

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:

L3

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:

L3 A
















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 SEEN

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)	<p style="text-align: center;">$Ba^{2+}(g) + 2I(g) + 2e^{-}$</p> <p style="text-align: center;">$Ba^{+}(g) + 2I(g) + e^{-}$ ✓</p> <p style="text-align: center;">$Ba(g) + 2I(g)$ ✓ $Ba^{2+}(g) + 2I^{-}(g)$ ✓</p> <p style="text-align: center;">$Ba(s) + 2I(g)$</p> <p style="text-align: center;">$Ba(s) + I_2(s)$ ✓</p> <p style="text-align: center;">$BaI_2(s)$</p>	4	AO1.2 ×4	

Question		Answer	Marks	AO element	Guidance
	(ii)	<p>FIRST CHECK THE ANSWER ON ANSWER LINE If answer = -1872 award 2 marks</p> <p>-----</p> <p>$\Delta H_{\text{lattice}} =$ $2(+ 296) - 965 - 503 - 180 + 2(-107) - 602 \checkmark$</p> <p>$\Delta H_{\text{lattice}} = -1872 \text{ (kJ mol}^{-1}\text{)} \checkmark$</p>	2	AO2.2 x2	<p>ALLOW for 1 mark +1872 (wrong sign on answer)</p> <p>Common errors for 1 mark</p> <ul style="list-style-type: none"> -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) <p>For other answers, check for a single transcription error or calculation error which could merit 1 mark if all values have been used.</p> <p>DO NOT ALLOW any answer which involves two errors</p>
	(b)	<p>1st IE of Mg and Sr (Mg) removes electron from shell closer to the nucleus / smaller atomic radius \checkmark</p> <p>Greater nuclear attraction (between atom and outer electron) \checkmark</p>	4	AO1.1 AO1.2 AO1.1 AO1.2	<p>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</p> <p>ALLOW Greater attraction between nucleus (and outer electron)</p>

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

Question	Answer	Marks	AO element	Guidance
17	<p><i>Please refer to the marking instructions on page 5 of this mark scheme for guidance on marking this question.</i></p> <p>Level 3 (5–6 marks) ALL 3 correct orders linked to explanations AND rate equation AND rate constant</p> <p><i>There is a well-developed line of reasoning which is clear and logically structured.</i></p> <p>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</p>	6	AO3.1 ×3 AO3.2 ×3	<p>Indicative scientific points may include</p> <p>Orders</p> <ul style="list-style-type: none"> • 1st order wrt Br⁻ • 1st order wrt BrO₃⁻ • 2nd order wrt H⁺ <p>Rate equation</p> <ul style="list-style-type: none"> • rate = k [Br⁻] [BrO₃⁻] [H⁺]² <p>Calculation of k from any row of data, e.g.</p> $k = \frac{\text{Rate}}{[\text{Br}^-][\text{BrO}_3^-][\text{H}^+]^2}$ $k = \frac{2.52 \times 10^{-4}}{0.020 \times 0.120 \times (0.080)^2} = 16.4(0625)$

	<p>OR</p> <p>Three correct orders with an attempt at: Some evidence of an explanation link to an order rate equation rate constant</p> <p>OR</p> <p>Two correct orders linked to explanations AND rate equation AND rate constant consistent with the candidate's orders</p> <p><i>There is a line of reasoning with some structure and supported by some evidence.</i></p> <p>Level 1 (1–2 marks) Two correct orders</p> <p>OR</p> <p>One correct order AND attempts to determine rate equation OR rate constant.</p> <p>OR</p> <p>One correct order AND attempts an explanation.</p> <p><i>There is an attempt at a logical structure with a reasoned conclusion from the evidence.</i></p> <p>0 marks <i>No response worthy of credit.</i></p>		<p>-----</p> <p>Explanations from results e.g.</p> <p>Br⁻ [Br] × 3 rate × 3 Expts 1 and 2</p> <p>BrO₃⁻ [Br] × 2 AND [BrO₃⁻] ÷ 2 rate: no change Expts 1 and 3 OR [Br] × 2/3 AND [BrO₃⁻] ÷ 2 rate: × 1/3 Expts 2 and 3</p> <p>H⁺ [BrO₃⁻] ÷ 2 AND [H⁺] × 5 rate × 12.5 Expts 1 and 4 OR [Br] ÷ 3 and [BrO₃⁻] ÷ 2 and [H⁺] × 5 rate × 4.17 Expts 2 and 4 OR [Br] ÷ 2 and [H⁺] × 5 rate × 12.5 Expts 3 and 4</p> <p>ALLOW a sequential approach where they apply known orders first</p> <p>ALLOW minor slips as we are looking for an holistic approach to LoR marking</p> <p>NOTE: A clear and logically structured response would link orders to the experiment and experimental results provided. They could provide units</p> <p>Units dm⁹ mol⁻³ s⁻¹ ALLOW any order, e.g. mol⁻³ dm⁹ s⁻¹</p>
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Question		Answer	Marks	AO element	Guidance
18	(a)	<p>FIRST CHECK THE ANSWER ON ANSWER LINE If answer = -4950 award 3 marks</p> <hr/> <ul style="list-style-type: none"> $q = mc\Delta T$ $= 150 \times 4.18 \times 10.5$ $= 6583.5 \text{ (J) OR } 6.5835 \text{ (kJ) } \checkmark$ $n(\text{C}_7\text{H}_{16})$ $= \frac{0.133}{100} = 1.33 \times 10^{-3} \checkmark$ $\Delta_c H = q \div n$ $= \frac{6.5835}{1.33 \times 10^{-3}}$ $= -4950 \text{ kJ mol}^{-1}$ - sign required \checkmark 	3	<p>AO2.4 ×1</p> <p>AO2.8 ×2</p>	<p>ALLOW 3 SF up to the calculated value Ignore RE after 3SF</p> <p>IGNORE sign</p> <p>ALLOW ECF from incorrect q and/or n</p> <p>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)</p>
	(b)	<p>FIRST CHECK THE ANSWER ON ANSWER LINE If answer = -3535 award 2 marks</p> <hr/> <p>186 = $\Delta_c H(\text{C}_9\text{H}_{20}) - \Delta_c H(\text{C}_5\text{H}_{12}) - 2 \Delta_c H(\text{C}_2\text{H}_4)$ OR From Hess cycle with all numerical values used and correct multiples used/labelled</p> $ \begin{array}{c} \text{C}_9\text{H}_{20}(\text{g}) \xrightarrow{+186} \text{C}_5\text{H}_{12}(\text{g}) + 2\text{C}_2\text{H}_4(\text{g}) \\ \downarrow -6171 \quad \downarrow \Delta_c H(\text{C}_5\text{H}_{12}) \quad \downarrow 2 \times -1411 \\ \text{common combustion products} \quad \quad \quad \checkmark \end{array} $ <p>$\Delta_c H(\text{C}_5\text{H}_{12}) = (-6171) - 2(-1411) - 186$ $= -3535 \text{ kJ mol}^{-1} \checkmark$</p>	2	<p>AO2.2 ×2</p>	<p>IGNORE any incorrect combustion products on bottom line.</p> <p>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)</p> <p>For other answers, check for a single transcription error or calculation error using all values which could merit 1 mark</p>

(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 ✓ (-) ΔS = correct gradient from graph OR (-)0.127 (kJ K ⁻¹ mol ⁻¹) ✓ ΔS = gradient × -1000 = (+)127 (J K ⁻¹ mol ⁻¹) ✓ Minimum $T (\Delta G = 0) = 370$ (K) ✓ ΔH (y-intercept) = (+)46 (kJ mol ⁻¹) ✓	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 e.g. (-) ΔS = 105 / 830 = (-)0.127 ALLOW (-)0.122 to (-)0.131 ALLOW 122 to 131 This mark subsumes gradient mark ALLOW 340 to 370 ALLOW 67 to 97 AND °C DO NOT ALLOW -ve T in K ALLOW 43 to 47 Candidates can receive full credit for calculating ΔS , T and/or ΔH from previously determined values e.g. $T = \frac{\Delta H}{\Delta S} = \frac{46}{0.127} = 362\text{K}$

Question			Answer	Marks	AO element	Guidance
19	(a)	(i)	$(K_p) = \frac{p(\text{N}_2\text{O}_4(\text{g}))}{p(\text{NO}_2(\text{g}))^2} \checkmark$ <p>Units $\text{atm}^{-1} \checkmark$</p> <p>CHECK THE ANSWER ON ANSWER LINE if answer = 1.17×10^{-2} OR 1.18×10^{-2} award 3 calculation marks</p> <hr style="border-top: 1px dashed blue;"/> <p>Calculation</p> <ul style="list-style-type: none"> $n_{\text{N}_2\text{O}_4} = 0.3(00)$ (mol) AND $n_{\text{total}} = 5.7(0)$ (mol) \checkmark $p_{\text{NO}_2} = \left(\frac{5.4(0)}{5.7(0)}\right) \times 5.00 = 4.74$ (atm) AND $p_{\text{N}_2\text{O}_4} = \left(\frac{0.3(00)}{5.7(0)}\right) \times 5.00 = 0.263$ (atm) \checkmark K_p to 3 SF $(K_p = \frac{0.263}{4.74^2} =) 1.17 \times 10^{-2} \checkmark$ 	5	AO1.2 ×1 AO1.2 ×1 AO2.6 ×3	<p>ALLOW species without state symbols and without brackets. e.g., $p\text{SO}_3^2$, $pp\text{SO}_3^2$, PSO_3^2, $p(\text{SO}_3)^2$, $(p\text{SO}_3)^2$ etc. DO NOT ALLOW square brackets</p> <p>ALLOW atm as ECF if K_p is upside down</p> <p>ALLOW ECF throughout ALLOW 3 SF up to the calculated value. IGNORE RE after 3SF</p> <p><i>Calculator value</i> $p_{\text{NO}_2} = 4.7368\dots$ $p_{\text{N}_2\text{O}_4} = 0.26315\dots$</p> <p>Mark use of 2SF in working as incorrect once and then allow ECF Answer MUST be 3 SF</p> <p>Common error for 2 calculation marks: 2.47×10^{-2} (using 0.6 mol N_2O_4)</p>

Question	Answer	Marks	AO element	Guidance
(ii)	<p>Higher temperature ΔH is negative / exothermic (for forward reaction) AND equilibrium shifts to left/to LHS/decreases yield ✓</p> <p>Higher pressure 2 (gaseous) moles form 1 (gaseous) mole/ to side with fewer moles AND Equilibrium shifts to right /RHS/increases yield ✓</p> <p>Comparison Difficult to predict relative contributions of two opposing factors ✓</p>	3	AO2.1 ×2 AO3.1 ×1	<p>ORA</p> <p>ALLOW correct equilibrium shifts without explanations for 1 mark</p> <p>ALLOW opposing effects may not be the same size ALLOW effects could cancel each other out ALLOW effects oppose one another</p> <p>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</p>

Question	Answer	Marks	AO element	Guidance
(b)	<p>Rearranging ideal gas equation</p> $n = \frac{pV}{RT} \checkmark$ <p>Unit conversion AND substitution into $n = \frac{pV}{RT}$:</p> <ul style="list-style-type: none"> • $R = 8.314$ OR 8.31 • V in $\text{m}^3 = 74 \times 10^{-6}$ • T in $\text{K} = 348$ • P in $\text{Pa} = 101 \times 10^3$ <p>e.g. $\frac{101 \times 10^3 \times 74.0 \times 10^{-6}}{8.314 \times 348} \checkmark$</p> <p>Calculation of n</p> $n = 2.58\text{.....} \times 10^{-3} \text{ (mol)} \checkmark$ <p>Calculation of M</p> $M = (0.28 \div 2.58\text{....} \times 10^{-3}) = 108(\text{.....}) \checkmark$ <p>Molecular formula that is the closest to the calculated M_r value. e.g. $M_r 108 = \text{N}_2\text{O}_5 \checkmark$</p>	5	<p>AO2.1 ×1</p> <p>AO2.6 ×3</p> <p>AO3.2 ×1</p>	<p>FULL ANNOTATIONS MUST BE USED</p> <hr style="border-top: 1px dashed blue;"/> <p>ALLOW ECF throughout if all values have been used to calculate n</p> <p>IF $n = \frac{pV}{RT}$ is omitted, ALLOW when values are substituted into rearranged ideal gas equation</p> <p>CARE: Correct n value subsumes first marking point only as two incorrect unit conversions can lead to correct n</p> <p>Calculator value: from 8.314 $n = 2.583234483 \times 10^{-3}$ from 8.31 $n = 2.584477917 \times 10^{-3}$</p> <p>Calculator value: M from 8.314 = 108.3912443 M from 8.31 = 108.3390955 M from $0.28 \div 2.58 \times 10^{-3} = 108.5$ OR 109</p> <p>ALLOW ECF from calculation of n provided formula of oxide contains at least one N i.e. NO ($M_r = 30$)</p>

Question			Answer	Marks	AO element	Guidance
						<p>-----</p> <p>Use of 24 dm³: Final 2 marks possible by ECF</p> <p>e.g. $n = \frac{74.0}{24000} = 3.08 \times 10^{-3}$</p> <p>No mark (<i>calculation much simpler</i>)</p> <p>$M = \frac{0.28}{3.08 \times 10^{-3}} = 90(.8)$ ECF</p> <p>N_3O_3 ECF</p> <p>DO NOT ALLOW N_2O_4 (in question)</p> <p>ALLOW ECF matching calculated M</p>

Question			Answer	Marks	AO element	Guidance
20	(a)	(i)	<p>FIRST CHECK THE ANSWER ON ANSWER LINE if answer = 6.77 award 2 marks</p> <p>-----</p> <p>$K_w = [H^+][OH^-]$ OR $K_w = [H^+]^2$ OR $[H^+] = \sqrt{K_w}$ ✓</p> <p>$([H^+] = \sqrt{(2.92 \times 10^{-14})})$ $pH = -\log(1.71 \times 10^{-7}) = 6.77$ ✓</p>	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)		<ul style="list-style-type: none"> Equation $Sr + 2H_2O \rightarrow Sr(OH)_2 + H_2$ ✓ <p>CHECK THE ANSWER ON ANSWER LINE if answer = 11.51 award 4 calculation marks</p> <p>-----</p> <ul style="list-style-type: none"> $n(Sr(OH)_2)$ $= \frac{0.145}{121.6} = 1.1924... \times 10^{-3}$ ✓ [OH⁻] $= 2 \times (1.1924 \times 10^{-3} \div 0.25) = 9.539... \times 10^{-3}$ ✓ [H⁺] = $K_w \div [OH^-]$ $= \frac{2.92 \times 10^{-14}}{9.539... \times 10^{-3}} = 3.061... \times 10^{-12}$ ✓ 	5	AO2.6 AO2.4 ×3 AO1.2 ×1	<p>IGNORE state symbols (even if wrong) ALLOW multiples</p> <p>ALLOW Sr²⁺ + 2OH⁻ for Sr(OH)₂</p> <p>ALLOW 3 SF up to the calculated value. Ignore RE after 3SF.</p> <p>ALLOW ECF throughout but final answer must be pH>7</p>

		<ul style="list-style-type: none"> • $\text{pH} = -\log(3.061... \times 10^{-12}) = 11.51 \checkmark$ <p>2 DP required</p>		<p>Final answer must be from calculated values.</p> <p>Common errors for 3 calculation marks</p> <p>11.98 (<i>Use of $K_w = 1 \times 10^{-14}$</i>) 11.21 (<i>no $\times 2$</i>) 10.91 (<i>\div by 2</i>)</p> <p>Common error for 2 calculation marks</p> <p>pH = 11.67 (<i>no $\times 2$ and wrong K_w</i>)</p> <hr/> <p>Alternative method for:- pH = pK_w – pOH</p> <ul style="list-style-type: none"> • $n(\text{Sr}(\text{OH})_2)$ $= \frac{0.145}{121.6} = 1.1924... \times 10^{-3}$ • $[\text{OH}^-]$ $= 2 \times (1.1924 \times 10^{-3} \div 0.25) =$ $9.539... \times 10^{-3}$ • $\text{pH} = \text{pK}_w - \text{pOH}$ $= (-\log 2.92 \times 10^{-14}) - (-\log 9.539... \times 10^{-3})$ • $\text{pH} = 13.53(46) - 2.02(05)$ $= 11.51$
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	(c)	(i) $\text{SrCO}_3 + 2\text{HNO}_3 \rightarrow \text{Sr}(\text{NO}_3)_2 + \text{H}_2\text{O} + \text{CO}_2 \checkmark$	1	AO2.6	<p>IGNORE state symbols</p> <p>DO NOT ALLOW H_2CO_3 for $\text{H}_2\text{O} + \text{CO}_2$ (question states that a gas was produced)</p> <p>ALLOW multiples</p>
		<p>(ii)</p> <p>M_r of SrCO_3 is different to M_r CaCO_3 / moles SrCO_3 are different to moles $\text{CaCO}_3 \checkmark$</p> <p>M_r of $\text{SrCO}_3 > M_r$ CaCO_3 / moles $\text{SrCO}_3 <$ moles CaCO_3 AND More moles/volume gas (from CaCO_3) \checkmark</p>	2	<p>AO3.1 ×1</p> <p>AO3.2 ×1</p>	<p>ALLOW ORA</p> <p>ALLOW $n(\text{SrCO}_3) = (1.00 \div 147.6) = 6.78 \times 10^{-3}$ (mol) AND $n(\text{CaCO}_3) = (1.00 \div 100.1) = 9.99 \times 10^{-3}$ (mol)</p> <p>For the 2nd mark, we are assessing the idea of the greater moles of carbonate produces more gas.</p> <p>Subsumes first mark</p> <p>ALLOW $n(\text{SrCO}_3) = (1.00 \div 147.6) = 6.78 \times 10^{-3}$ (mol) AND $n(\text{CaCO}_3) = (1.00 \div 100.1) = 9.99 \times 10^{-3}$ (mol) AND Calculated values (CO_2) 163 cm^3 AND 240 cm^3</p>

	(d)	(i)	$\text{Mg} + 2\text{H}^+ \rightarrow \text{Mg}^{2+} + \text{H}_2$ ✓	1	AO2.6	ALLOW multiples ALLOW Mg^{+2} IGNORE state symbols
		(ii)	<p>HCl is a strong acid/completely dissociates AND CH_3COOH is a weak acid/partially dissociates ✓</p> <p>Greater H^+ concentration in HCl AND More frequent collisions / faster rate of reaction ✓</p> <p>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 ✓</p>	3	<p>AO1.1 ×1</p> <p>AO3.1 ×2</p>	<p>IGNORE HCl is a stronger acid than ethanoic acid.</p> <p>ALLOW ORA</p> <p>DO NOT ALLOW dibasic/tribasic</p>
	(e)	(i)	One mole of (butanoic) acid donates/dissociates to form one mole of protons/ H^+ ✓	1	AO1.1	<p>ALLOW One molecule of (butanoic) acid donates/dissociates to form one proton/H^+</p> <p>ALLOW only one hydrogen ion in the acid can be replaced per molecule (in an acid-base reaction)</p>
		(ii)	<p>FIRST CHECK THE ANSWER ON ANSWER LINE IF ANSWER = $1.5(3) \times 10^{-5}$ award 4 marks</p> <p>-----</p>	4	<p>AO1.2 ×1</p>	<p>FULL ANNOTATIONS MUST BE USED</p> <p>-----</p> <p>ALLOW ECF throughout</p>

		<ul style="list-style-type: none"> • $[H^+] = 10^{-pH}$ OR $10^{-5.07}$ OR 8.51×10^{-6} ✓ • $\left(\frac{3.39}{56.1}\right)$ OR 0.0604 (0.06042781) (nA^- in buffer) = ($n(KOH)$) OR 0.0604 x 4 OR 0.242 ✓ ($[A^-]$ in buffer) • nHA in buffer = $(0.376 \times 0.25) - 0.0604$ = $(0.094) - 0.0604$ OR 0.0336 (0.03357219...) OR $[HA]$ in buffer = $(0.376 - 0.242)$ OR 0.0336×4 OR 0.134 (0.13428877) ✓ • $K_a = \frac{[H^+][A^-]}{[HA]}$ = $\frac{8.51 \times 10^{-6} \times 0.242}{0.134}$ = $1.5 \dots \times 10^{-5}$ (1.5319942×10^{-5}) ✓ 		AO2.6 x3	<p>ALLOW 2 SF for $[H^+]$ (use of pH)</p> <p>ALLOW 3 SF up to the calculated value. Ignore RE after 3SF for moles and concentration values</p> <p>Mark use of 2SF in working as incorrect once and then allow ECF</p> <p>ALLOW full marks for use of moles (volumes cancel)</p> $K_a = \frac{8.51 \times 10^{-6} \times 0.0604}{0.0336}$ $= 1.53 \times 10^{-5}$ <p>ALLOW final answer to 2SF</p> <p>Common errors for 3 marks $5.47(1731026) \times 10^{-6}$ (not subtracting moles of KOH from HA)</p>
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	(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
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Question			Answer	Marks	AO element	Guidance			
21	(a)	(i)	Colourless to (pale) pink	1	AO1.1	ALLOW Pale purple DO NOT ALLOW purple			
		(ii)	<table border="1" style="margin-left: 20px;"> <tr> <td style="padding: 2px 10px;">12.65</td> <td style="padding: 2px 10px;">12.95</td> <td style="padding: 2px 10px;">12.75</td> </tr> </table> <p style="margin-left: 20px;">✓</p> $\frac{12.65+12.75}{2} = 12.7(0) \text{ cm}^3 \checkmark$	12.65	12.95	12.75	2	AO2.8 x2	
12.65	12.95	12.75							
		(iii)	<p>FIRST CHECK THE ANSWER ON ANSWER LINE if answer = 6.35×10^{-3} award 3 marks</p> <p>-----</p> <p>$n(\text{MnO}_4^-)$ in titration $= (0.00250 \times \frac{12.7}{1000})$ $= 3.175 \times 10^{-5} \checkmark$</p> <p>$n(\text{Fe}^{2+})$ in 25.0 cm³ $= (3.175 \times 10^{-5} \times 5)$ $= 1.5875 \times 10^{-4} \text{ (mol)} \checkmark$</p> <p>$[\text{Fe}^{2+}] = (1.5875 \times 10^{-4} \div 0.025)$ OR $(1.5875 \times 10^{-4} \times 40)$ $= 6.35 \times 10^{-3} \text{ (mol dm}^{-3}\text{)} \checkmark$</p>	3	AO2.8 x3	<p>ALLOW ECF from incorrect titre in 21 a ii) for 3 marks e.g. Titre of 12.78 cm³ gives 6.39×10^{-3} -----</p> <p>ALLOW 3 SF or more throughout</p> <p>ALLOW ECF throughout</p> <p>ALLOW $n(\text{Fe}^{2+})$ in 250 cm³ = 1.5875×10^{-3} (mol) so $[\text{Fe}^{2+}]$ in 25 cm³ $= 1.5875 \times 10^{-3} \div 0.25 = 6.35 \times 10^{-3}$</p> <p>Common errors for 2 marks</p> <p>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 ($\div 5$)</p>			

	(b)	<p>System 1/$E^\ominus(\text{Zn})$ is more negative/less positive than system 2/$E^\ominus(\text{Fe}^{3+})$ ✓</p> <p>Eqm 2 shifts to right AND Eqm 1 shifts to left OR Zinc reduces iron(III) ions (to iron(II)) OR $\text{Zn} + 2\text{Fe}^{3+} \rightarrow \text{Zn}^{2+} + 2\text{Fe}^{2+}$ ✓</p> <p>System 1/$E^\ominus(\text{Zn})$ is more negative than system 3/$E^\ominus(\text{MnO}_4^-)$ ✓</p> <p>Eqm 3 shifts to right AND Eqm 1 shifts to left OR (if unfiltered), MnO_4^- oxidise zinc OR $2\text{MnO}_4^- + 5\text{Zn} + 16\text{H}^+ \rightarrow 2\text{Mn}^{2+} + 5\text{Zn}^{2+} + 8\text{H}_2\text{O}$ ✓</p>	4	AO3.1 ×1 AO3.4 ×1 AO3.1 ×1 AO3.4 ×1	ALLOW ORA throughout IGNORE larger/smaller/greater/less throughout ALLOW $E^\ominus = (+)1.53(\text{V})$ ALLOW comparison if Fe system is identified ALLOW $E^\ominus = (+) 2.27(\text{V})$ ALLOW comparison if MnO_4^- is identified
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Question		Answer	Marks	AO element	Guidance
22	(a)	<p><i>Please refer to the marking instructions on page 5 of this mark scheme for guidance on how to mark this question.</i></p> <p>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)</p> <p><i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i></p> <p>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</p> <p>OR Explains both the terms ‘d-block element’ and ‘transition element’ AND Links terms to at least TWO correct electron configurations</p> <p>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</p>	6	AO1.1 ×4 AO1.2 ×2	<p>Indicative scientific points may include:</p> <p>Terms 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</p> <p>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</p> <p>d-block element: ALLOW examples with an ion with an incomplete d-subshell, e.g. Fe²⁺ - [Ar]4s⁰3d⁶</p> <p>ALLOW examples with highest energy electrons in a d-subshell, e.g. Fe - [Ar]4s²3d⁶</p> <p>Not all d-block are transition elements: Sc and Zn form ions with complete or empty d-shells ORA</p> <p>For Sc³⁺, ALLOW Sc⁺³ OR Sc forms a 3+ ion For Zn²⁺, ALLOW Zn⁺² OR Zn forms a 2+ ion</p> <p>Sc³⁺ 1s²2s²2p⁶3s²3p⁶ Sc³⁺ AND d subshell empty / d orbital(s) empty Zn²⁺ 1s²2s²2p⁶3s²3p⁶3d¹⁰ Zn²⁺ AND d subshell full / ALL d orbitals full</p>

Question	Answer	Marks	AO element	Guidance
	<p><i>There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.</i></p> <p>Level 1 (1–2 marks)</p> <p>Explains the term ‘d-block element’ OR ‘transition element’ AND Attempts to link terms with ONE correct electron configuration</p> <p>OR</p> <p>Explains the term ‘d-block element’ AND ‘transition element’</p> <p>OR</p> <p>Explains the term ‘d-block element’ OR ‘transition element’ AND Explains why not all d-block are transition elements</p> <p>OR</p> <p>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)</p> <p><i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i></p> <p>0 marks No response or no response worthy of credit</p>			<p>ALLOW minor slips on inner shell electron configurations</p> <p>-----</p> <p>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</p>

Question		Answer	Marks	AO element	Guidance
	(b) (i)	<p>Cu Precipitation with OH⁻/NH₃ 2 marks</p> <p>(Pale) Blue (precipitate) AND Cu(OH)₂ (can be seen in the equation) ✓</p> <p>$\text{Cu}^{2+} + 2\text{OH}^{-} \rightarrow \text{Cu}(\text{OH})_2 \checkmark$</p> <p>OR</p> <p>Precipitation with I⁻ 2 marks</p> <p>White (precipitate) AND CuI ✓</p> <p>$2\text{Cu}^{2+} + 4\text{I}^{-} \rightarrow 2\text{CuI} + \text{I}_2 \checkmark$</p> <hr/> <p>Cr Precipitation with OH⁻/NH₃ 2 marks</p> <p>(Dark) Grey-Green (precipitate) AND Cr(OH)₃ ✓</p> <p>$\text{Cr}^{3+} + 3\text{OH}^{-} \rightarrow \text{Cr}(\text{OH})_3 \checkmark$</p>	2	AO1.1 AO1.2	<p>ALLOW any one precipitation reaction any one ligand substitution</p> <p>ALLOW other correct equations linked to correct colour change -check with TL</p> <p>IGNORE state symbols</p> <p>DO NOT ALLOW dark/royal blue (complex ion colour)</p> <p>ALLOW Cu(H₂O)₄(OH)₂</p> <p>ALLOW [Cu(H₂O)₆]²⁺ + 2OH⁻ → Cu(OH)₂(H₂O)₄ + 2H₂O OR [Cu(H₂O)₆]²⁺ + 2OH⁻ → Cu(OH)₂ + 6H₂O OR [Cu(H₂O)₆]²⁺ + 2NH₃ → Cu(OH)₂(H₂O)₄ + 2NH₄⁺</p> <hr/> <p>ALLOW Green ALLOW Cr(H₂O)₃(OH)₃</p> <p>ALLOW [Cr(H₂O)₆]³⁺ + 3OH⁻ → Cr(OH)₃(H₂O)₃ + 3H₂O OR [Cr(H₂O)₆]³⁺ + 3NH₃ → Cr(OH)₃(H₂O)₃ + 3NH₄⁺ OR [Cr(H₂O)₆]³⁺ + 3OH⁻ → Cr(OH)₃ + 6H₂O</p>

Question		Answer	Marks	AO element	Guidance
(b)	(ii)	<p>Cu Ligand substitution with NH₃/Cl⁻ 2 marks</p> <p>NH₃ Deep/dark/royal blue (solution) AND [Cu(NH₃)₄(H₂O)₂]²⁺ ✓</p> <p>[Cu(H₂O)₆]²⁺ + 4NH₃ → [Cu(NH₃)₄(H₂O)₂]²⁺ + 4H₂O ✓</p> <p>OR</p> <p>Cl⁻ yellow (solution) AND [CuCl₄]²⁻ ✓</p> <p>[Cu(H₂O)₆]²⁺ + 4Cl⁻ → [CuCl₄]²⁻ + 6H₂O ✓</p> <hr style="border-top: 1px dashed black;"/> <p>Cr Ligand substitution with NH₃ 2 marks</p> <p>NH₃ Purple (solution) AND [Cr(NH₃)₆]³⁺ ✓</p> <p>[Cr(H₂O)₆]³⁺ + 6NH₃ → [Cr(NH₃)₆]³⁺ + 6H₂O ✓</p> <p>OR</p> <p>Dark Green (solution) AND [Cr(OH)₆]³⁻ ✓</p> <p>[Cr(H₂O)₆]³⁺ + 6OH⁻ → [Cr(OH)₆]³⁻ + 6H₂O ✓</p>	2	AO1.1 AO1.2	<p>ALLOW other correct equations linked to correct colour change -check with TL</p> <p>ALLOW ECF on any incorrect charges of the complex ions when linked to colour via an equation.</p>
(c)		<p>Charge: -1 OR - OR 1- ✓</p> <p>Coordination number: 6 ✓</p>	2	AO1.2 ×2	<p>ALLOW [Co(C₂O₄)₂(H₂O)₂]⁻</p> <p>DO NOT ALLOW Co⁻</p> <p>IGNORE sign</p>

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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