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 SEEN

11. Annotations available in RM Assessor

Annotation	Meaning
✓	Correct response
✗	Incorrect response
^	Omission mark
BOD	Benefit of doubt given
CON	Contradiction
RE	Rounding error
SF	Error in number of significant figures
ECF	Error carried forward
L1	Level 1
L2	Level 2
L3	Level 3
NBOD	Benefit of doubt not given
SEEN	Noted but no credit given
I	Ignore
BP	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**.

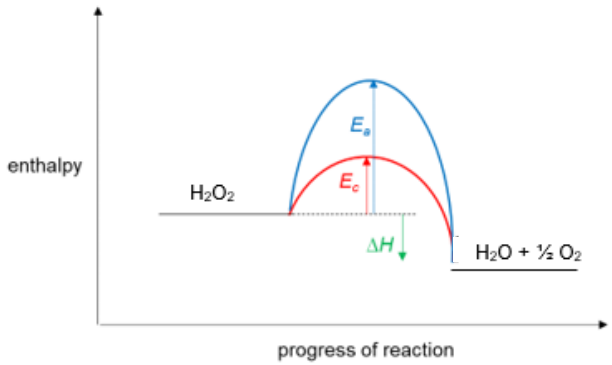
Please ask for help or guidance whenever you need it. Your first point of contact is your Team Leader.

SECTION A

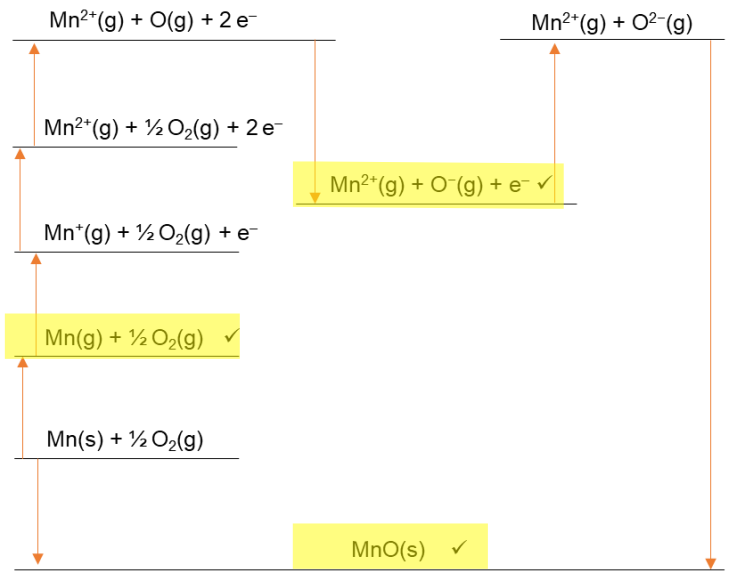
Question	Answer	Marks	Guidance
1	D	1	
2	B	1	
3	C	1	
4	B	1	
5	C	1	
6	D	1	
7	A	1	**ALLOW** -56 (correct numerical answer)
8	B	1	
9	B	1	**ALLOW** +133 (correct numerical answer)
10	D	1	
11	C	1	
12	A	1	
13	D	1	
14	D	1	
15	C	1	

SECTION B

Question			Answer	Marks	Guidance
16	(a)	(i)	**FIRST CHECK ANSWER ON ANSWER LINE** **If answer = –117 kJ mol^{-1}, award 4 marks.** ---------- ΔH = –286– (–188) = –98 kJ mol^{-1} ✓ ΔS = 70 + ½(205) – 110 = 62.5 (J K^{-1} mol^{-1}) or 0.0625 (kJ K^{-1} mol^{-1})✓ $\Delta G = \Delta H - T\Delta S$ = –98 – (298 × 0.0625) ✓ ΔG = –117 kJ mol^{-1} **(3SF)** ✓	4	**ALLOW ECF** throughout **ALLOW** –98000 – (298 × 62.5) **Common Errors for ΔG** ***3 marks*** *–18700 (ΔS not converted to kJ)* –493 (ΔH = –286 + (–188) = –474) *–147 (ΔS = 165: not halving 205)* *– 99.6 (T not converted to K)* *–18.7 (ΔH not converted J but ΔS J K^{-1} 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)	 H_2O_2 on LHS **AND** $H_2O + ½ O_2$ on RHS **AND** **ΔH** labelled with product line below reactant line **AND** Arrow downwards ✓	3	**Care** enthalpy profile must match ΔH **sign** in16 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 –**ΔH **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*$_c$** correctly labelled 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 **–**Δ*H* value (from16 a) i))
		(ii)	(MnO_2) is in different phase/state (to the reactant / H_2O_2) **OR** catalyst is a solid **AND** reactant is liquid✓	**1**	**ASSUME** 'it' is MnO_2 **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** Mn^{2+} Mn^{3+} **DO NOT ALLOW** + 4 (this is the oxidation state in MnO_2)

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)		3	Care: State symbols are required

Question			Answer	Marks	Guidance
		(iii)	**FIRST CHECK ANSWER ON ANSWER LINE** **If answer = –3798 award 2 marks** ---------- ΔH lattice = – 281 – 249 – 717 – 1509 – (–141) – 798 + (–385) ✓ ΔH lattice = –3798 (kJ mol^{-1}) ✓	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> ✓	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.

<table>
<tr><th colspan="3">Question</th><th>Answer</th><th>Marks</th><th>Guidance</th></tr>
<tr><td></td><td>(b)*</td><td></td><td>

Please refer to the marking instructions on page 4 of this mark scheme for guidance on how to mark this question.

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*

There is a well-developed line of reasoning which is clear and logically structured.

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

There is a line of reasoning with some structure and supported by some evidence.

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

There is an attempt at a logical structure with a reasoned conclusion from the evidence.

</td><td>6</td><td>

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><th></th><th>Minutes</th><th>Seconds</th></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) $\times 10^{-8}$ mol dm^{-3} min^{-1}</td><td>(-) (2.5 to 3.0)$\times 10^{-10}$ 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) x 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.

</td></tr>
</table>

Question			Answer	Marks	Guidance
			0 marks *No response worthy of credit*		**If time has been measured in minutes** **(see below for values using seconds).** **Indicative scientific points may include:** **Evidence for 1st order** 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 $c = 0.61 \times 10^{-7}$ mol dm^{-3} (t = 3 min) Gradient at *c*/2 is half gradient at *c* e.g. $c = 0.8 \times 10^{-7}$ mol dm^{-3}, gradient = 2.2×10^{-8} (mol dm^{-3} min^{-1}) **AND** $c = 0.4 \times 10^{-7}$ mol dm^{-3}, gradient = 1.1×10^{-8} (mol dm^{-3} min^{-1}) For chosen method, conclude that the reaction is 1st order wrt CV. **Rate at three minutes** Tangent shown on graph as line at t = 3 min Gradient in range: $(1.5 – 1.8) \times 10^{-8}$ rate as gradient with units: mol dm^{-3} min^{-1} **OR** $k = \frac{\ln 2}{t_{½}} = 0.28 \text{min}^{-1}$ And k substituted into rate equation. e.g. Rate = k [CV] Rate = $0.277 \times 0.61 \times 10^{-7}$ = 1.7×10^{-8} mol dm^{-3} min^{-1} **Determination of *k*** 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. $k = \frac{\ln 2}{t_{½}} = 0.28\ min^{-1}$ **Units of *k*:** min^{-1} **If time has been measured in seconds:** **Evidence for 1st order** 1st order clearly linked to half-life **OR** 2 gradients: **Half life** Half- life shown on graph Half- life range 144 to 156 s Two 'constant' half lives **OR Two gradients → two rates** 2 tangents shown on graph at *c* and *c*/2 This could include $c = 0.6 \times 10^{-8}$ mol dm^{-3} (t = 3 min) Gradient at *c*/2 is half gradient at *c* e.g. $c = 0.8 \times 10^{-7}$ mol dm^{-3}, gradient = 3.7×10^{-10} mol dm^{-3} s^{-1} **AND** $c = 0.4 \times 10^{-7}$ mol dm^{-3}, gradient = 1.8×10^{-10} mol dm^{-3} s^{-1} For chosen method, conclude that the reaction is 1st order wrt CV. **Rate at 180 seconds** Gradient in range (2.5 to 3.0) $\times 10^{-10}$ rate as gradient with units: mol dm^{-3} s^{-1} **OR** $k = \frac{\ln 2}{t_{½}} = 4.6 \times 10^{-3}\ s^{-1}$ And *k* substituted into rate equation. e.g. Rate = *k* [CV] Rate = $0.00462 \times 0.61 \times 10^{-7}$ = 2.8×10^{-10} mol dm^{-3} s^{-1} **Determination of *k*** *k* clearly linked to rate **OR** half-life:

Question			Answer	Marks	Guidance
					e.g. $k = \frac{\text{rate}}{[CV]} = \frac{2.75 \times 10^{-10}}{0.62 \times 10^{-7}} = 4.4 \times 10^{-3}\ s^{-1}$ k in range (4.0 to 4.8) x $10^{-3}\ s^{-1}$ **OR** e.g. $k = \frac{\ln 2}{t_{½}} = 0.28\ min^{-1}$ **OR** $4.6 \times 10^{-3}\ s^{-1}$ **Units of *k*:** s^{-1}

Question			Answer	Marks	Guidance
18	(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 ✓ $N\ SO_3$ = 1.35 , $n\ O_2$ = 0.45(0) **AND** n total = 2.7(0) Partial pressures ✓ $p(SO_3)$: $\frac{1.35}{2.7(0)} \times 2.80$ **OR** 1.4(0) $p(SO_2)$: $\frac{0.900}{2.7(0)} \times 2.80$ **OR** 0.933 $p(O_2)$: $\frac{0.450}{2.7(0)} \times 2.80$ **OR** 0.467 $(K_p) = \frac{p(SO_2)\ p(O_2)^{1/2}}{p(SO_3)}$ **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 $\frac{atm^1 \times atm^{1/2}}{atm^1} = atm^{1/2}$ ✓	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** $p(SO_3)$ = 1.4, n 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** $(K_p) = \frac{p(SO_2)\ p^{1/2}(O_2)}{p(SO_3)}$ **ALLOW** $K_p^2 = \frac{p(SO_2)^2 \times p(O_2)}{p(SO_3)^2}$ **IGNORE** [ ] (we are just looking for the calculation) **ALLOW ECF** for units of an incorrect K_p expression **ALLOW** $atm^{0.5}$ **DO NOT ALLOW** √atm

<table>
<tr><th colspan="3">Question</th><th>Answer</th><th>Marks</th><th>Guidance</th></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td>Common errors
4 marks
(3 marks for calculation + unit mark)

0.207 (from expression $\frac{p(SO_2)^2 \times p(O_2)}{p(SO_3)^2}$) Unit: atm

2.20 (from inverted expression) Unit: $atm^{-1/2}$</td></tr>
<tr><td></td><td></td><td>(ii)</td><td>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 $7.7 \times 10^{-2} > 3.3 \times 10^{-5}$ ✓</td><td>2</td><td>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</td></tr>
<tr><td></td><td></td><td>(iii)</td><td>One mark per correct row ✓✓

<table><tr><th>Change</th><th>Decrease</th><th>No change</th><th>Increase</th></tr><tr><td>No catalyst</td><td></td><td>✓</td><td></td></tr><tr><td>Increased pressure</td><td></td><td>✓</td><td></td></tr></table></td><td>2</td><td></td></tr>
</table>

Question			Answer	Marks	Guidance
	(b)	**(**i)	There are 3 bonding regions **OR** 3 double bonds (round the S atom).	**1**	**ALLOW** electron regions / areas of electron density **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** $= 1.1(22\ldots) \times 10^{-2}$ ✓ $(K_a) = (\frac{[H^+]^2}{[ClCH_2COOH]})$ $= \frac{(1.122\ldots \times 10^{-2})^2}{(0.090)}$ **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 $[HA]_{equ}$ $\frac{(1.122\ldots \times 10^{-2})^2}{(0.079)}$ **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 cm^3 ✓ $n(Ba(OH)_2)$ =) $0.0560 \times \frac{12.5}{1000}$ $= 7.00 \times 10^{-4}$ ✓ $n(CH_3COOH$ =) $2 \times$ (moles $Ba(OH)_2$) $= 1.40 \times 10^{-3}$ ✓ (concentration =) $\frac{1.4 \times 10^{-3}}{(10/1000)}$ $= 0.14(0)$ (mol dm^{-3}) ✓	**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
			<u>Alternative method based on calculating pK_a from the half neutralisation point.</u> pH and $[H^+]$ reading will come from the candidates graph and the data points provided. e.g. pH at half neutralisation 6.25 cm^3 = pH 4.7 = pK_a ✓ $K_a = 10^{-4.7}$ $= 1.995 \times 10^{-5}$ ✓ $[H^+]$ at pH 3.3 (obtained from data on the graph provided) $10^{-3.3} = 5.012 \times 10^{-4}$ (mol dm^{-3}) ✓ $[HA] = \frac{[H^+]^2}{[K_a]}$ $= \frac{(5.012 \times 10^{-4})^2}{(1.995 \times 10^{-5})}$ = 0.0126 (mol dm^{-3}) ✓		**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.

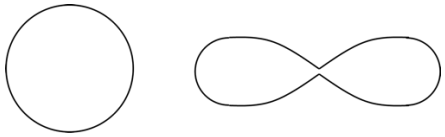
	(c)*		*Please refer to the marking instructions on page 5 of this mark scheme for guidance on how to mark this question.* **Level 3 (5–6 marks)** Describe the types of structure and bonding of all four elements **AND** explains most of the differences in melting points in terms of the relative strengths of the forces between the particles. *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)** 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. *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)** 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)

			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. **0 marks** *No response or no response worthy of credit.*		*__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.

Question			Answer	Marks	Guidance
21	(a)		$2\ Ba + O_2 \rightarrow 2\ BaO$ ✓ $BaO + H_2O \rightarrow Ba(OH)_2$ ✓ Neutralisation **OR** acid-base ✓	3	**ALLOW** multiples **IGNORE** state symbols, even if incorrect **ALLOW** $Ba + H_2O \rightarrow BaO + H_2$ (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** ---------- $n(I^-) = \frac{26.2 \times 0.150}{1000} = 3.93 \times 10^{-3}$ ✓ $n(IO_3^-) = \frac{3.93 \times 10^{-3}}{5} = 7.86 \times 10^{-4}$ ✓ mass KIO_3 in 2 tablets = $7.86 \times 10^{-4} \times 214 = 0.168204$ g ✓ mass KIO_3 in 1 tablet = 0.084102 g = 84 mg (**nearest whole number**)✓	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** Fe^{2+} **AND** Fe^{3+} ✓ Pt **AND** H_2 **AND** H^+ **AND** delivery system for H_2 gas ✓ Standard conditions 1 mol dm^{-3} **AND** Temperature: 298 K / 25 ºC **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 Fe^{2+} **AND** Fe^{3+} only. i.e. need 1 mol dm^{-3} for $[H^+]$ **IGNORE** H_2SO_4 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)	$Li + CoO_2 \rightarrow LiCoO_2$ ✓	**1**	**ALLOW** ⇌ **DO NOT ALLOW** uncancelled 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** *Cell equation* (2×) $H_2 \rightleftharpoons 2H^+ + 2e^-$ **AND** $O_2 + 4H^+ + 4e^- \rightleftharpoons 2H_2O$ **AND** $2\ H_2 + O_2 \rightarrow 2H_2O$ ✓ **Alkaline** *Cell equation* (2×) $H_2 + 2OH^- \rightleftharpoons 2H_2O + 2e^-$ **AND** $O_2 + 2H_2O + 4e^- \rightleftharpoons 4OH^-$ **AND** $2\ H_2 + O_2 \rightarrow 2\ H_2O$ ✓	3	**IGNORE** state symbols throughout **ALLOW** multiples **ALLOW** ⇌ Overall equation **AND** with evidence of working: e.g. half-equations written out / combined but not cancelled **/** with crossings out **OR** System 6 goes forward / reduced **OR** system 3 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** System 4 goes forward / reduced **OR** system 2 goes backwards oxidised **ALLOW** 1 mark for both equations with uncancelled species. **ALLOW** 1 mark for System 6 / reduced goes forward and system 3 goes backwards oxidised **AND** System 4 / goes forward / reduced and system 2 / goes backwards / oxidised

Question			Answer	Marks	Guidance
22	(a)		s orbital p orbital ✓  Fe = $(1s^2)2s^22p^63s^23p^64s^23d^6$ **AND** Fe^{2+} = $(1s^2)2s^22p^63s^23p^63d^6$ ✓	2	**IGNORE** shading **IGNORE** axes directions x, y, z **DO NOT ALLOW** multiple p orbitals For electron configuration, **ALLOW** $4s^2$ after $3d^6$ i.e. $1s^22s^22p^63s^23p^63d^64s^2$ **ALLOW** upper case D, etc and subscripts, e.g. ……$4S_23D_1$ **ALLOW** $4s^0$ **IGNORE** $[Ar]3d^6\ 4s^2$
	(b)	(i)	(**A** =) $[Co(H_2O)_6]^{2+}$ ✓ (**B** =) $Co(OH)_2$ ✓ (**C** =) $[CoCl_4]^{2-}$ **OR** $CoCl_4^{2-}$✓	3	**IGNORE** state symbols even if incorrect [ ] essential **ALLOW** $[Co(OH)_2(H_2O)_4]$ **OR** $Co(OH)_2(H_2O)_4$ **ALLOW** -2 for 2- i.e. $[CoCl_4]^{-2}$

Question			Answer	Marks	Guidance
		(ii)	Complex : $[Co(NH_3)_4Cl_2]$ ✓ Charge +1 / + / 1+ ✓	2	**IGNORE** Any charges for 1st mark **ALLOW** $[CoCl_2(NH_3)_4]$ **ALLOW** $[Co(Cl)_2(NH_3)_4]$ **DO NOT ALLOW** $[Co(Cl_2)(NH_3)_4]$ **DO NOT ALLOW** if charges shown in formula within brackets for 2nd mark
	(c)		Oxygen (O lone pair) forms a coordinate/dative bond to Fe(II)/Fe/Iron/Fe^{2+} ✓ replaced by H_2O or CO_2 **OR** O_2 bonds reversibly (with metal ion) ✓ **FIRST CHECK ANSWER ON ANSWER LINE** **If 7.3(0) AND not healthy / below 7.35 award three calculation marks** ---------- $[H^+] = K_a \times \frac{[H_2CO_3]}{[HCO_3^-]}$ **OR** $\frac{[HCO_3^-]}{[H_2CO_3]} = \frac{K_a}{[H^+]}$ ✓ $[H^+] = 5.02 \times 10^{-8}$ ✓	5	**ALLOW** word equations using → and ⇌ **IGNORE** number of coordinate bonds **ALLOW ORA** **Check for alternative methods on mark scheme.** **ALLOW ECF** throughout **ALLOW** $[A^-]$ for $[HCO_3^-]$ **AND/OR** [HA] for $[H_2CO_3]$ (asked for in 19 a) ii)) **ALLOW** $[H^+] = K_a \div \frac{[HCO_3^-]}{[H_2CO_3]}$ **ALLOW** $\frac{[H_2CO_3]}{[HCO_3^-]} = \frac{[H^+]}{K_a}$ $[H^+]$ value subsumes MP3 **ALLOW** $[H^+] = 5.02 \times 10^{-8}$ up to the calculator value ($5.023529412 \times 10^{-8}$) **DO NOT ALLOW** a weak acid approach for marking points 3 and 5. i.e. $[H^+]$ can be awarded.

<table>
<tr><th colspan="3">Question</th><th>Answer</th><th>Marks</th><th>Guidance</th></tr>
<tr><td></td><td></td><td></td><td>pH = –log(5.02 × 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>
<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 ✓</td><td></td><td>**ALLOW** 7.3 up to calculator value (pH =7.298991951)

ALLOW $[H^+] = 3.98 \times 10^{-8}$ from average pH 7.40 used.
3</td></tr>
</table>

Question			Answer	Marks	Guidance
			<u>Alternative method 2:</u> $pH = pK_a + \log \frac{[HCO_3^-]}{[H_2CO_3]}$ ✓ pKa = 6.37 ✓ $6.37 + \log \frac{(8.5)}{(1)}$ 7.3(0) **AND** not healthy / below 7.35 ✓		

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