their markers before live marking commences and should check this when reviewing scripts.

8. The scoris **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 scoris 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 **21(d)**.

11. **Annotations**

Annotation	Meaning
DO NOT ALLOW	Answers which are not worthy of credit
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
AW	Alternative wording
ORA	Or reverse argument
	Correct response
	Incorrect response
	Omission mark
	Benefit of doubt given
	Contradiction
	Rounding error

	Error in number of significant figures
	Error carried forward
	Level 1
	Level 2
	Level 3
	Benefit of doubt not given
	Noted but no credit given
	Ignore

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.

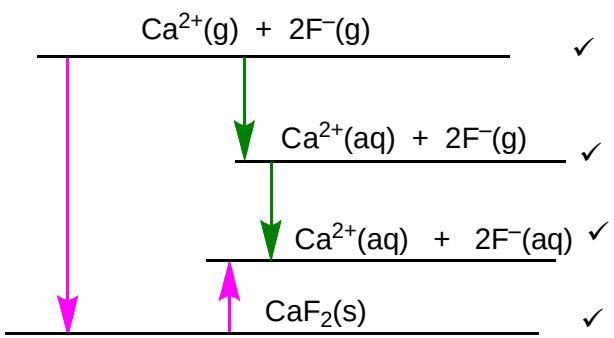
You should ensure also that you are familiar with the administrative procedures related to the marking process. These are set out in the OCR booklet **Instructions for Examiners**. If you are examining for the first time, please read carefully **Appendix 5 Introduction to Script Marking: Notes for New 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	AO element	Guidance
1	C	1	AO2.2	
2	C	1	AO2.2	
3	B	1	AO2.2	
4	D	1	AO2.4	
5	A	1	AO1.2	
6	C	1	AO1.2	
7	D	1	AO2.3	
8	A	1	AO1.1	
9	B	1	AO1.2	
10	C	1	AO2.6	
11	A	1	AO1.2	
12	D	1	AO2.5	
13	B	1	AO1.1	
14	C	1	AO1.1	
15	D	1	AO1.1	
	Total	15		

SECTION B

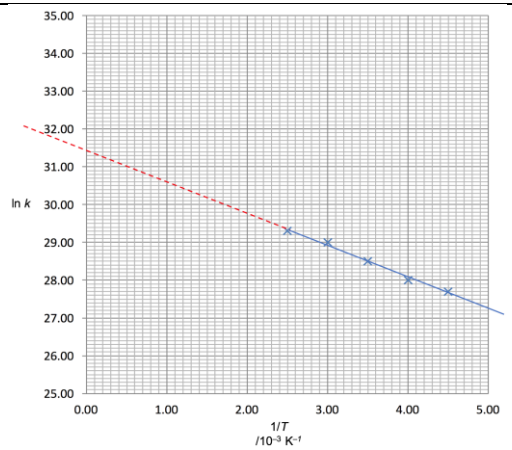
Question			Answer	Marks	Guidance
16	(a)	(i)	(enthalpy change when) 1 mole of gaseous ions react **OR** 1 mole of hydrated/aqueous ions are formed ✓ gaseous ions dissolve in **water** **OR** gaseous ions form aqueous/hydrated ions ✓	2	**IGNORE** 'energy released' **OR** 'energy required'
	(a)	(ii)	 ✓ ✓ ✓ ✓	4	Correct species **AND** state symbols required for each mark. (mark independently) On 2nd line, **ALLOW** $Ca^{2+}(g) + 2F^-(aq)$ (i.e. F^- hydrated before Ca^{2+}) On 3rd line, **ALLOW** $CaF_2(aq)$ **DO NOT ALLOW** when first seen but **ALLOW ECF** for '**2**' missing and for use of the following ions Fl^- F_2^- $Ca^{+/3+}$

Question			Answer	Marks	Guidance
	(a)	(iii)	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF answer = –504 (kJ mol^{-1}) award 2 marks** **IF answer = –1008 (kJ mol^{-1}) award 1 mark** **----------** $2 \times \Delta_{hyd}H(F^-)$ = [–2630 + 13] – (–1609) **OR** – 2617 + 1609 **OR** –1008 (kJ mol^{-1}) ✓ $\Delta_{hyd}H(F^-) = \frac{-1008}{2}$ = –504 ✓ (kJ mol^{-1})	**2**	**IF** alternative answer, check to see if there is any **ECF** credit possible using working below. '–' sign is needed. **COMMON ERRORS** for 1 mark: (+)2694: *signs all reversed* –2113: *sign wrong for –1609* –2126: *sign wrong for 2630* –517: *sign wrong for 13* +504: *sign wrong* **IF ALL 3 relevant values from the information at the start of Q16a(iii) have NOT been used, award zero marks unless one number has a transcription error, where 1 mark can be awarded ECF**
	(a)	(iv)	***Correct comparison of Δ_{hyd} linked to sizes*** $\Delta_{hyd}H$ (F^-) more negative/exothermic (than $\Delta_{hyd}H$ (Cl^-)) **AND** F^- has smaller size (than Cl^-) ✓ ***Comparison of attraction between ions and water*** F^- OR smaller sized ion linked to greater attraction **to H_2O** ✓	**2**	**ORA** **IGNORE 'atomic'** before radius when comparing size of ions **IGNORE** charge density **IGNORE** electronegativity **IGNORE** nuclear attraction **DO NOT ALLOW** 'forms stronger hydrogen bonds with water' **OR** 'forms stronger van der Waals' forces with water' **ALLOW** 'forms bonds' for attraction' **DO NOT ALLOW** F^- greater attraction to H_2O if given as larger ion Assume 'F' / 'Fluorine' means 'ions' but **DO NOT ALLOW** 'F molecules'

Question			Answer	Marks	Guidance
	(b)	(i)	**Average bond enthalpy** Breaking of one mole of bonds ✓ In gaseous molecules ✓	2	 **IGNORE** energy required **OR** energy released **IGNORE** heterolytic / homolytic **DO NOT ALLOW** bonds formed **DO NOT ALLOW** ionic bonds **IGNORE** species for molecules
	(b)	(ii)	**FIRST, CHECK ANSWER ON ANSWER LINE** **IF answer = (+) 158 award 3 marks** **----------** **Bond enthalpy of F–F** (ΔH for (O–H) bonds broken =) 1856 **OR** 4 × 464 (kJ mol^{-1}) ✓ (ΔH for bonds made =) 2770 (kJ mol^{-1}) **OR** 498 **AND** 2272 (kJ mol^{-1}) **OR** 498 **AND** 4 × 568 (kJ mol^{-1}) ✓ (bond enthalpy) F–F = $\frac{2770 - 1856 - 598}{2}$ = (+)158 (kJ mol^{-1}) ✓	3	**ANNOTATE ANSWER WITH TICKS AND CROSSES** **IGNORE** sign **IGNORE** sign **ALLOW ECF** **Common errors** **Award 2 marks** for; –158 (Wrong sign) (±)316 (No ÷ 2) (+) 622 (use of 2 x 464) (+) 457 (omitting – 598) (+) 756 (use of +598) **Award 1 mark** for; (+) 970 (use of 2 x 464 and +598)
			Total	15	

Question			Answer	Marks	Guidance
17	(a)*		*Please refer to the marking instructions on page 5 of this mark scheme for guidance on how to mark this question.* **Level 3 (5–6 marks)** A comprehensive conclusion which uses quantitative results for determination of the reaction orders. **AND** Determines *k* from correct rate equation. **AND** Proposes the two-step mechanism which adds up to overall equation *with no intermediate electrons*. *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated. The working for the scientific content is clearly linked to the experimental evidence.* **Level 2 (3–4 marks)** Reaches a sound, but not comprehensive, conclusion based on the quantitative results. **AND** Correctly identifies the orders and rate equation. **AND** Calculates the rate constant **OR** Proposes the two-step mechanism with reactants of first step matching rate equation or matches orders *There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence. The working for the scientific content is clearly linked to the experimental evidence.*	6	**Indicative scientific points may include:** **Orders and rate equation** • Fe^{3+} 1st order **AND** I^- 2nd order **OR** *rate* = $k[Fe^{3+}][I^-]^2$ • Supported by experimental results **Calculation of *k*, including units** • *k* correctly calculated **AND** correct units, e.g. $k = \frac{8.10 \times 10^{-4}}{(4.00 \times 10^{-2}) \times (3.00 \times 10^{-2})^2} = 22.5$ • $dm^6\,mol^{-2}\,s^{-1}$ **OR** $mol^{-2}\,dm^6\,s^{-1}$ **Two-step mechanism** • Two steps add up to give overall equation • Slow step/ rate-determining step matches stoichiometry of rate equation. • Each step balances by species and charge **e.g.** $Fe^{3+}(aq) + 2I^-(aq) \rightarrow [FeI_2]^+$ SLOW $Fe^{3+}(aq) + [FeI_2]^+ \rightarrow 2Fe^{2+}(aq) + I_2(aq)$ FAST $Fe^{3+}(aq) + 2I^-(aq) \rightarrow Fe^{2+}(aq) + I_2^-(aq)$ SLOW $Fe^{3+}(aq) + I_2^-(aq) \rightarrow Fe^{2+}(aq) + I_2(aq)$ FAST $Fe^{3+}(aq) + 2I^-(aq) \rightarrow Fe^+ + I_2$ SLOW $Fe^{3+}(aq) + Fe^+ \rightarrow 2Fe^{2+}(aq)$ FAST There may be other feasible possibilities

Question			Answer	Marks	Guidance
			Level 1 (1–2 marks) Attempts to reach a simple conclusion for orders **AND** Attempts a relevant rate equation. *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant The working for the scientific content is clearly linked to the experimental evidence.* **0 marks** No response or no response worthy of credit.		

Question			Answer	Marks	Guidance
	(b)	(i)	 **Gradient** Correct gradient calculated from best-fit straight line drawn within the range ±800 → ±1040 ✓ ***E*ₐ calculation** E_a = (–) gradient × 8.314 ✓ *e.g. from ±820, E_a = (+)6817.48* (J mol^{-1}) ***E*ₐ to 3 SF AND** use of 10^{-3} for gradient ✓ *e.g. from ±820, E_a = (+)6820* (J mol^{-1})	3	**ALLOW** lines which do not intercept y-axis **ALLOW** mark for gradient if correct working shown within E_a calculation without gradient being calculated separately **ALLOW** ±0.8(00) → ±1.04(0) (*omission of 10^{-3}*) **ALLOW** ECF for calculated gradient x 8.314 If value of gradient not shown separately, **ALLOW** E_a in range: 6650 → 8650 **OR** 6.65 → 8.65 (*omission of 10^{-3}*) **This mark subsumes gradient mark** **NOTE: Omission of 10^{-3} can get 1st 2 marks**

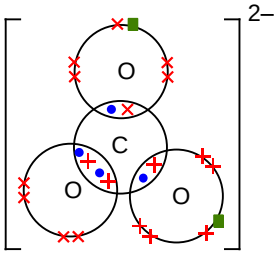
Question			Answer	Marks	Guidance
		(ii)	Intercept shown on graph *could be by extrapolation of line, or label on y axis* **AND** ln A linked to intercept value *e.g. ln A = 31.4* ✓ Calculation of $A = e^{intercept}$ ✓ *e.g.* $A = e^{31.4} = 4.33 \times 10^{13}$	**2**	***ALLOW*** *y = 31.4* **ALLOW** substitution of correct values of ln k and 1/T into $\ln k = -E_a/R \times 1/T + \ln A$ to give a value of ln A which approximately matches the intercept if given $\ln A = \ln k + (E_a/R \times 1/T)$ *Calculation of* $A = e^{lnA}$ ***OR*** $e^{\ln k + (Ea/R \times 1/T)}$ **ALLOW** ECF from incorrect ln *A* $e^{31.2} = 3.55 \times 10^{13}$ $e^{31.3} = 3.92 \times 10^{13}$ $e^{31.35} = 4.12 \times 10^{13}$ $e^{31.45} = 4.56 \times 10^{13}$ $e^{31.5} = 4.79 \times 10^{13}$ $e^{31.6} = 5.29 \times 10^{13}$ $e^{31.7} = 5.85 \times 10^{13}$ $e^{31.8} = 6.46 \times 10^{13}$ $e^{31.9} = 7.14 \times 10^{13}$ $e^{32.0} = 7.9(0) \times 10^{13}$ $e^{32.1} = 8.73 \times 10^{13}$ IF 2 DP answer given, check rounding from calculator value, not 3 DP values given Eg $e^{31.7} = 5.8497 \times 10^{13}$ *and* $= 5.8 \times 10^{13}$*(2SF)*
			Total	**11**	

Question			Answer	Marks	Guidance
18	(a)		$K_c = \frac{[NO_2]^2}{[NO]^2\,[O_2]}$ ✓ Units = $dm^3\ mol^{-1}$ ✓	2	Must be square brackets **IGNORE** state symbols **ALLOW** $mol^{-1}\ dm^3$ **ALLOW** $mol\ dm^{-3}$ as ECF from inverted K_c expression
	(b)		**FIRST CHECK THE ANSWER ON THE ANSWER LINE IF answer = 1.2 (mol) award 4 marks** **Unless otherwise stated, marks are for correctly calculated values. Working shows how values have been derived.** $[NO] = \frac{0.40}{4.0} = 0.1(0)\ (mol\ dm^{-3})$ **AND** $[O_2] = \frac{0.80}{4.0} = 0.2(0)\ (mol\ dm^{-3})$ ✓ $[NO_2]^2 = 45 \times 0.10^2 \times 0.20$ **OR** = 0.09(0) ✓ $[NO_2] = \sqrt{(45 \times 0.10^2 \times 0.20)}$ **OR** = 0.3(0) $(mol\ dm^{-3})$ ✓ amount $NO_2 = 0.30 \times 4 = 1.2$ (mol) ✓	4	***ANNOTATIONS MUST BE USED*** For **all** parts, **ALLOW** numerical answers from 2 significant figures up to the calculator value Ignore rounding errors after second significant figure 1st mark is for realising that concentrations need to be calculated. **ALLOW ECF** **Correct numerical answer with no working would score all previous calculation marks** Making point 2 subsumes point 1 Making point 3 subsumes points 2 and 1 Common errors 9.6 = 3 marks mol of NO and O_2 used 0.36 = 3 marks mol of NO_2 calculated from $[NO_2]^2$ 2.4 = 2 marks mol of NO and O_2 used and no mol of NO_2 calculated

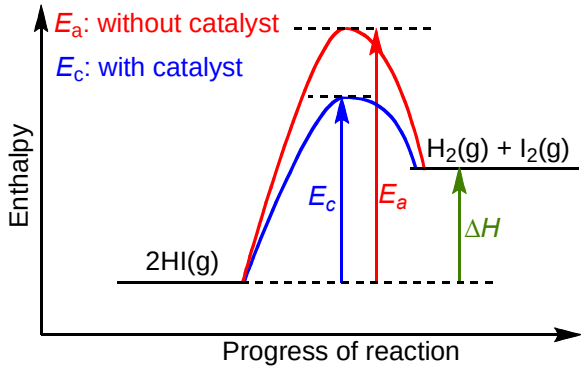
Question			Answer	Marks	Guidance
	(c)	(i)	Exothermic **AND** K_p decreases as temperature increases ✓	1	**ALLOW** K_c for K_p **ALLOW** Equilibrium shifts to left hand side as temperature increases
	(c)	(ii)	***Equilibrium shift*** (Equilibrium position) shifts to right / forward / towards products ✓ ***Effect of increased pressure on K_p expression*** *R*atio (in K_p expression) decreases **OR** Denominator/bottom of K_p expression increases more (than numerator/top) ✓ ***Equilibrium shift (K_p expression)*** Ratio (in K_p expression) increases **to restore K_p** **OR** Numerator/top of K_p expression increases **to restore K_p** ✓	3	**FULL ANNOTATIONS NEEDED** **ALLOW** K_c for K_p throughout the response. **ALLOW** K_p (initially) decreases for second marking point **IF** K_p is seen to be restored later in the process. **ALLOW** more NO_2 / product formed to restore K_p **ALLOW** ratio adjusts to restore K_p
			Total	10	

Question			Answer	Marks	Guidance
19	(a)	(i)	$K_a = \frac{[H^+]\,[CH_3COO^-]}{[CH_3COOH]}$ ✓	1	**IGNORE** state symbols Must be square brackets **IGNORE** expressions with HA or with $[H^+]^2$
		(ii)	**FIRST, CHECK ANSWER ON ANSWER LINE** **IF answer = 4.76 award 3 marks** --- **$[H^+] = 10^{-pH}$** $= 10^{-2.41} = 3.89 \times 10^{-3}$ (mol dm^{-3}) ✓ ***K*$_a$** $= \frac{[H^+]^2}{[CH_3COOH]} = \frac{(3.89 \times 10^{-3})^2}{0.870}$ $= 1.74 \times 10^{-5}$ (mol dm^{-3}) ✓ **p*K*$_a$** $= -\log K_a = -\log 1.74 \times 10^{-5} = 4.76$ ✓	3	**ALLOW** use of **HA** and **A$^-$** **ALLOW 3 SF** up to calculator value of: $3.89045145 \times 10^{-3}$ correctly rounded ***K*$_a$** $1.739725573 \times 10^{-3}$ **NOTE:** 1.74×10^{-5} is same from unrounded $[H^+]$ calculator value and 3 SF $[H^+]$ value **2 DP required**
		(iii)	% dissociation $= \frac{[H^+]}{[CH_3COOH]} \times 100$ $= \frac{3.89 \times 10^{-3}}{0.870} \times 100 = 0.447(\%)$ ✓	1	**3 SF required**

Question	Answer	Marks	Guidance
(b)	**FIRST, CHECK ANSWER ON ANSWER LINE** **IF answer = 95.9(%) award 4 marks** **----------** **$[H^+] = 10^{-pH}$** $= 10^{-13.48} = 3.31 \times 10^{-14}$ (mol dm^{-3}) ✓	**4**	**ALLOW ECF** throughout **IGNORE** rounding errors beyond 3rd SF throughout **ALLOW** 3.3×10^{-14} (mol dm^{-3})
	$[OH^-]$ from K_w $= \frac{1.00 \times 10^{-14}}{3.31 \times 10^{-14}} = 0.302$ (mol dm^{-3}) ✓		**ALLOW** 0.30 **ALLOW** 0.303 if 3.3×10^{-14} used in the first marking point **ALLOW** pOH method:, pOH = 14 – 13.48 = 0.52 $[OH^-] = 10^{-0.52} = 0.302$ (mol dm^{-3})
	***Mass of* (NaOH)** $= 0.302 \times \frac{100}{1000} \times 40.0 = 1.21$ (g) ✓		**ALLOW** $[OH^-] \times 0.1 \times 40$
	% of NaOH to 3 SF $= \frac{1.21}{1.26} \times 100 = 95.9$ (%) ✓		Rounding $[OH^-]$ to 0.3(0) gives 1.2/1.26 = 95.2% Award 4 marks Rounding $[OH^-]$ to 0.303 gives 1.212/1.26 = 96.2% Award 4 marks

Question	Answer	Marks	Guidance
(c)	 **Global rules** • C and O electrons must be shown differently, e.g. • for C and × for O • Na electrons shown with different symbol **MARKING** ***Bonding around central C atom*** ✓ • 4 electrons for C shown as • **OR** × • 4 electrons for O, different from C as • **OR** × • C=O bond with 2 C electrons **AND** 2 O electrons • Two C–O bonds with 1 C electron **AND** 1 O electron ***Non-bonded (nb) electrons around 3 O atoms*** ✓ • C=O oxygen has 4 nb 'O' electrons • Each C–O oxygen has 5 nb 'O' electrons **AND** 1 'extra' electron with different symbol	**2**	**NOT REQUIRED** • Charge ('2–') **IGNORE** incorrect charges • Brackets • Circles **IGNORE** inner shells **ALLOW** rotated diagram **ALLOW** diagram with missing C or O symbols. In **C=O bond**, **ALLOW** sequence × × • • In **C–O bond**, **ALLOW** 'extra' electron with different symbol for O electron **ALLOW** non-bonding electrons unpaired **ALLOW** 'extra' electron as • **OR** × if it has been **labelled** 'extra electron' or similar
	Total	**11**	

Question			Answer	Marks	Guidance
20	(a)		**ASSUME** trend is down the group (unless stated otherwise) **Forces** London forces increase **OR** induced dipole(–dipole) interactions increase ✓ **Reason** (Number of) electrons increases ✓ **Link to energy and particles** More energy to break intermolecular forces **OR** to break London forces **OR** to break induced dipole(–dipole) interactions ✓	3	**FULL ANNOTATIONS MUST BE USED** ---------- **ALLOW** reverse argument throughout **IGNORE** van der Waals'/vdW forces **DO NOT ALLOW** hydrogen bonds **OR** permanent dipole(-dipole) interactions for first and third marking points **ALLOW** more (electron) shells **DO NOT ALLOW** covalent bonds break

Question	Answer	Marks	Guidance
(b)	 2HI(g) on LHS **AND** $H_2(g) + I_2(g)$ on RHS ✓ ΔH labelled with product above reactant **AND** arrow upwards ✓ E_a **AND** E_c correctly labelled with E_c below E_a ✓	3	**FULL ANNOTATIONS MUST BE USED** **Mark each point independently** **IGNORE** state symbols. ΔH: **DO NOT ALLOW** $-\Delta H$. **ALLOW** ΔH arrow even with a gap at the top and bottom, i.e. does not quite reach reactant or product line E_a: **ALLOW** no arrowhead or arrowheads at both ends of E_a line E_a line must reach (near or not too far beyond) maximums regardless of position **ALLOW** AE or EA for E_a Exothermic diagram can access the first and third marks
(c)	**FIRST CHECK THE ANSWER ON THE ANSWER**	4	**If there is an alternative answer, check to see if**

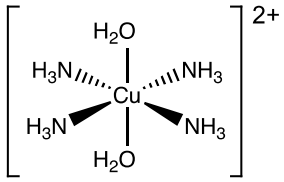
Question			Answer	Marks	Guidance
			LINE **IF *M* = 183 AND Formula = Cl_2O_7 award 4 marks** **IF *M* = 183 award 3 marks** --- **Use of data and unit conversions** • (R = 8.314) • T in K: 373K • V in m^3: 76.0×10^{-6} • (p in Pa: 1.00×10^5) ✓ **Calculation of n** $n = \frac{(1.00 \times 10^5) \times (76.0 \times 10^{-6})}{8.314 \times 373}$ $n = 2.45 \times 10^{-3}$ (mol) ✓ **Molar mass** $M = \frac{m}{n} = \frac{0.4485}{2.45 \times 10^{-3}} = 183$ (g mol^{-1}) ✓ **Molecular formula** Cl_2O_7 ✓		**there is any ECF credit possible using working below** Correct value of n subsumes first mark **ALLOW ECF** from incorrectly **calculated** *n* **ALLOW ECF** from incorrect M if formula of Cl_xO_y is the **closest** to the with **calculated** value of *M* **IGNORE** use of 24 000 cm^3 for calculation of n **BUT** then Mark molar mass and Molecular formula by **ECF** for two marks maximum. $n = \frac{76.0}{24000} = 3.17 \times 10^{-3}$ (mol) $M = \frac{0.4485}{3.17 \times 10^{-3}}$ = 141.6/141.5 (g mol^{-1}) ✓ Molecular formula = Cl_3O_2 ✓
	(d)	**(i)**	Titres correct and **ALL** recorded to **2 decimal places**	**2**	

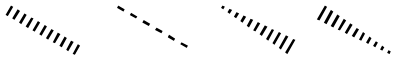
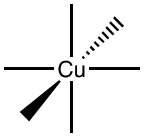
Question			Answer	Marks	Guidance
			Titre: 24.00 23.40 23.75 23.85 ✓ mean titre = 23.80 (cm^3) ✓		**ALLOW** 23.8 cm^3
	(d)	**(ii)**	Percentage uncertainty = $\frac{0.05 \times 2}{23.40} \times 100 = 0.43$ (%) ✓	**1**	**ALLOW ECF** from incorrect subtraction in **(i)** or incorrect mean **ALLOW** 0.42% from titre values 2, 3 or 4 or mean titre or trial titre. **2 DP required**
	(d)	**(iii)**	Add starch (near the end point) ✓ Blue to colourless ✓	**2**	**ALLOW** blue/black **OR** black **OR** purple for colour of mixture **ALLOW** blue colour disappears (to colourless) **IGNORE** 'clear' **IGNORE** 'colorimetry'
	(d)	**(iv)**	**FIRST CHECK THE ANSWER ON THE ANSWER LINE** **IF B = $RbIO_3$ AND relative formula mass = 260.5**	**5**	

Question			Answer	Marks	Guidance
			award 5 marks **IF relative formula mass = 260.5 award 4 marks** --- **$n(S_2O_3^{2-})$ in titration** $= \frac{0.150 \times 23.80}{1000} = 3.57 \times 10^{-3}$ (mol) ✓ **$n(IO_3^-)$ in titration** $= \frac{3.57 \times 10^{-3}}{6} = 5.95 \times 10^{-4}$ (mol) ✓ **$n(IO_3^-)$ in original 250 cm^3** $= 10 \times 5.95 \times 10^{-4} = 5.95 \times 10^{-3}$ (mol) ✓ **Relative formula mass of B** $= \frac{1.55}{5.95 \times 10^{-3}} = 260.5$ (g mol^{-1}) ✓ **Formula of B (must be derived from relative formula mass)** Iodate of Group 1 metal that most closely matches calculated molar mass of **B** Formula from 260.5 = $RbIO_3$ ✓		**ALLOW ECF** from incorrect mean titre in **(a)(i)** **ECF** from $n(S_2O_3^{2-})$ in titration **ALLOW** a two-step calculation $n(I_2) = n(S_2O_3^{2-}) \div 2$ and $n(IO_3^-) = n(I_2) \div 3$ **ECF** from $n(IO_3^-)$ in titration **ECF** from $n(IO_3^-)$ in original 250 cm^3 **IF** scaling × 10 is omitted, **ALLOW ECF** from $n(IO_3^-)$ in titration **ALLOW ECF** from incorrect RFM of **B** provided metal is from Group 1 **ALLOW** $RbIO_3^-$ **DO NOT ALLOW** $RbIO_3$ without relative formula mass value. **DO NOT ALLOW** 260.4 (without working) and $RbIO_3$ **IF B** = $RbIO_3$ AND relative formula mass = 261 award 5 marks
			Total	**20**	

Question			Answer	Marks	Guidance
21	(a)		Ni: $1s^2 2s^2 2p^6 3s^2 3p^6 3d^8 4s^2$ ✓ Ni^{2+}: $1s^2 2s^2 2p^6 3s^2 3p^6 3d^8$ ✓	2	**ALLOW** 4s before 3d, ie $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^8$ **ALLOW** $1s^2$ written after answer prompt (*ie* $1s^2$ twice) **ALLOW** upper case D, etc and subscripts, e.g. …..$4S_2 3D_8$ **ALLOW** for Ni^{2+} **…….**$4s^0$ **DO NOT ALLOW** [Ar] as shorthand for $1s^2 2s^2 2p^6 3s^2 3p^6$ Look carefully at $1s^2 2s^2 2p^6 3s^2 3p^6$ – there may be a mistake
	(b)	(i)	*Circuit*: complete circuit **AND** voltmeter **AND** salt bridge linking two half-cells ✓ *Half cells*: Pt **AND** I^- **AND** I_2 ✓ Ni **AND** Ni^{2+} ✓ *Standard conditions*: 1 mol dm^{-3} solutions **AND** 298 K / 25ºC ✓	4	Voltmeter must be shown **AND** salt bridge must be labelled **ALLOW** small gaps in circuit **ALLOW** half cells drawn either way around **IGNORE 2** before I^-(aq) **DO NOT ALLOW** I_2(g) **OR** I_2(s) **OR** I_2(l) **ALL** conditions required **BUT ALLOW** 1 mol dm^{-3}/1M if omitted here but shown for just one solution in diagram Look on diagram in addition to answer lines **IGNORE** pressure *Not relevant for this cell* **DO NOT ALLOW** 1 mol for concentration
	(b)	(ii)	*E* = 0.79 (V) ✓	1	**IGNORE** sign
	(c)	(i)	$H_2O_2(aq) + 2H^+(aq) + 2Fe^{2+}(aq) \rightarrow 2Fe^{3+}(aq) + 2H_2O(l)$ ✓	1	**ALLOW** multiples **IGNORE** state symbols, even if wrong

Question			Answer	Marks	Guidance
	(c)	(ii)	**Equations** $3Zn(s) + Cr_2O_7^{2-}(aq) + 14H^+(aq) \rightarrow 3Zn^{2+}(aq) + 2Cr^{3+}(aq) + 7H_2O(l)$ ✓ $Zn(s) + 2Cr^{3+}(aq) \rightarrow Zn^{2+}(aq) + 2Cr^{2+}(aq)$ ✓ **Comparison of *E* values (seen once)** *E* of Zn is more negative/less positive than *E* of $Cr_2O_7^{2-}$ **OR** *E* of Zn is more negative/less positive than *E* of Cr^{3+} ✓ **Equilibrium shift related to *E* values** More negative/less positive **OR** Zn system shifts left **OR** Less negative/more positive $Cr_2O_7^{2-}$ system shifts right **OR** Less negative/more positive Cr^{3+} system shifts right ✓	4	**ALLOW** multiples **IGNORE** state symbols, even if wrong **ALLOW** E_{cell} is (+) 2.09V for $Zn/Cr_2O_7^{2-}$ cell **OR** **ALLOW** E_{cell} is (+) 0.34V for Zn/Cr^{3+} cell **IGNORE** 'lower/higher' For 'shifts left': **ALLOW** '(Zn) is oxidised' **OR** 'electrons are lost (from Zn)' For 'shifts right', **ALLOW** '(Cr) is reduced' **OR** 'electrons are gained'
	(d)		*Please refer to the marking instructions on page 5 of this mark scheme for guidance on how to mark this*	6	**Indicative scientific points may include:**

Question	Answer	Marks	Guidance
	question. **Level 3 (5–6 marks)** All three reactions are covered in detail with **C**, **D**, **E** and **F** identified with clear explanations. *There is a well-developed line of reasoning which is clear and logically structured with clear chemical communication and few omissions. The information presented is relevant and substantiated.* **Level 2 (3–4 marks)** All three reactions are covered but explanations may be incomplete **OR** Two reactions are explained in detail. *There is an attempt at a logical structure with a line of reasoning. The information is relevant e.g. formulae may contain missing brackets or numbers and supported by some evidence.* **Level 1 (1–2 marks)** Make two simple explanations from any one reaction. **OR** Makes one simple explanation from each of two reactions *There is an attempt at a logical structure with a line of reasoning The information is in the most part relevant.* **0 marks** No response worthy of credit.		**REACTION 1 ($CuSO_4/NH_3$)** ***Product*** **C** : $[Cu(NH_3)_4(H_2O)_2]^{2+}$ ***Equation*** $[Cu(H_2O)_6]^{2+} + 4NH_3 \rightarrow [Cu(NH_3)_4(H_2O)_2]^{2+} + 4H_2O$ ***Structure of trans stereoisomer***  Correct connectivity **REACTION 2 (Cu_2O/H_2SO_4)** ***Products*** **D** : $CuSO_4$ **OR** $[Cu(H_2O)_6]^{2+}$ **E**: Cu ***Equation*** $Cu_2O + H_2SO_4 \rightarrow CuSO_4 + Cu + H_2O$ ***Oxidation numbers*** $Cu(+1) \rightarrow Cu(+2) + Cu(0)$ **REACTION 3 (CuO/HNO_3)** ***Equation*** $CuO + 2HNO_3 \rightarrow Cu(NO_3)_2 + H_2O$ ***Molar ratios*** $= \frac{Cu}{63.5} : \frac{H}{1.0} : \frac{N}{14.0} : \frac{O}{16.0} = \frac{26.29}{63.5} : \frac{2.49}{1.0} : \frac{11.59}{14.0} : \frac{59.63}{16.0}$ ***Formula of F*** $CuH_6N_2O_9$ **F**: $Cu(NO_3)_2 \cdot 3H_2O$ (**OR** $Cu(NO_3)_2(H_2O)_3$) **----------** **Further guidance on use of wedges**

Question			Answer	Marks	Guidance
					• 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': • For bond into paper, **ALLOW**:  • **ALLOW** following geometry: 
			Total	**18**	