

Periodic table, elements and physical chemistry

June 2024 exam series

MARK SCHEME

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GCE

Chemistry A

H432/01: Periodic table, elements and physical chemistry

A Level

Mark Scheme for June 2024

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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. 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 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 **17b** and **20c**

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 

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**.

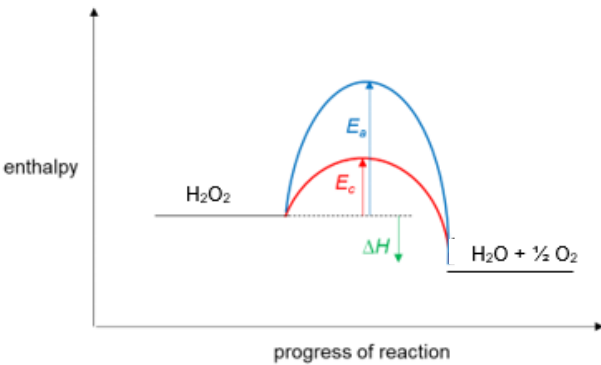
Please ask for help or guidance whenever you need it. Your first point of contact is your Team Leader.

SECTION A

Question	Answer	Marks	Guidance
1	D	1	
2	B	1	
3	C	1	
4	B	1	
5	C	1	
6	D	1	
7	A	1	ALLOW -56 (correct numerical answer)
8	B	1	
9	B	1	ALLOW +133 (correct numerical answer)
10	D	1	
11	C	1	
12	A	1	
13	D	1	
14	D	1	
15	C	1	

SECTION B

Question			Answer	Marks	Guidance
16	(a)	(i)	FIRST CHECK ANSWER ON ANSWER LINE If answer = -117 kJ mol^{-1}, award 4 marks. $\Delta H = -286 - (-188)$ $= -98 \text{ kJ mol}^{-1} \checkmark$ $\Delta S = 70 + \frac{1}{2}(205) - 110 = 62.5 \text{ (J K}^{-1} \text{ mol}^{-1})$ or $0.0625 \text{ (kJ K}^{-1} \text{ mol}^{-1}) \checkmark$ $\Delta G = \Delta H - T\Delta S$ $= -98 - (298 \times 0.0625) \checkmark$ $\Delta G = -117 \text{ kJ mol}^{-1} \text{ (3SF)} \checkmark$	4	ALLOW ECF throughout ALLOW $-98000 - (298 \times 62.5)$ Common Errors for ΔG 3 marks -18700 (ΔS not converted to kJ) -493 ($\Delta H = -286 + (-188) = -474$) -147 ($\Delta S = 165$: not halving 205) -99.6 (T not converted to K) -18.7 (ΔH not converted J but $\Delta S \text{ J K}^{-1} \text{ mol}^{-1}$) $(+)79.4$ ($-188 - (-286) = +98$) 2 marks $(+) 117$ (incorrect signs for ΔH and ΔS) Final Answer MUST BE 3 SF

Question	Answer	Marks	Guidance
(ii)	(Rate of reaction) slow OR Activation energy high ✓	1	ALLOW ΔG takes no account of rate of reaction ALLOW molecules do not have sufficient energy to equal or exceed the activation energy. IGNORE molecules do not have sufficient energy to react. DO NOT ALLOW there is not enough activation energy
(b)	(i)  H₂O₂ on LHS AND H₂O + ½ O₂ on RHS AND ΔH labelled with product line below reactant line AND Arrow downwards ✓	3	Care enthalpy profile must match ΔH sign in 16 a) i) – check calculation ALLOW endothermic profile as ECF from + ΔH calculated in 16 a) i) for all three marks State symbols not required ΔH DO NOT ALLOW $-\Delta H$ DO NOT ALLOW double headed arrow on ΔH ALLOW ΔH arrow even with small gap at the top and bottom, i.e. line does not quite reach reactant or product line.

Question			Answer	Marks	Guidance
			E_a correctly labelled ✓ E_c <u>correctly labelled</u> with $E_c < E_a$ ✓		E_a and E_c ALLOW no arrowhead or arrowheads at both end of E_a or E_c lines E_a or E_c lines must reach maximum (or near to maximum) on curve ALLOW overlapping lines OR lines on side reaching maximum For E_a, ALLOW AE OR A_E OR Eact OR suitable alternatives ALLOW ECF marks for E_a and E_c for correctly labelled endothermic diagram from a $-\Delta H$ value (from 16 a) i))
		(ii)	(MnO₂) is in different phase/state (to the reactant / H₂O₂) OR catalyst is a <u>solid</u> AND reactant is <u>liquid</u> ✓	1	ASSUME 'it' is MnO₂ ALLOW 'species in the reaction' IGNORE references to products
		(iii)	Mn is +2 AND +3 OR Mn is +1 AND +6 ✓	1	+ required ALLOW 2+ and 3+ DO NOT ALLOW Mn²⁺ Mn³⁺ DO NOT ALLOW + 4 (this is the oxidation state in MnO₂)

Question			Answer	Marks	Guidance
	(c)	(i)	(Enthalpy / heat energy change / released when) 1 mol of (ionic lattice) ✓ Is formed from its gaseous ions ✓	2	ALLOW 1 mol of (ionic) compound/product/substance IGNORE energy released/required ALLOW $M^+(g) + X^-(g) \rightarrow MX(s)$ DO NOT ALLOW <u>one mole</u> of gaseous ions
		(ii)	Energy level diagram showing the formation of $MnO(s)$ from $Mn(s)$ and $O_2(g)$. The diagram includes the following energy levels and transitions: $Mn(s) + \frac{1}{2} O_2(g)$ (bottom level) $Mn(g) + \frac{1}{2} O_2(g)$ ✓ $Mn^+(g) + \frac{1}{2} O_2(g) + e^-$ $Mn^{2+}(g) + \frac{1}{2} O_2(g) + 2 e^-$ $Mn^{2+}(g) + O^-(g) + e^-$ ✓ $Mn^{2+}(g) + O^{2-}(g)$ (top level) $MnO(s)$ ✓ (bottom right level) Arrows indicate the following transitions: - Upward arrows from $Mn(s) + \frac{1}{2} O_2(g)$ to $Mn(g) + \frac{1}{2} O_2(g)$ ✓, $Mn^+(g) + \frac{1}{2} O_2(g) + e^-$, and $Mn^{2+}(g) + \frac{1}{2} O_2(g) + 2 e^-$. - Downward arrows from $Mn^{2+}(g) + \frac{1}{2} O_2(g) + 2 e^-$ to $Mn^{2+}(g) + O^-(g) + e^-$ ✓, and from $Mn^{2+}(g) + O^-(g) + e^-$ ✓ to $Mn^{2+}(g) + O^{2-}(g)$. - A long downward arrow from $Mn^{2+}(g) + O^{2-}(g)$ to $MnO(s)$ ✓. - A long upward arrow from $Mn(s) + \frac{1}{2} O_2(g)$ to $Mn^{2+}(g) + O^{2-}(g)$.	3	Care: State symbols are required

Question			Answer	Marks	Guidance
		(iii)	FIRST CHECK ANSWER ON ANSWER LINE If answer = -3798 award 2 marks ----- $\Delta H_{\text{lattice}}$ $= -281 - 249 - 717 - 1509 - (-141) - 798 + (-385) \checkmark$ $\Delta H_{\text{lattice}} = -3798 \text{ (kJ mol}^{-1}\text{)} \checkmark$	2	Common errors for 1 mark -4080 (use of -141) -3674 (use of +249/2 and correctly rounded) -3673.5 (use of +249/2) -3236 (use of +281) -3300 (use of +249) -3028 (use of -385) -2364 (use of +717) -2202 (use of +798) -780 (use of +1509) +3798 (wrong sign on answer) For other answers, check for a single transcription error or calculation error which could merit 1 mark

Question			Answer	Marks	Guidance
17	(a)		(Over time) concentration decreases AND collisions are less <u>frequent</u> $\checkmark$	1	ALLOW less moles/particles per unit volume. ALLOW fewer collisions per second/per unit time IGNORE (over time) fewer reacting particles IGNORE ...chance of.. IGNORE amount decreases IGNORE successful IGNORE particles more spread out/further apart DO NOT ALLOW particles have less energy in terms of energy distribution.

Question	Answer	Marks	Guidance															
(b)*	<i>Please refer to the marking instructions on page 4 of this mark scheme for guidance on how to mark this question.</i> Level 3 (5–6 marks) A comprehensive conclusion using quantitative data from graph to correctly determine 1st order conclusion for CV using half lives/gradients AND rate at 3 minutes AND determination of k <i>There is a well-developed line of reasoning which is clear and logically structured.</i> Level 2 (3–4 marks) Reaches a conclusion using quantitative data from graph to correctly determine rate at 3 minutes AND determination of k. OR Half- lives/gradient with 1st order conclusion for CV AND determination of k OR determined rate AND half-life/first order for CV OR Attempts to determine rate, k and order for CV <i>There is a line of reasoning with some structure and supported by some evidence.</i> Level 1 (1–2 marks) Reaches a simple conclusion using at least one piece of quantitative data from the graph, i.e. Attempts to calculate rate at three minutes OR k OR links half lives to 1st order.3 <i>There is an attempt at a logical structure with a reasoned conclusion from the evidence.</i>	6	Indicative scientific points may include: Care: ALLOW the use of ECF for values obtained from a previously, incorrectly, calculated value. ALLOW minor slips as we are looking for a holistic approach to LoR marking. <table><tr><td></td><td>Minutes</td><td>Seconds</td></tr><tr><td>Half life values</td><td>2.4 to 2.6 min</td><td>144 to 156 s</td></tr><tr><td>Rate at three minutes</td><td>(-) (1.5 to 1.8) ×10⁻⁸ mol dm⁻³ min⁻¹</td><td>(-) (2.5 to 3.0)×10⁻¹⁰ mol dm⁻³ s⁻¹</td></tr><tr><td>Value of k</td><td>0.24 to 0.30 min⁻¹</td><td>(4.0 to 5.0) × 10⁻³ s⁻¹</td></tr><tr><td>Units of k</td><td>min⁻¹</td><td>s⁻¹</td></tr></table> Examples of the communication statement being met would typically include: - For L1 and L2: full working on the graph and/or appropriate units for calculated values. - For L3: full working on the graph and appropriate units for calculated values.		Minutes	Seconds	Half life values	2.4 to 2.6 min	144 to 156 s	Rate at three minutes	(-) (1.5 to 1.8) ×10 ⁻⁸ mol dm ⁻³ min ⁻¹	(-) (2.5 to 3.0)×10 ⁻¹⁰ mol dm ⁻³ s ⁻¹	Value of k	0.24 to 0.30 min ⁻¹	(4.0 to 5.0) × 10 ⁻³ s ⁻¹	Units of k	min ⁻¹	s ⁻¹
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Units of k	min ⁻¹	s ⁻¹																

Question	Answer	Marks	Guidance
	0 marks <i>No response worthy of credit</i>		If time has been measured in minutes (see below for values using seconds). Indicative scientific points may include: <u>Evidence for 1st order</u> 1st order clearly linked to half-life OR 2 gradients: Half life Half- life shown on graph Half- life range 2.4 to 2.6 min Two 'constant' half lives OR Two gradients → two rates 2 tangents shown on graph at c and $c/2$ This could include $c = 0.61 \times 10^{-7} \text{ mol dm}^{-3}$ ($t = 3 \text{ min}$) Gradient at $c/2$ is half gradient at c e.g. $c = 0.8 \times 10^{-7} \text{ mol dm}^{-3}$, gradient = $2.2 \times 10^{-8} (\text{mol dm}^{-3} \text{ min}^{-1})$ AND $c = 0.4 \times 10^{-7} \text{ mol dm}^{-3}$, gradient = $1.1 \times 10^{-8} (\text{mol dm}^{-3} \text{ min}^{-1})$ For chosen method, conclude that the reaction is 1st order wrt CV. <u>Rate at three minutes</u> Tangent shown on graph as line at $t = 3 \text{ min}$ Gradient in range: $(1.5 - 1.8) \times 10^{-8}$ rate as gradient with units: $\text{mol dm}^{-3} \text{ min}^{-1}$ OR $k = \frac{\ln 2}{t_{1/2}} = 0.28 \text{ min}^{-1}$ And k substituted into rate equation. e.g. Rate = $k [\text{CV}]$ Rate = $0.277 \times 0.61 \times 10^{-7}$ = $1.7 \times 10^{-8} \text{ mol dm}^{-3} \text{ min}^{-1}$ <u>Determination of k</u> k clearly linked to rate OR half-life: e.g. $k = \frac{\text{rate}}{[\text{CV}]} = \frac{1.75 \times 10^{-8}}{0.62 \times 10^{-7}} = 0.28$ k in range: 0.24 - 0.30 min^{-1}

Question	Answer	Marks	Guidance
			OR e.g. $k = \frac{\ln 2}{t_{1/2}} = 0.28 \text{ min}^{-1}$ Units of k: min^{-1} <u>If time has been measured in seconds:</u> Evidence for 1st order 1st order clearly linked to half-life OR 2 gradients: Half life <u>Half- life shown on graph</u> Half- life range 144 to 156 s Two 'constant' half lives OR Two gradients → two rates <u>2 tangents shown on graph at c and $c/2$</u> This could include $c = 0.6 \times 10^{-8} \text{ mol dm}^{-3}$ ($t = 3 \text{ min}$) Gradient at $c/2$ is half gradient at c e.g. $c = 0.8 \times 10^{-7} \text{ mol dm}^{-3}$, gradient = $3.7 \times 10^{-10} \text{ mol dm}^{-3} \text{ s}^{-1}$ AND $c = 0.4 \times 10^{-7} \text{ mol dm}^{-3}$, gradient = $1.8 \times 10^{-10} \text{ mol dm}^{-3} \text{ s}^{-1}$ For chosen method, conclude that the reaction is 1st order wrt CV. Rate at 180 seconds Gradient in range $(2.5 \text{ to } 3.0) \times 10^{-10}$ rate as gradient with units: $\text{mol dm}^{-3} \text{ s}^{-1}$ OR $k = \frac{\ln 2}{t_{1/2}} = 4.6 \times 10^{-3} \text{ s}^{-1}$ And k substituted into rate equation. e.g. Rate = $k [\text{CV}]$ Rate = $0.00462 \times 0.61 \times 10^{-7}$ = $2.8 \times 10^{-10} \text{ mol dm}^{-3} \text{ s}^{-1}$ Determination of k k clearly linked to rate OR half-life:

Question			Answer	Marks	Guidance
					e.g. $k = \frac{\text{rate}}{[\text{CV}]} = \frac{2.75 \times 10^{-10}}{0.62 \times 10^{-7}} = 4.4 \times 10^{-3} \text{ s}^{-1}$ k in range $(4.0 \text{ to } 4.8) \times 10^{-3} \text{ s}^{-1}$ OR e.g. $k = \frac{\ln 2}{t_{1/2}} = 0.28 \text{ min}^{-1}$ OR $4.6 \times 10^{-3} \text{ s}^{-1}$ Units of k: s^{-1}

Question			Answer	Marks	Guidance						
1 8	(a)	(i)	FIRST CHECK THE ANSWER ON ANSWER LINE IF answer = 0.455 award 4 marks AND IF units = atm^{1/2} award 5 marks Equilibrium moles ✓ $N \text{ SO}_3 = 1.35$, $n \text{ O}_2 = 0.45(0)$ AND $n \text{ total} = 2.7(0)$ Partial pressures ✓ <table><tr><td>$p(\text{SO}_3)$</td><td>$\frac{1.35}{2.7(0)} \times 2.80$ OR $1.4(0)$</td></tr><tr><td>$p(\text{SO}_2)$</td><td>$\frac{0.900}{2.7(0)} \times 2.80$ OR 0.933</td></tr><tr><td>$p(\text{O}_2)$</td><td>$\frac{0.450}{2.7(0)} \times 2.80$ OR 0.467</td></tr></table> $(K_p) = \frac{p(\text{SO}_2) p(\text{O}_2)^{1/2}}{p(\text{SO}_3)}$ OR $(K_p) = \frac{(0.933) \times (0.467)^{1/2}}{(1.40)}$ ✓ Answer to 3 SF $K_p = 0.455$ ✓ Units Substitution of units into correct K_p expression $\frac{\text{atm}^1 \times \text{atm}^{1/2}}{\text{atm}^1} = \text{atm}^{1/2}$ ✓	$p(\text{SO}_3)$	$\frac{1.35}{2.7(0)} \times 2.80$ OR $1.4(0)$	$p(\text{SO}_2)$	$\frac{0.900}{2.7(0)} \times 2.80$ OR 0.933	$p(\text{O}_2)$	$\frac{0.450}{2.7(0)} \times 2.80$ OR 0.467	5	IF there is an alternative answer, check for any ECF credit possible using working below. ----- ALLOW 3SF or more unless there is a trailing zero e.g. ALLOW $p(\text{SO}_3) = 1.4$, $n \text{ total} = 2.7$ ALLOW all marks to be awarded if atmospheres are converted into other pressure units e.g. to kPa. ALLOW use of fractions for intermediate working ALLOW $(K_p) = \frac{p(\text{SO}_2) p^{1/2}(\text{O}_2)}{p(\text{SO}_3)}$ ALLOW $K_p^2 = \frac{p(\text{SO}_2)^2 \times p(\text{O}_2)}{p(\text{SO}_3)^2}$ IGNORE [] (we are just looking for the calculation) ALLOW ECF for units of an incorrect K_p expression ALLOW $\text{atm}^{0.5}$ DO NOT ALLOW $\sqrt{\text{atm}}$
$p(\text{SO}_3)$	$\frac{1.35}{2.7(0)} \times 2.80$ OR $1.4(0)$										
$p(\text{SO}_2)$	$\frac{0.900}{2.7(0)} \times 2.80$ OR 0.933										
$p(\text{O}_2)$	$\frac{0.450}{2.7(0)} \times 2.80$ OR 0.467										

Question			Answer	Marks	Guidance												
					Common errors 4 marks (3 marks for calculation + unit mark) 0.207 (from expression $\frac{p(\text{SO}_2)^2 \times p(\text{O}_2)}{p(\text{SO}_3)^2}$) Unit: atm 2.20 (from inverted expression) Unit: atm ^{-1/2}												
		(ii)	ΔH is +ve / endothermic (in forward direction). AND (At higher temperature,) equilibrium shifts to right hand side ✓ (T_2) has greater K_p value OR $7.7 \times 10^{-2} > 3.3 \times 10^{-5}$ ✓	2	ORA throughout ALLOW towards the products for right hand side ALLOW increases yield of products DO NOT ALLOW T_1 has greater K_p value												
		(iii)	One mark per correct row ✓✓ <table border="1"><thead><tr><th>Change</th><th>Decrease</th><th>No change</th><th>Increase</th></tr></thead><tbody><tr><td>No catalyst</td><td></td><td>✓</td><td></td></tr><tr><td>Increased pressure</td><td></td><td>✓</td><td></td></tr></tbody></table>	Change	Decrease	No change	Increase	No catalyst		✓		Increased pressure		✓		2	
Change	Decrease	No change	Increase														
No catalyst		✓															
Increased pressure		✓															

Question			Answer	Marks	Guidance
	(b)	(i)	There are 3 bonding regions OR 3 <u>double bonds</u> (round the S atom).	1	ALLOW electron regions / areas of <u>electron density</u> ALLOW - It has a resonance structure with all 3 bonds being the same/inbetween a single and double bond OR has 3 σ bonds. DO NOT ALLOW bonding pairs
		(ii)	S/Sulfur and O/Oxygen have different electronegativities (and S–O bonds are polar) ✓ (SO ₂ lone pair gives) non-linear shape / asymmetrical AND dipoles don't cancel / dipoles do not act in opposite directions OR uneven electron charge density AND dipoles don't cancel ✓	2	ALLOW if partial charges are seen on diagram. DO NOT ALLOW sulfur is more electronegative than oxygen For non-linear, ALLOW bent OR v-shaped IGNORE shapes seen in diagrams, treat as rough working IGNORE polar bonds cancel IGNORE polarity cancels DO NOT ALLOW charges cancel ORA e.g. SO ₃ trigonal planar shape/symmetrical AND dipoles cancel / dipoles act in opposite directions OR even electron charge density AND dipoles cancel

Question			Answer	Marks	Guidance
19	(a)	(i)	$(K_a) = \frac{[H^+][ClCH_2COO^-]}{[ClCH_2COOH]}$ ✓	1	DO NOT ALLOW without square brackets DO NOT ALLOW $\frac{[H^+]^2}{[ClCH_2COOH]}$ DO NOT ALLOW $\frac{[H^+][A^-]}{[HA]}$
		(ii)	$[H^+] = [A^-]$ OR $[H^+]$ from water is negligible OR dissociation of water is negligible ✓	1	Answer must be in terms of concentration ALLOW $[H^+] \approx [A^-]$ IGNORE $HA \rightleftharpoons H^+ + A^-$ is a 1:1 mole ratio.
		(iii)	FIRST CHECK ANSWER ON ANSWER LINE If answer = 2.85 OR 2.86 OR 2.87 award 3 marks $([H^+] =) 10^{-1.95}$ OR $= 1.1(22...) \times 10^{-2}$ ✓ $(K_a) = \left(\frac{[H^+]^2}{[ClCH_2COOH]} \right)$ $= \frac{(1.122... \times 10^{-2})^2}{(0.090)}$ OR $\frac{(1.12 \times 10^{-2})^2}{(0.090)}$ OR $\frac{(1.1 \times 10^{-2})^2}{(0.090)}$ $= 1.4(0) \times 10^{-3}$ OR $= 1.39 \times 10^{-3}$ OR $= 1.34 \times 10^{-3}$ ✓ $(pK_a = -\log_{10}(K_a) =) 2.85, 2.86$ OR 2.87 (2DP) ✓	3	ALLOW ECF throughout ALLOW $[H^+] = 1.1 \times 10^{-2}$ up to calculator value ALLOW 2 sig figs up to calculator value. ALLOW calculations based on finding the $[HA]_{\text{equ}}$ $\frac{(1.122... \times 10^{-2})^2}{(0.079)}$ OR $\frac{(1.12 \times 10^{-2})^2}{(0.079)}$ OR $\frac{(1.1 \times 10^{-2})^2}{(0.079)}$ $= 1.59 \times 10^{-3}$ OR $= 1.59 \times 10^{-3}$ OR $= 1.53 \times 10^{-3}$ ✓ $(pK_a = -\log_{10}(K_a) =) 2.80$ OR 2.80 OR 2.81 (2DP) ✓ Must be 2DP

Question			Answer	Marks	Guidance
					Common error: 2 marks 0.90 (not using $[H^+]^2$)
	(b)	(i)	Smooth s-shaped curve using a best fit line that goes through the majority of points. ✓ Reading off x-axis at 12.5 cm³ ✓ $n(\text{Ba}(\text{OH})_2) = 0.0560 \times \frac{12.5}{1000}$ $= 7.00 \times 10^{-4} \text{ ✓}$ $n(\text{CH}_3\text{COOH}) = 2 \times (\text{moles Ba}(\text{OH})_2)$ $= 1.40 \times 10^{-3} \text{ ✓}$ $(\text{concentration}) = \frac{1.4 \times 10^{-3}}{(10/1000)}$ $= 0.14(0) \text{ (mol dm}^{-3}\text{) ✓}$	5	DO NOT ALLOW point to point DO NOT ALLOW tram/feather lines. ALLOW Reading off x-axis from 12.4 – 12.6 cm ³ ALLOW ECF throughout ALLOW 3SF or more unless there is a trailing zero <u>Alternative answers:</u> 0.139 (mol dm ⁻³) (from reading off x-axis at 12.4 cm ³) 0.141 (mol dm ⁻³) (from reading off x-axis at 12.6 cm ³) Common errors: 3 Marks 0.134 (Use of 12 cm ³) 0.202 (use of 18 cm ³)

Question	Answer	Marks	Guidance
	Alternative method based on calculating pK_a from the half neutralisation point. pH and $[H^+]$ reading will come from the candidates graph and the data points provided. e.g. pH at half neutralisation $6.25 \text{ cm}^3 = \text{pH } 4.7 = pK_a \checkmark$ $K_a = 10^{-4.7}$ $= 1.995 \times 10^{-5} \checkmark$ $[H^+]$ at pH 3.3 (obtained from data on the graph provided) $10^{-3.3} = 5.012 \times 10^{-4} \text{ (mol dm}^{-3}) \checkmark$ $[HA] = \frac{[H^+]^2}{[K_a]}$ $= \frac{(5.012 \times 10^{-4})^2}{(1.995 \times 10^{-5})}$ $= 0.0126 \text{ (mol dm}^{-3}) \checkmark$		ALLOW MP2 for $K_a = 1.7 \times 10^{-5}$ to 1.8×10^{-5} (knowledge of actual K_a value) ALLOW ECF from any quoted K_a
(ii)	Phenol red OR Phenolphthalein✓	1	Both indicators can change colour on the sharp vertical section of the candidates curve.

Question			Answer	Marks	Guidance
20	(a)	(i)	killing bacteria ✓	1	ALLOW killing microorganisms / microbes / sterilises water IGNORE 'removing' bacteria
		(ii)	$Cl_2 + 2Br^- \rightarrow Br_2 + 2Cl^-$ ✓ Chlorine is more reactive than bromine AND iodine is less reactive than bromine OR chlorine is a stronger oxidising agent than bromine AND iodine is a weaker oxidising agent than bromine. ✓	2	DO NOT ALLOW full equation IGNORE state symbols CARE with endings (e.g. ide and ine) ALLOW ORA ALLOW reactivity $Cl > Br > I$ ALLOW bromide is a stronger reducing agent than chloride AND bromide is a weaker reducing agent than iodide IGNORE displacement IGNORE references to down the group. IGNORE all comparisons of electron structure/electron affinity
	(b)		Equation for Step 1 $F_2 + NO_2 \rightarrow F + NO_2F$ ✓ Rate Equation $Rate = k [F_2][NO_2]$ ✓	2	Mark independently ALLOW $rate = k [NO_2][F_2]$ Care – k must be included.

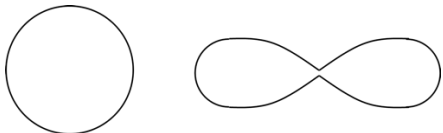
	(c)*	<i>Please refer to the marking instructions on page 5 of this mark scheme for guidance on how to mark this question.</i> Level 3 (5–6 marks) Describe the types of structure and bonding of all four elements AND explains most of the differences in melting points in terms of the relative strengths of the forces between the particles. <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3–4 marks) Attempt to describe the types of bonding of three elements AND explains most of the differences in melting points in terms of the relative strengths of the forces between the particles. OR Describe in detail and bonding of two of the three types of structure AND explains most of the differences in melting points in terms of the relative strengths of the forces between the particles. <i>There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.</i> Level 1 (1–2 marks) Attempt to describe the bonding of two elements AND explains most of the differences in melting points in terms of the relative strengths of the forces between the particles. OR Describes in detail the bonding of one of the three types of structure AND explains the melting point in terms of the strength of the forces between the particles.	6	Indicative scientific points may include: ALLOW minor omissions as we are looking for a holistic approach to LoR marking. Al (Giant metallic) • Giant metallic structure/lattice • Strong metallic bonding • Electrostatic attraction between (positive) metal ions/cations and delocalised electrons • A lot of energy needed to break bonds Si (Giant covalent) • Each Si atom forms 4 bonds / bonds with 4 other Si atoms • Giant covalent structure/lattice • Strong covalent bonds between atoms • Between shared pair of electrons and adjacent nuclei. • Most energy needed to break bonds P, S (Simple covalent) • <u>Simple</u> covalent / molecular structure/lattice • Strong covalent bonds between atoms • Weak induced dipole–dipole interactions between molecules* • Least energy to overcome the forces • Melting point of $S_8 > P_4$ • More electrons • Stronger induced dipole–dipole interactions • DO NOT ALLOW breaks BONDS • IGNORE van der Waals' (VDW)
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		<i>The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear.</i> 0 marks <i>No response or no response worthy of credit.</i>	*ALLOW London (dispersion) forces for induced dipole–dipole interactions. Aspects of the communication statement might typically not have been met when irrelevant information (e.g. ionisation energies, ionic radius etc) have been included.
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Question	Answer	Marks	Guidance
21 (a)	$2 \text{ Ba} + \text{O}_2 \rightarrow 2 \text{ BaO} \checkmark$ $\text{BaO} + \text{H}_2\text{O} \rightarrow \text{Ba(OH)}_2 \checkmark$ Neutralisation OR acid-base $\checkmark$	3	ALLOW multiples IGNORE state symbols, even if incorrect ALLOW $\text{Ba} + \text{H}_2\text{O} \rightarrow \text{BaO} + \text{H}_2$ (reaction with steam) ALLOW other correct equations e.g. with less reactive metal oxide
(b)	FIRST CHECK ANSWER ON ANSWER LINE If answer = 84 award 4 marks ----- $n(\text{I}^-) = \frac{26.2 \times 0.150}{1000} = 3.93 \times 10^{-3} \checkmark$ $n(\text{IO}_3^-) = \frac{3.93 \times 10^{-3}}{5} = 7.86 \times 10^{-4} \checkmark$ mass KIO_3 in 2 tablets = $7.86 \times 10^{-4} \times 214 = 0.168204 \text{ g}$ $\checkmark$ mass KIO_3 in 1 tablet = $0.084102 \text{ g} = 84 \text{ mg}$ (nearest whole number) $\checkmark$	4	ALLOW 3 SF or more throughout ALLOW ECF throughout Care – other sequence of calculations can be valid. <u>Alternative route</u> M3 mol (IO_3^-) in one tablet = $\frac{7.86 \times 10^{-4}}{2} = 3.93 \times 10^{-4}$ M4 Mass (KIO_3) in one tablet = $3.93 \times 10^{-4} \times 214 = 84$ Final answer must be a whole number Common Errors 3 marks: 69 mg (using M_r of IO_3^-) 421mg (not divided by 5)

Question		Answer	Marks	Guidance
	(c)	Complete circuit AND voltmeter AND labelled salt bridge linking two half-cells ✓ Pt AND Fe²⁺ AND Fe³⁺ ✓ Pt AND H₂ AND H⁺ AND delivery system for H₂ gas ✓ Standard conditions 1 mol dm⁻³ AND Temperature: 298 K / 25 °C AND Pressure: 1 atm / 100 kPa/101 kPa ✓	4	Electrodes / salt bridge must at least touch the surface of solutions ALLOW small gaps in circuit wires ALLOW half-cells drawn on either side ALLOW a formula of a strong acid for H⁺ <u>For standard conditions:</u> Can be awarded if all quoted on standard condition line or in labelled diagram. ALLOW 1M ALLOW equimolar solutions for Fe²⁺ AND Fe³⁺ only. i.e. need 1 mol dm⁻³ for [H⁺] IGNORE H₂SO₄ in diagram unless concentration is stated with a value other than 0.5 moldm⁻³ DO NOT ALLOW if any concentration is incorrect
	(d) (i)	Li + CoO ₂ → LiCoO ₂ ✓	1	ALLOW ⇌ DO NOT ALLOW uncanceled species

Question	Answer	Marks	Guidance
	(ii) Cell potentials: $(E^\ominus) = 1.23 - 0.00$ OR 1.23 (V) OR (redox system 6 – redox system 3) = 1.23 (V) AND $(E^\ominus) = 0.40 - (-0.83) = 1.23$ (V) OR (redox system 4 – redox system 2) = 1.23 (V) ✓ Acidic <i>Cell equation</i> $(2\times) \text{H}_2 \rightleftharpoons 2\text{H}^+ + 2\text{e}^-$ AND $\text{O}_2 + 4\text{H}^+ + 4\text{e}^- \rightleftharpoons 2\text{H}_2\text{O}$ AND $2 \text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$ ✓ Alkaline <i>Cell equation</i> $(2\times) \text{H}_2 + 2\text{OH}^- \rightleftharpoons 2\text{H}_2\text{O} + 2\text{e}^-$ AND $\text{O}_2 + 2\text{H}_2\text{O} + 4\text{e}^- \rightleftharpoons 4\text{OH}^-$ AND $2 \text{H}_2 + \text{O}_2 \rightarrow 2 \text{H}_2\text{O}$ ✓	3	IGNORE state symbols throughout ALLOW multiples ALLOW $\rightleftharpoons$ Overall equation AND with evidence of working: e.g. half-equations written out / combined but not cancelled / with crossings out OR <u>System 6</u> goes forward / reduced OR <u>system 3</u> goes backwards / oxidised ALLOW multiples Overall equation AND with evidence of working: e.g. half-equations written out / combined but not cancelled / with crossings out OR <u>System 4</u> goes forward / reduced OR <u>system 2</u> goes backwards oxidised ALLOW 1 mark for both equations with uncanceled species. ALLOW 1 mark for <u>System 6</u> / reduced goes forward and <u>system 3</u> goes backwards oxidised AND <u>System 4</u> / goes forward / reduced and <u>system 2</u> / goes backwards / oxidised

Question			Answer	Marks	Guidance
22	(a)		s orbital p orbital ✓  Fe = $(1s^2)2s^22p^63s^23p^64s^23d^6$ AND Fe²⁺ = $(1s^2)2s^22p^63s^23p^63d^6$ ✓	2	IGNORE shading IGNORE axes directions x, y, z DO NOT ALLOW multiple p orbitals For electron configuration, ALLOW 4s² after 3d⁶ i.e. $1s^22s^22p^63s^23p^63d^64s^2$ ALLOW upper case D, etc and subscripts, e.g. 4S₂3D₁ ALLOW 4s⁰ IGNORE [Ar]3d⁶ 4s²
	(b)	(i)	(A =) $[\text{Co}(\text{H}_2\text{O})_6]^{2+}$ ✓ (B =) $\text{Co}(\text{OH})_2$ ✓ (C =) $[\text{CoCl}_4]^{2-}$ OR CoCl_4^{2-} ✓	3	IGNORE state symbols even if incorrect [] essential ALLOW $[\text{Co}(\text{OH})_2(\text{H}_2\text{O})_4]$ OR $\text{Co}(\text{OH})_2(\text{H}_2\text{O})_4$ ALLOW -2 for 2- i.e. $[\text{CoCl}_4]^{-2}$

Question	Answer	Marks	Guidance
	(ii) Complex : $[\text{Co}(\text{NH}_3)_4\text{Cl}_2]$ ✓ Charge +1 / + / 1+ ✓	2	IGNORE Any charges for 1st mark ALLOW $[\text{CoCl}_2(\text{NH}_3)_4]$ ALLOW $[\text{Co}(\text{Cl})_2(\text{NH}_3)_4]$ DO NOT ALLOW $[\text{Co}(\text{Cl}_2)(\text{NH}_3)_4]$ DO NOT ALLOW if charges shown in formula within brackets for 2nd mark
	(c) Oxygen (O lone pair) forms a <u>coordinate/dative</u> bond to <u>Fe(II)/Fe/Iron/Fe²⁺</u> ✓ replaced by H₂O or CO₂ OR O₂ bonds <u>reversibly</u> (with metal ion) ✓ FIRST CHECK ANSWER ON ANSWER LINE If 7.3(0) AND not healthy / below 7.35 award three calculation marks ----- $[\text{H}^+] = K_a \times \frac{[\text{H}_2\text{CO}_3]}{[\text{HCO}_3^-]}$ OR $\frac{[\text{HCO}_3^-]}{[\text{H}_2\text{CO}_3]} = \frac{K_a}{[\text{H}^+]} \quad \checkmark$ $[\text{H}^+] = 5.02 \times 10^{-8}$ ✓	5	ALLOW word equations using → and ⇌ IGNORE number of coordinate bonds ALLOW ORA Check for alternative methods on mark scheme. ALLOW ECF throughout ALLOW $[\text{A}^-]$ for $[\text{HCO}_3^-]$ AND/OR $[\text{HA}]$ for $[\text{H}_2\text{CO}_3]$ (asked for in 19 a) ii)) ALLOW $[\text{H}^+] = K_a \div \frac{[\text{HCO}_3^-]}{[\text{H}_2\text{CO}_3]}$ ALLOW $\frac{[\text{H}_2\text{CO}_3]}{[\text{HCO}_3^-]} = \frac{[\text{H}^+]}{K_a}$ $[\text{H}^+]$ value subsumes MP3 ALLOW $[\text{H}^+] = 5.02 \times 10^{-8}$ up to the calculator value (5.023529412 × 10⁻⁸) DO NOT ALLOW a weak acid approach for marking points 3 and 5. i.e. $[\text{H}^+]$ can be awarded.

Question	Answer	Marks	Guidance																				
	pH = $-\log(5.02 \times 10^{-8}) = 7.3(0)$ AND not healthy / below 7.35 ✓ <u>Alternative method 1:</u> pH of healthy blood is between 7.35 and 7.45 <table border="1" data-bbox="380 609 1090 1224"> <tr> <td>pH 7.35</td><td></td><td>pH 7.45</td><td></td></tr> <tr> <td>$[H^+] = 4.47 \times 10^{-8}$</td><td>OR</td><td>$[H^+] = 3.55 \times 10^{-8}$</td><td>✓</td></tr> <tr> <td>$\frac{[HCO_3^-]}{[H_2CO_3]} = \frac{K_a}{[H^+]}$</td><td></td><td>$\frac{[HCO_3^-]}{[H_2CO_3]} = \frac{K_a}{[H^+]}$</td><td>✓</td></tr> <tr> <td>$\frac{[HCO_3^-]}{[H_2CO_3]} = \frac{4.27 \times 10^{-7}}{4.47 \times 10^{-8}}$</td><td></td><td>$\frac{[HCO_3^-]}{[H_2CO_3]} = \frac{4.27 \times 10^{-7}}{3.55 \times 10^{-8}}$</td><td></td></tr> <tr> <td>$\frac{[HCO_3^-]}{[H_2CO_3]} = 9.55:1$</td><td></td><td>$\frac{[HCO_3^-]}{[H_2CO_3]} = 12.03:1$</td><td></td></tr> </table> 8.5:1 does not lie in the range of 9.55:1 to 12.03:1 AND unhealthy ✓	pH 7.35		pH 7.45		$[H^+] = 4.47 \times 10^{-8}$	OR	$[H^+] = 3.55 \times 10^{-8}$	✓	$\frac{[HCO_3^-]}{[H_2CO_3]} = \frac{K_a}{[H^+]}$		$\frac{[HCO_3^-]}{[H_2CO_3]} = \frac{K_a}{[H^+]}$	✓	$\frac{[HCO_3^-]}{[H_2CO_3]} = \frac{4.27 \times 10^{-7}}{4.47 \times 10^{-8}}$		$\frac{[HCO_3^-]}{[H_2CO_3]} = \frac{4.27 \times 10^{-7}}{3.55 \times 10^{-8}}$		$\frac{[HCO_3^-]}{[H_2CO_3]} = 9.55:1$		$\frac{[HCO_3^-]}{[H_2CO_3]} = 12.03:1$			ALLOW 7.3 up to calculator value (pH = 7.298991951) ALLOW $[H^+] = 3.98 \times 10^{-8}$ from average pH 7.40 used. 3
pH 7.35		pH 7.45																					
$[H^+] = 4.47 \times 10^{-8}$	OR	$[H^+] = 3.55 \times 10^{-8}$	✓																				
$\frac{[HCO_3^-]}{[H_2CO_3]} = \frac{K_a}{[H^+]}$		$\frac{[HCO_3^-]}{[H_2CO_3]} = \frac{K_a}{[H^+]}$	✓																				
$\frac{[HCO_3^-]}{[H_2CO_3]} = \frac{4.27 \times 10^{-7}}{4.47 \times 10^{-8}}$		$\frac{[HCO_3^-]}{[H_2CO_3]} = \frac{4.27 \times 10^{-7}}{3.55 \times 10^{-8}}$																					
$\frac{[HCO_3^-]}{[H_2CO_3]} = 9.55:1$		$\frac{[HCO_3^-]}{[H_2CO_3]} = 12.03:1$																					

Question			Answer	Marks	Guidance
			<u>Alternative method 2:</u> $\text{pH} = \text{pK}_a + \log \frac{[\text{HCO}_3^-]}{[\text{H}_2\text{CO}_3]} \quad \checkmark$ $\text{pK}_a = 6.37 \quad \checkmark$ $6.37 + \log \frac{(8.5)}{(1)}$ $7.3(0) \text{ AND not healthy / below } 7.35 \quad \checkmark$		

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