GCE

Chemistry A

H432/01: Periodic table, elements and physical chemistry

A Level

Mark Scheme for June 2023

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This mark scheme is published as an aid to teachers and students, to indicate the requirements of the examination. It shows the basis on which marks were awarded by examiners. It does not indicate the details of the discussions which took place at an examiners' meeting before marking commenced.

All examiners are instructed that alternative correct answers and unexpected approaches in candidates' scripts must be given marks that fairly reflect the relevant knowledge and skills demonstrated.

Mark schemes should be read in conjunction with the published question papers and the report on the examination.

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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:

   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. 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, using the Level descriptors to help you decide whether it is a strong or weak answer. The indicative scientific content in the Guidance column 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 skills and science content evidenced within the answer, first decide which set of level descriptors, Level 1, Level 2 or Level 3, best describes the overall quality of the answer.

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 skills and science content determines the level.

The communication statement determines the mark within a level.

Level of response questions on this paper are **17** and **22a**

The only annotation on a level of response question should be the indication of the level.

A level annotation should be used where all marks for a level have been achieved.
e.g. if a candidate has 6 marks, they would have this annotation on their script:



If a candidate has achieved 5 marks then they have reached Level 3 but will not have met the communication statement.
They should have the following annotations on their scripts:



The same principle should be applied to Level 2 and Level 1.

No marks (0) should have a cross: 

Place the annotations alongside the mark for the question.

On additional pages, annotate using 

11. Annotations available in RM Assessor

Annotation	Meaning
	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
	Blank page

12. Abbreviations, annotations and conventions used in the detailed Mark Scheme (to include abbreviations and subject-specific conventions).

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

13. **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.

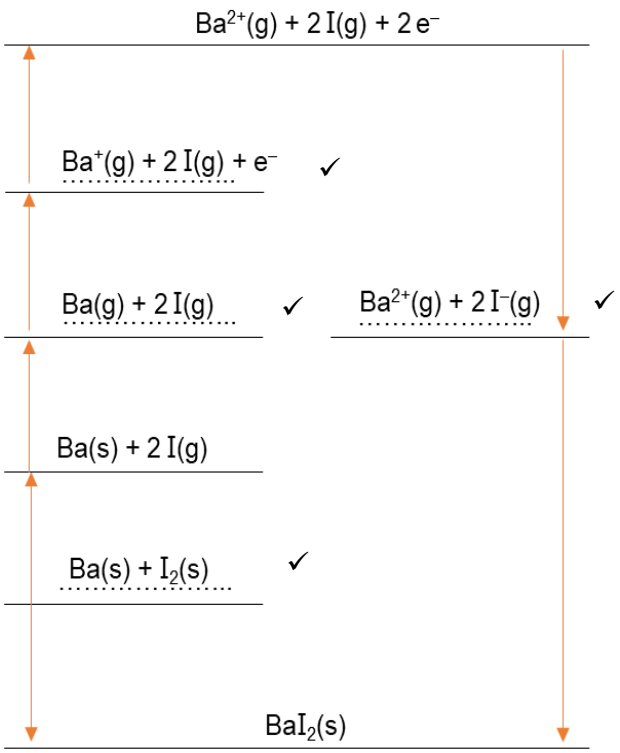
You should ensure also that you are familiar with the administrative procedures related to the marking process. These are set out in the OCR booklet **Instructions for Examiners**. If you are examining for the first time, please read carefully **Appendix 5 Introduction to Script Marking: Notes for New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

SECTION B

Question			Answer	Marks	AO element	Guidance
16	(a)	(i)		4	AO1.2 ×4	

Question			Answer	Marks	AO element	Guidance
		(ii)	**FIRST CHECK THE ANSWER ON ANSWER LINE** **If answer = –1872 award 2 marks** --- ΔH lattice = 2(+ 296) – 965 – 503 – 180 + 2(–107)– 602 ✓ ΔH lattice = –1872 (kJ mol^{-1}) ✓	**2**	AO2.2 ×2	**ALLOW** for 1 mark +1872 (wrong sign on answer) **Common errors for 1 mark** –3056 (–296 x 2 instead of 296 x2) –2168 (296 x 1 instead of 296 x2) –1765 (–107 x 1 instead of –107 x 2) –1512 (180 instead of –180) –1444 (107 x 2 instead of –107 x 2) – 866 (503 instead of –503) – 668 (602 instead of –602) +58 (965 instead of -965) **For other answers**, check for a **single** transcription error or calculation error which could merit 1 mark if all values have been used. **DO NOT ALLOW** any answer which involves two errors
	(b)		**Ist IE of Mg and Sr** (Mg) removes electron from shell closer to the nucleus / smaller **atomic** radius ✓ Greater nuclear **attraction** (between atom and outer electron) ✓	**4**	AO1.1 AO1.2 AO1.1 AO1.2	**ORA throughout** **ALLOW** going down the group for comparison of Mg/Sr Assume 'it' means Mg **ALLOW** (Mg) fewer shells **ALLOW** less shielding **ALLOW** removal of electron from 3s rather than 5s **ALLOW** Greater attraction between nucleus (and outer electron)

Question			Answer	Marks	AO element	Guidance
			2nd/1st IE of Sr 2nd electron removed from cation/positively charged **ion** **OR** proton:electron ratio (in (1)+ ion) is great**er** (than in atom) ✓ Greater nuclear **attraction** / **attraction** between ion (and outer electron)✓			**ALLOW** Sr^+ **ion** smaller (than Sr atom) **ALLOW same** number of protons/nuclear charge **attracting** one fewer electron **IGNORE** repulsion between electrons in the s orbital **IGNORE** shielding

Question			Answer	Marks	AO element	Guidance
17			*Please refer to the marking instructions on page 5 of this mark scheme for guidance on marking this question.* **Level 3 (5–6 marks)** ALL 3 correct orders linked to explanations **AND** rate equation **AND** rate constant *There is a well-developed line of reasoning which is clear and logically structured.* **Level 2 (3–4 marks)** Three correct orders **AND** two out of: some evidence of an explanation linked to an order rate equation rate constant	6	AO3.1 ×3 AO3.2 ×3	**Indicative scientific points may include** **Orders** • 1st order wrt Br^- • 1st order wrt BrO_3^- • 2nd order wrt H^+ **Rate equation** • rate = k $[Br^-]$ $[BrO_3^-]$ $[H^+]^2$ **Calculation of k from any row of data, e.g.** $k = \frac{\text{Rate}}{[Br^-][BrO_3^-][H^+]^2}$ $k = \frac{2.52 \times 10^{-4}}{0.020 \times 0.120 \times (0.080)^2} = 16.4(0625)$

			OR Three correct orders **with an attempt at:** Some evidence of an explanation link to an order rate equation rate constant OR Two correct orders linked to explanations **AND** rate equation **AND** rate constant consistent with the candidate's orders *There is a line of reasoning with some structure and supported by some evidence.* **Level 1 (1–2 marks)** Two correct orders **OR** One correct order **AND** attempts to determine rate equation **OR** rate constant. **OR** One correct order **AND** attempts an explanation. *There is an attempt at a logical structure with a reasoned conclusion from the evidence.* **0 marks** *No response worthy of credit.*			---------- **Explanations from results e.g.** **Br^-** $[Br^-] \times 3$ rate $\times 3$ Expts 1 and 2 **BrO_3^-** $[Br^-] \times 2$ **AND** $[BrO_3^-] \div 2$ rate: no change Expts 1 and 3 **OR** $[Br^-] \times 2/3$ **AND** $[BrO_3^-] \div 2$ rate: $\times 1/3$ Expts 2 and 3 **H^+** $[BrO_3^-] \div 2$ **AND** $[H^+] \times 5$ rate $\times 12.5$ Expts 1 and 4 **OR** $[Br^-] \div 3$ and $[BrO_3^-] \div 2$ and $[H^+] \times 5$ rate $\times 4.17$ Expts 2 and 4 **OR** $[Br^-] \div 2$ and $[H^+] \times 5$ rate $\times 12.5$ Expts 3 and 4 **ALLOW** a sequential approach where they apply known orders first **ALLOW** minor slips as we are looking for an holistic approach to LoR marking **NOTE**: A clear and logically structured response would link orders to the experiment and experimental results provided. They could provide units **<u>Units</u>** $dm^9\ mol^{-3}\ s^{-1}$ **ALLOW** any order, e.g. $mol^{-3}\ dm^9\ s^{-1}$

Question			Answer	Marks	AO element	Guidance
18	(a)		**FIRST CHECK THE ANSWER ON ANSWER LINE** **If answer = –4950 award 3 marks** --- • $q = mc\Delta T$ = 150 x 4.18 x 10.5 = 6583.5 (J) **OR** 6.5835 (kJ) ✓ • $n(C_7H_{16})$ $= \frac{0.133}{100} = 1.33 \times 10^{-3}$ ✓ • $\Delta_cH = q \div n$ $= \frac{6.5835}{1.33 \times 10^{-3}}$ = **–**4950 kJ mol^{-1} **– sign required** ✓	3	AO2.4 ×1 AO2.8 ×2	**ALLOW** 3 SF up to the calculated value Ignore RE after 3SF **IGNORE** sign **ALLOW ECF** from incorrect *q* and/or *n* **Common errors for 2 marks** +4950 kJ mol^{-1} (wrong sign) -5077 (use of 0.0013 and 6.6 2SF) -5064 (use of 0.0013 2SF) -4962 (use of 6.6kJ use of 2SF)
	(b)		**FIRST CHECK THE ANSWER ON ANSWER LINE** **If answer = –3535 award 2 marks** --- 186 = $\Delta_cH(C_9H_{20}) - \Delta_cH(C_5H_{12}) - 2\,\Delta_cH(C_2H_4)$ **OR** From Hess cycle with all numerical values used and correct multiples used/labelled +186 $C_9H_{20}(g) \rightarrow C_5H_{12}(g) + 2C_2H_4(g)$ – 6171 ; $\Delta_cH(C_5H_{12})$; 2 x –1411 common combustion products ✓ $\Delta_cH(C_5H_{12}) = (–6171) – 2(–1411) -186$ = –3535 kJ mol^{-1} ✓	2	AO2.2 ×2	**IGNORE** any incorrect combustion products on bottom line. **Common errors for 1 mark** +3535 (wrong sign for final answer) +8807 (use of +6171) -9179 (use of +1411) -4946 (use of 1 x -1411) -3163 (use of +186) **For other answers**, check for a **single** transcription error or calculation error using **all values** which could merit 1 mark

	(c)	**(i)**	(ΔS) is positive **AND** more molecules / moles of (gaseous) product /produced✓	**1**	AO2.5 ×1	**ALLOW** reaction produces more (gaseous) molecules /moles of products than reactants **IGNORE** explanations based on ΔG
		(ii)	Best fit line drawn ✓	**5**	AO3.1 ×2 AO3.2 ×3	Allow **ECF** throughout Place tick for line of best fit on the graph Allow lines that will extrapolate to y axis at 43-47 and x axis at 820-840 **DO NOT ALLOW** outside ranges **ALLOW** rounding to 2SF
			(–)ΔS = correct gradient from graph **OR** (–)0.127 (**k**J K^{-1} mol^{-1}) ✓			e.g. (–)ΔS = 105 / 830 = (–)0.127 **ALLOW** (–)0.122 to (–)0.131
			ΔS = gradient × –1000 = (+)127 (J K^{-1} mol^{-1}) ✓			**ALLOW** 122 to 131 This mark subsumes gradient mark
			Minimum T (ΔG = 0) = 370 (K) ✓			**ALLOW** 340 to 370 **ALLOW** 67 to 97 **AND** °C **DO NOT ALLOW** -ve T in K
			ΔH (y-intercept) = (+)46 (kJ mol^{-1}) ✓			**ALLOW** 43 to 47 Candidates can receive full credit for calculating ΔS, T and/or ΔH from previously determined values e.g $T = \frac{\Delta H}{\Delta S} = \frac{46}{0.127} = 362K$

Question			Answer	Marks	AO element	Guidance
19	(a)	(i)	$(K_p) = \frac{p(N_2O_4(g))}{p(NO_2(g))^2}$ ✓	5	AO1.2 ×1	**ALLOW** species without state symbols and without brackets. e.g., pSO_3^2 , $ppSO_3^2$, PSO_3^2, $p(SO_3)^2$ $(pSO_3)^2$ etc. **DO NOT ALLOW** square brackets
			Units atm^{-1} ✓		AO1.2 ×1	**ALLOW** atm as **ECF** if K_p is upside down
			CHECK THE ANSWER ON ANSWER LINE **if answer = 1.17×10^{-2} OR 1.18×10^{-2} award 3 calculation marks** ----------			
			Calculation • $n N_2O_4$ = 0.3(00) (mol) **AND** $n$total = 5.7(0) (mol) ✓		AO2.6 ×3	**ALLOW ECF** throughout **ALLOW** 3 SF up to the calculated value. **IGNORE** RE after 3SF
			• $pNO_2 = (\frac{5.4(0)}{5.7(0)} \times 5.00 =) 4.74$ (atm) **AND** $pN_2O_4 = (\frac{0.3(00)}{5.7(0)} \times 5.00 =) 0.263$ (atm) ✓			*Calculator value* pNO_2 = 4.7368…… pN_2O_4 = 0.26315….
			• **K_p to 3 SF** $(K_p = \frac{0.263}{4.74^2} =) 1.17 \times 10^{-2}$ ✓			Mark use of 2SF in working as incorrect **once** and then allow ECF Answer MUST be 3 SF **Common error for 2 calculation marks:** 2.47×10^{-2} (using 0.6 mol N_2O_4)

Question			Answer	Marks	AO element	Guidance
		(ii)	**Higher temperature** ΔH is negative / exothermic (for forward reaction) **AND** equilibrium shifts to left/to LHS/decreases yield ✓	**3**	AO2.1 ×2	**ORA**
			Higher pressure 2 (gaseous) moles form 1 (gaseous) mole/ to side with fewer moles **AND** Equilibrium shifts to right /RHS/increases yield ✓		AO3.1 ×1	**ALLOW** correct equilibrium shifts without explanations for 1 mark
			Comparison Difficult to predict relative contributions of two opposing factors ✓			**ALLOW** opposing effects may not be the same size **ALLOW** effects could cancel each other out **ALLOW** effects oppose one another **DO NOT ALLOW** if both equilibrium shifts are in the same direction **DO NOT ALLOW** just 'it is difficult to predict equilibrium position' (in question) For the **3rd mark**, we are assessing the idea that we don't know which factor is dominant

Question	Answer	Marks	AO element	Guidance
(b)	***Rearranging ideal gas equation*** $n = \frac{pV}{RT}$ ✓ ***Unit conversion AND substitution into*** $n = \frac{pV}{RT}$ **:** • *R = 8.314* ***OR*** *8.31* • *V* in $m^3 = 74 \times 10^{-6}$ • *T in K = 348* • *P in Pa = 101 x* 10^3 *e.g.* $\frac{101 \times 10^3 \times 74.0 \times 10^{-6}}{8.314 \times 348}$ ✓ ***Calculation of n*** *n* = 2.58…… $\times 10^{-3}$ (mol) ✓ ***Calculation of M*** *M* = (0.28 ÷ 2.58…. x 10^{-3}) = 108(……) ✓ ***Molecular formula*** that is the closest to the calculated M_r value. e.g. M_r 108 = N_2O_5 ✓	5	AO2.1 ×1 AO2.6 ×3 AO3.2 ×1	**FULL ANNOTATIONS MUST BE USED** --- **ALLOW ECF** throughout if all values have been used to calculate n **IF** $n = \frac{pV}{RT}$ is omitted, **ALLOW** when values are substituted into rearranged ideal gas equation **CARE:** Correct n value subsumes first marking point **only** as two incorrect unit conversions can lead to correct n Calculator value: from 8.314 *n* = 2.583234483 $\times 10^{-3}$ from 8.31 *n* = 2.584477917 $\times 10^{-3}$ Calculator value: *M* from 8.314 = 108.3912443 *M* from 8.31 = 108.3390955 M from 0.28 ÷ 2.58 x 10^{-3} = 108.5 **OR** 109 **ALLOW ECF** from calculation of *n* *provided formula of oxide contains at least one N i.e. NO (Mr = 30)*

Question			Answer	Marks	AO element	Guidance
						--- **Use of 24 dm^3**: Final 2 marks possible by **ECF** e.g. $n = \frac{74.0}{24000} = 3.08 \times 10^{-3}$ **No mark** (*calculation much simpler*) $M = \frac{0.28}{3.08 \times 10^{-3}} = 90(.8)$ **ECF** N_3O_3 **ECF** **DO NOT ALLOW** N_2O_4 (in question) **ALLOW ECF** matching calculated *M*

Question			Answer	Marks	AO element	Guidance
20	(a)	(i)	**FIRST CHECK THE ANSWER ON ANSWER LINE** **if answer = 6.77 award 2 marks** --- $K_w = [H^+][OH^-]$ **OR** $K_w = [H^+]^2$ **OR** $[H^+] = \sqrt{K_w}$ ✓ ($[H^+] = \sqrt{(2.92 \times 10^{-14})}$) $pH = -\log(1.71 \times 10^{-7}) = 6.77$ ✓	**2**	AO1.1 ×1 AO2.2 ×1	**DO NOT ALLOW** use of A^- or X^-
		(ii)	(In pure water), $[H^+]$ (always) equals $[OH^-]$	**1**	AO3.2 ×1	**ALLOW** moles/number of H^+ is (always) equal to moles/number of OH^- **DO NOT ALLOW** ratio $[H^+] : [OH^-]$ doesn't change
	(b)		• **Equation** $Sr + 2H_2O \rightarrow Sr(OH)_2 + H_2$ ✓ **CHECK THE ANSWER ON ANSWER LINE** **if answer = 11.51 award 4 calculation marks** --- • ***n*(Sr(OH)$_2$)** $= \frac{0.145}{121.6} = 1.1924\ldots \times 10^{-3}$ ✓ • **$[OH^-]$** $= 2 \times (1.1924 \times 10^{-3} \div 0.25) = 9.539\ldots \times 10^{-3}$ ✓ • **$[H^+]$** = $K_w \div [OH^-]$ $= \frac{2.92 \times 10^{-14}}{9.539.. \times 10^{-3}} = 3.061\ldots \times 10^{-12}$ ✓	**5**	AO2.6 AO2.4 ×3 AO1.2 ×1	**IGNORE** state symbols (even if wrong) **ALLOW** multiples **ALLOW** $Sr^{2+} + 2OH^-$ for $Sr(OH)_2$ **ALLOW** 3 SF up to the calculated value. Ignore RE after 3SF. **ALLOW** ECF throughout but final answer must be pH>7

			• **pH** = –log(3.061… x 10^{-12}) = 11.51 ✓ **2 DP** required			**Final answer must be from calculated values.** **Common errors for 3 calculation marks** 11.98 *(Use of K_w = 1 × 10^{-14})* 11.21 *(no × 2)* 10.91 *(÷ by 2)* **Common error for 2 calculation marks** pH = 11.67 *(no × 2 and wrong K_w)* --- **Alternative method for:-** **pH = pKw – pOH** • ***n*(Sr(OH)$_2$)** = $\frac{0.145}{121.6}$ = 1.1924… x 10^{-3} • **[OH^-]** = 2 x (1.1924 x 10^{-3} ÷ 0.25) = 9.539… x 10^{-3} • ***pH** = pKw - pOH* *= (-log 2.92 x 10^{-14}) - (-log 9.539..x 10^{-3})* • ***pH** = 13.53(46) - 2.02(05)* ***= 11.51***

	(c)	**(i)**	$SrCO_3 + 2HNO_3 \rightarrow Sr(NO_3)_2 + H_2O + CO_2$ ✓	**1**	AO2.6	**IGNORE** state symbols **DO NOT ALLOW** H_2CO_3 for $H_2O + CO_2$ (question states that a gas was produced) **ALLOW** multiples
		(ii)	M_r of $SrCO_3$ is different to M_r $CaCO_3$ / moles $SrCO_3$ are different to moles $CaCO_3$ ✓ M_r of $SrCO_3$ **>** M_r $CaCO_3$ / moles $SrCO_3$ **<** moles $CaCO_3$ **AND** **More** moles/volume gas (from $CaCO_3$)✓	**2**	AO3.1 ×1 AO3.2 ×1	**ALLOW** ORA **ALLOW** $n(SrCO_3) = (1.00 \div 147.6) = 6.78 \times 10^{-3}$ (mol) **AND** $n(CaCO_3) = (1.00 \div 100.1) = 9.99 \times 10^{-3}$ (mol) For the 2nd mark, we are assessing the idea of the greater moles of carbonate produces more gas. Subsumes first mark **ALLOW** $n(SrCO_3) = (1.00 \div 147.6) = 6.78 \times 10^{-3}$ (mol) **AND** $n(CaCO_3) = (1.00 \div 100.1) = 9.99 \times 10^{-3}$ (mol) **AND** Calculated values (CO_2) 163 cm^3 **AND** 240 cm^3

	(d)	**(i)**	$Mg + 2H^+ \rightarrow Mg^{2+} + H_2$ ✓	**1**	AO2.6	**ALLOW** multiples **ALLOW** Mg^{+2} **IGNORE** state symbols
		(ii)	HCl is a strong acid/completely dissociates **AND** CH_3COOH is a weak acid/partially dissociates ✓ Greater H^+ concentration in HCl **AND** More frequent collisions / faster rate of reaction ✓ More CH_3COOH dissociates until same number of moles of H^+ released **OR** same total moles H^+ produced (by the end) **OR** (Both acids are monobasic) and have the same number of moles of acid ✓	**3**	AO1.1 ×1 AO3.1 ×2	**IGNORE** HCl is a strong**er** acid than ethanoic acid. **ALLOW** ORA **DO NOT ALLOW** dibasic/tribasic
	(e)	**(i)**	One **mole** of (butanoic) acid donates/dissociates to form one **mole** of protons/H^+ ✓	**1**	AO1.1	**ALLOW** One **molecule** of (butanoic) acid donates/dissociates to form one proton/H^+ **ALLOW** only one hydrogen ion in the acid can be replaced per molecule (in an acid-base reaction)
		(ii)	**FIRST CHECK THE ANSWER ON ANSWER LINE** **IF ANSWER =** $1.5(3) \times 10^{-5}$ **award 4 marks** ----------	**4**	AO1.2 ×1	**FULL ANNOTATIONS MUST BE USED** ---------- **ALLOW ECF** throughout

			• $[H^+] = 10^{-pH}$ **OR** $10^{-5.07}$ **OR** 8.51×10^{-6} ✓		AO2.6 ×3	**ALLOW 2 SF** for $[H^+]$ (use of pH)
			• $(\frac{3.39}{56.1})$ **OR** 0.0604 (0.06042781) (nA$^-$ in buffer) = (n(KOH)) **OR** 0.0604 x 4 **OR** 0.242 ✓ ([A$^-$] in buffer)			**ALLOW** 3 SF up to the calculated value. Ignore RE after 3SF for moles and concentration values Mark use of 2SF in working as incorrect **once** and then allow ECF
			• nHA in buffer = (0.376 x 0.25) – 0.0604 = (0.094) – 0.0604 **OR** 0.0336 (0.03357219...) **OR** [HA] in buffer = (0.376 – 0.242) **OR** 0.0336 x 4 **OR** 0.134 (0.13428877) ✓			
			• $K_a = [H^+][A^-] \div [HA]$ $= \frac{8.51 \times 10^{-6} \times 0.242}{0.134}$ = 1.5….. $\times 10^{-5}$ (1.5319942×10^{-5})✓			**ALLOW** full marks for use of moles (volumes cancel) $K_a = \frac{8.51 \times 10^{-6} \times 0.0604}{0.0336}$ $=1.53 \times 10^{-5}$ **ALLOW** final answer to 2SF **Common errors for 3 marks** 5.47(1731026) x 10^{-6} (not subtracting moles of KOH from HA)

	(f)		ratio/proportion [HA]/[A^-] is the same	**1**	AO3.1	**ALLOW** Change in [HA] and [A^-] is proportional **ALLOW** the concentrations of the weak acid and conjugate base change by same amount

Question			Answer	Marks	AO element	Guidance
21	(a)	(i)	Colourless to (pale) pink	1	AO1.1	**ALLOW** **Pale** purple **DO NOT ALLOW** purple
		(ii)	12.65 | 12.95 | 12.75 ✓ $\frac{12.65+12.75}{2}$ = 12.7(0) cm^3 ✓	2	AO2.8 x2	
		(iii)	**FIRST CHECK THE ANSWER ON ANSWER LINE** **if answer =** 6.35×10^{-3} **award 3 marks** --- **$n(MnO_4^-)$ in titration** = $(0.00250 \times \frac{12.7}{1000})$ = 3.175×10^{-5} ✓ **$n(Fe^{2+})$ in 25.0 cm^3** = $(3.175 \times 10^{-5} \times 5)$ = 1.5875×10^{-4} (mol) ✓ **$[Fe^{2+}]$** = $(1.5875 \times 10^{-4} \div 0.025)$ **OR** $(1.5875 \times 10^{-4}$ x 40) = 6.35×10^{-3} (mol dm^{-3}) ✓	3	AO2.8 ×3	**ALLOW ECF** from incorrect titre in 21 a ii) for 3 marks e.g. Titre of 12.78 cm^3 gives 6.39 x 10^{-3} --- **ALLOW 3 SF or more throughout** **ALLOW ECF** throughout **ALLOW** $n(Fe^{2+})$ in 250 cm^3 = 1.5875×10^{-3} (mol) so $[Fe^{2+}]$ in 25 cm^3 = $1.5875 \times 10^{-3} \div 0.25 = 6.35 \times 10^{-3}$ **Common errors for 2 marks** 2.46 x 10^{-2} (volumes transposed) 1.25 x 10^{-2} (same volume used twice) 1.27 x 10^{-3} (no x 5) 2.54 x 10^{-4} (÷5)

	(b)			**4**	AO3.1 ×1	**ALLOW ORA** throughout **IGNORE** larger/smaller/greater/less throughout
			System 1/E⊖(Zn) is more negative/less positive than *system 2/ E*⊖(Fe^{3+}) ✓		AO3.4 ×1	**ALLOW** E^{e} = (+)1.53(V) **ALLOW** comparison if Fe system is identified
			Eqm 2 shifts to right **AND** Eqm 1 shifts to left **OR** Zinc reduces iron(III) ions (to iron(II)) **OR** $Zn + 2Fe^{3+} \rightarrow Zn^{2+} + 2Fe^{2+}$ ✓		AO3.1 ×1 AO3.4 ×1	
			System 1/E⊖(Zn) is more negative than *system 3/ E*⊖(MnO_4^-) ✓			**ALLOW** E^{e} = (+) 2.27(V) **ALLOW** comparison if MnO_4^- is identified
			Eqm 3 shifts to right **AND** Eqm 1 shifts to left **OR** (If unfiltered), MnO_4^- oxidise zinc **OR** $2MnO_4^- + 5Zn + 16H^+ \rightarrow 2Mn^{2+} + 5Zn^{2+} + 8H_2O$ ✓			

Question			Answer	Marks	AO element	Guidance
22	(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)** Explains the terms 'd-block element' **AND** 'transition element' **AND** Explains why not all d-block are transition elements **AND** At least **THREE correct** electron configurations (need to be one electron configuration of d block atom, transition element ion and zinc (or scandium) ion *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated*. **Level 2 (3–4 marks**) Explains both the terms 'd-block element' and 'transition element' **AND** Explains why not all d-block are transition elements **OR** Explains both the terms 'd-block element' and 'transition element' **AND** Links terms to at least **TWO correct** electron configurations **OR** Explains the terms 'd-block element' **OR** 'transition element' **AND** Explains why not all d-block are transition elements **AND** Links terms to at least **ONE correct** electron configuration	**6**	AO1.1 ×4 AO1.2 ×2	**Indicative scientific points may include:** **<u>Terms</u>** **d-block element:** element with highest energy/ valence electron in d-orbital/sub-shell **OR** d subshell is being filled **DO NOT ALLOW** d block for d-subshells **Transition element**: element forming one or more ions (allow atom and ion - IUPAC definition) with incomplete/partially filled d-subshell/d-orbitals **DO NOT ALLOW** d shell **<u>d-block element:</u>** **ALLOW** examples with an ion with an incomplete d-subshell, e.g. Fe^{2+} - $[Ar]4s^03d^6$ **ALLOW** examples with highest energy electrons in a d-subshell, e.g. Fe - $[Ar]4s^23d^6$ **<u>Not all d-block are transition elements</u>**: Sc and Zn form ions with complete or empty d-shells **ORA** For Sc^{3+}, ALLOW Sc^{+3} OR Sc forms a 3+ ion For Zn^{2+}, ALLOW Zn^{+2} OR Zn forms a 2+ ion Sc^{3+} $1s^22s^22p^63s^23p^6$ Sc^{3+} **AND** d subshell empty / d orbital(s) empty Zn^{2+} $1s^22s^22p^63s^23p^63d^{10}$ Zn^{2+} **AND** d subshell full / ALL d orbitals full

Question			Answer	Marks	AO element	Guidance
			There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence. **Level 1 (1–2 marks)** Explains the term 'd-block element' **OR** 'transition element' **AND** Attempts to link terms with **ONE correct** electron configuration **OR** Explains the term 'd-block element' **AND** 'transition element' **OR** Explains the term 'd-block element' **OR** 'transition element' **AND** Explains why not all d-block are transition elements **OR** **Any TWO** out of **THREE correct** electron configurations (one element and one ion that is a transition element and one ion that is not a transition element) *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 or no response worthy of credit*			**ALLOW** minor slips on **inner shell** electron configurations --- **NOTE**: A clear and logically structured response would link definitions to electron configurations to support the explanations. If stated, for the level, there should be clear indication that the d subshell is full/empty or partially full

Question			Answer	Marks	AO element	Guidance
	(b)	(i)		2		**ALLOW** any one precipitation reaction any one ligand substitution
					AO1.1	**ALLOW** other correct equations linked to correct colour change -check with TL
			Cu **Precipitation with OH^-/NH_3** ***2 marks***		AO1.2	**IGNORE state symbols**
			(Pale) Blue (precipitate) **AND** $Cu(OH)_2$ (can be seen in the equation)✓			**DO NOT ALLOW dark/royal** blue (complex ion colour)
			$Cu^{2+} + 2OH^- \rightarrow Cu(OH)_2$ ✓			**ALLOW** $Cu(H_2O)_4(OH)_2$
						ALLOW $[Cu(H_2O)_6]^{2+} + 2OH^- \rightarrow Cu(OH)_2(H_2O)_4 + 2H_2O$ **OR** $[Cu(H_2O)_6]^{2+} + 2OH^- \rightarrow Cu(OH)_2 + 6H_2O$ **OR** $[Cu(H_2O)_6]^{2+} + 2NH_3 \rightarrow Cu(OH)_2(H_2O)_4 + 2NH_4^+$
			OR **Precipitation with I^-** ***2 marks*** White (precipitate) **AND** CuI ✓			
			$2Cu^{2+} + 4I^- \rightarrow 2CuI + I_2$✓			----------
			Cr **Precipitation with OH^-/NH_3** ***2 marks***			
			(Dark) Grey-Green (precipitate) **AND** $Cr(OH)_3$ ✓			**ALLOW** Green **ALLOW** $Cr(H_2O)_3(OH)_3$
			$Cr^{3+} + 3OH^- \rightarrow Cr(OH)_3$ ✓			**ALLOW** $[Cr(H_2O)_6]^{3+} + 3OH^- \rightarrow Cr(OH)_3(H_2O)_3 + 3H_2O$ **OR** $[Cr(H_2O)_6]^{3+} + 3NH_3 \rightarrow Cr(OH)_3(H_2O)_3 + 3NH_4^+$ **OR** $[Cr(H_2O)_6]^{3+} + 3OH^- \rightarrow Cr(OH)_3 + 6H_2O$

Question			Answer	Marks	AO element	Guidance
	(b)	(ii)	**Cu** **Ligand substitution with NH_3/Cl^-** ***2 marks*** **NH_3 Deep/dark/royal** blue (solution) **AND** $[Cu(NH_3)_4(H_2O)_2]^{2+}$ ✓ $[Cu(H_2O)_6]^{2+} + 4NH_3 \rightarrow [Cu(NH_3)_4(H_2O)_2]^{2+} + 4H_2O$ ✓ **OR** **Cl^-** yellow (solution) **AND** $[CuCl_4]^{2-}$ ✓ $[Cu(H_2O)_6]^{2+} + 4Cl^- \rightarrow [CuCl_4]^{2-} + 6H_2O$ ✓ --- **Cr** **Ligand substitution with NH_3** ***2 marks*** **NH_3** Purple (solution) **AND** $[Cr(NH_3)_6]^{3+}$ ✓ $[Cr(H_2O)_6]^{3+} + 6NH_3 \rightarrow [Cr(NH_3)_6]^{3+} + 6H_2O$ ✓ **OR** Dark Green (solution) **AND** $[Cr(OH)_6]^{3-}$ ✓ $[Cr(H_2O)_6]^{3+} + 6OH^- \rightarrow [Cr(OH)_6]^{3-} + 6H_2O$ ✓	**2**	AO1.1 AO1.2	**ALLOW** other correct equations linked to correct colour change -check with TL **ALLOW ECF** on any incorrect charges of the complex ions when linked to colour via an equation.
	(c)		Charge: –1 **OR** – **OR** 1– ✓ Coordination number: 6 ✓	**2**	AO1.2 ×2	**ALLOW** $[Co(C_2O_4)_2(H_2O)_2]^-$ **DO NOT ALLOW** Co^- **IGNORE** sign

Question			Answer	Marks	AO element	Guidance
	(d)		$3V^{3+} + Cr_2O_7^{2-} + 2H^+ \rightarrow 3VO_2^+ + 2Cr^{3+} + H_2O$ **ALL** reactant and product species correct ✓ Correct balancing (of correct equation) **AND** cancelling of species ✓	**2**	 AO2.5 AO2.6	 **IGNORE** Balancing and electrons for first mark **DO NOT ALLOW** electrons in final answer

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