



EXAM PAPERS PRACTICE

Boost your performance and confidence with these topic-based exam questions

Practice questions created by actual examiners and assessment experts

Detailed mark scheme

Suitable for all boards

Designed to test your ability and thoroughly prepare you

2002

XVIII

1583

Time allowed
89 Minutes

Score

174

Percentage

%

CHEMISTRY

**OCR
AS & A LEVEL**

Mark Schemes

Module 5: Physical chemistry and transition elements

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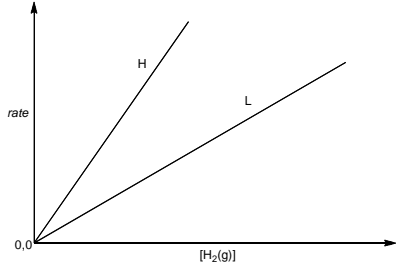
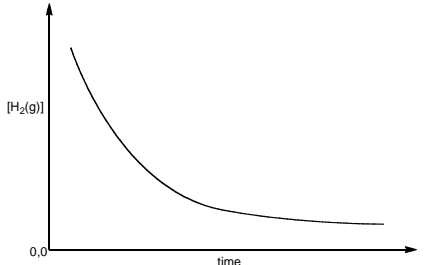


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Question	Answer	Marks	Guidance																																
1 (a)	<p>NOTE: First 3 marks are ONLY available from an expression using [NO]² Units are marked independently</p> <p>-----</p> <p>Using values ON THE CURVE in CORRECT expression mark 1</p> <p>Use of any two correct values for rate and [NO] from graph e.g. for 5.0×10^{-4} and 4.2×10^{-4},</p> $k = \frac{4.2 \times 10^{-4}}{(2.0 \times 10^{-2}) \times (5.0 \times 10^{-4})^2}$ <p>OR $4.2 \times 10^{-4} = k(2.0 \times 10^{-2}) \times (5.0 \times 10^{-4})^2 \checkmark$</p> <p>-----</p> <p>Calculation of k 2 marks</p> <p>FOR 1 MARK <i>k</i> calculated correctly from values obtained from graph BUT NOT in standard form AND/OR more than 2 SF e.g. $k = \frac{6.0 \times 10^{-4}}{(2.0 \times 10^{-2}) \times (6.0 \times 10^{-4})^2} = 83333.33 \checkmark$</p> <p>OR FOR 2 MARKS <i>k</i> calculated correctly from values obtained from graph AND in standard form AND TO 2 SF e.g. $k = 83333.33$ gives $8.3 \times 10^4 \checkmark$</p> <p>-----</p> <p>UNITS FOR 1 MARK: $\text{dm}^6 \text{mol}^{-2} \text{s}^{-1} \checkmark$</p>	1	<p>Note: rate and [NO] are any correct pair of readings from the graph, The [NO] below are the most commonly seen. For these [NO] values, these are the ONLY rates allowed</p> <table border="1"><thead><tr><th>[NO]</th><th>rate</th><th><i>k</i></th><th><i>k</i></th></tr></thead><tbody><tr><td>1.0×10^{-4}</td><td>0.1×10^{-4} to 0.2×10^{-4}</td><td>50000 100000</td><td>5.0×10^4 1.0×10^5</td></tr><tr><td>2.0×10^{-4}</td><td>0.6×10^{-4} to 0.7×10^{-4}</td><td>75000 87500</td><td>7.5×10^4 8.8×10^4</td></tr><tr><td>3.0×10^{-4}</td><td>1.5×10^{-4}</td><td>83333</td><td>8.3×10^4</td></tr><tr><td>4.0×10^{-4}</td><td>2.7×10^{-4}</td><td>84375</td><td>8.4×10^4</td></tr><tr><td>5.0×10^{-4}</td><td>4.2×10^{-4}</td><td>84000</td><td>8.4×10^4</td></tr><tr><td>6.0×10^{-4}</td><td>6.0×10^{-4}</td><td>83333</td><td>8.3×10^4</td></tr><tr><td>7.0×10^{-4}</td><td>8.2×10^{-4}</td><td>83673</td><td>8.4×10^4</td></tr></tbody></table> <p>IF OTHER values are given, mark using the same principle. If any doubt, contact TL.</p> <p>NOTE: IGNORE any numbers used from tangents</p> <p>-----</p> <p>SPECIAL CASES that ALLOW ECF for calculation of <i>k</i> from ONLY ONE of the following (2 marks)</p> <ol style="list-style-type: none">1. Powers of 10 incorrect or absent in initial <i>k</i> expression2. $[\text{H}_2]^2[\text{NO}]$ used instead of $[\text{H}_2][\text{NO}]^2$3. Any value within ± 0.2 of actual values from graph <p>-----</p> <p>4 ALLOW units in any order, e.g. $\text{mol}^{-2} \text{dm}^6 \text{s}^{-1}$</p>	[NO]	rate	<i>k</i>	<i>k</i>	1.0×10^{-4}	0.1×10^{-4} to 0.2×10^{-4}	50000 100000	5.0×10^4 1.0×10^5	2.0×10^{-4}	0.6×10^{-4} to 0.7×10^{-4}	75000 87500	7.5×10^4 8.8×10^4	3.0×10^{-4}	1.5×10^{-4}	83333	8.3×10^4	4.0×10^{-4}	2.7×10^{-4}	84375	8.4×10^4	5.0×10^{-4}	4.2×10^{-4}	84000	8.4×10^4	6.0×10^{-4}	6.0×10^{-4}	83333	8.3×10^4	7.0×10^{-4}	8.2×10^{-4}	83673	8.4×10^4
[NO]	rate	<i>k</i>	<i>k</i>																																
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Question		Answer	Marks	Guidance
(b)	(i)	 <p>One straight upward line AND starting at 0,0 ✓</p> <p>2nd straight upward line starting at 0,0 and steeper AND</p> <p>Steeper line labelled H OR less steep line labelled L ✓</p>	2	<p>ALLOW 1 mark for two upward sloping curves starting at origin</p> <p>AND upper curve labelled H and lower curve labelled L</p> <p>NOTE: ALLOW some leeway for lines starting from origin</p> <p>ALLOW straight line not drawn with ruler, i.e. is a straight line rather than a curve</p> <p>ALLOW similar labelling as long as it is clear which line is which</p>
(b)	(ii)	increases ✓	1	
(c)		<p>MARK INDEPENDENTLY</p> <hr/>  <p>Downward curve ✓</p> <p>Half life is constant ✓</p>	2	<p>ALLOW curve touching y axis</p> <p>ALLOW curve touching x axis</p> <p>ALLOW Two half lives are the same</p> <p>IGNORE 'regular' half life (not necessarily the same)</p>



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Question		Answer	Marks	Guidance
(d)	(i)	$\text{H}_2 + \text{N}_2\text{O} \rightarrow \text{N}_2 + \text{H}_2\text{O} \checkmark$	1	ONLY correct answer DO NOT ALLOW multiples
(d)	(ii)	Steps 1 AND Step 2 together give $2\text{NO} + \text{H}_2 \checkmark$	1	ALLOW Step 1 AND Step 2 together give species in same ratio as in rate equation ALLOW rate-determining step/slow step for Step 2 ALLOW H_2 reacts with N_2O_2 which is formed from 2NO NOTE: The response must link Step 1 with Step 2 Steps can be referenced from the species in each step
		Total	11	

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Question			Answer	Marks	Guidance
2	(a)	(i)	5 OR 5th (order) ✓	1	
	(a)	(ii)	(stoichiometry in) rate equation does not match (stoichiometry) in overall equation ✓ Collision unlikely with more than 2 ions/species/particles ✓	2	ALLOW moles/ions/species/particles/molecules/atoms throughout (<i>i.e. emphasis on particles</i>) IGNORE more reactants in overall equation If number of species is stated, ALLOW 3–5 only (<i>rate equation contains 5 ions</i>) DO NOT ALLOW negative ions would repel (<i>there is a mixture of positive and negative ions</i>) IGNORE more than two reactants collide (<i>not related to rate equation</i>)
	(b)		<div style="display: flex; justify-content: space-around;"> <div style="text-align: center;"> <p>Straight upward line AND starting at 0,0 ✓</p> </div> <div style="text-align: center;"> <p>Curve with increasing gradient, AND starting at 0,0 ✓</p> </div> </div>	2	ALLOW lines starting close to 0,0 ALLOW 2nd order line with 'straight' section early or late as long as an upward curve is seen between.
	(c)	(i)	5.4(0) ✓ 614.4(0) ✓	2	IGNORE sign ALLOW 614 OR 610



	(c) (ii)	<p>FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = 6.7×10^8 OR 670000000 $\text{dm}^{12} \text{mol}^{-4} \text{s}^{-1}$, award 3 marks IF answer = 6.7×10^8 OR 670000000 with incorrect units, award 2 marks</p> <p>k to >2 SF: 666666666.7 ✓ OR k to 2 SF: 6.7×10^8 OR 670000000 ✓✓</p> <p>units: $\text{dm}^{12} \text{mol}^{-4} \text{s}^{-1}$ ✓</p>		<p>ALLOW ECF from incorrect initial rates if 1st experimental results have not been used. (Look to 4(c)(i) to check) <i>i.e.</i> IF other rows have been used, then calculate the rate constant from data chosen.</p> <p>For k, ALLOW 1 mark for the following: 6.6×10^8 recurring 6.6×10^8 2 SF answer for k BUT one power of 10 out <i>i.e.</i> 6.7×10^9 OR 6.7×10^7</p> <p>3 ALLOW units in any order, e.g. $\text{mol}^{-4} \text{dm}^{12} \text{s}^{-1}$</p>
	(c) (iii)	<p>$(K_a =) 10^{-3.75}$ OR 1.78×10^{-4} (mol dm^{-3}) ✓</p> <p>$[\text{H}^+] = \sqrt{1.78 \times 10^{-4} \times 0.0200}$ $= 1.89 \times 10^{-3}$ (mol dm^{-3}) ✓</p> <p>initial rate = $6.7 \times 10^8 \times 0.01 \times 0.015^2 \times (1.89 \times 10^{-3})^2$ $= 5.33 \times 10^{-3}$ to 5.38×10^{-3} ($\text{mol dm}^{-3} \text{s}^{-1}$) OR 5.3×10^{-3} to 5.4×10^{-3} ($\text{mol dm}^{-3} \text{s}^{-1}$) ✓</p> <p>Actual value will depend on amount of acceptable rounding in steps and whether figures kept in calculator even if rounding is written down. ALLOW any value in range given above.</p>		<p>FULL ANNOTATIONS MUST BE USED</p> <p>-----</p> <p>For ALL marks, ALLOW 2 SF up to calculator value correctly rounded $1.77827941 \times 10^{-4}$</p> <p>ALLOW $\sqrt{10^{-3.75} \times 0.0200}$ for first marking point ALLOW 1.88×10^{-3} (mol dm^{-3})</p> <p>ALLOW ECF from calculated $[\text{H}^+(\text{aq})]$ and calculated answer for k from 4(c)(ii)</p> <p>3 e.g. If no square root taken, $[\text{H}^+] = 3.56 \times 10^{-6} \text{mol dm}^{-3}$ and $\text{rate} = 1.91 \times 10^{-8}$ OR 1.9×10^{-8} by ECF</p>
Total			13	



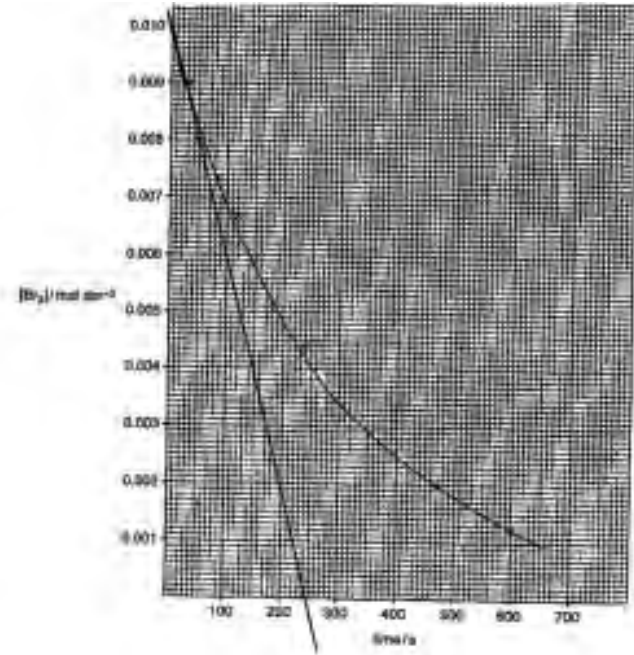
Question			er	Marks	Guidance
3	(a)	(i)	Time for concentration (of reactant) to fall to half original value ✓	1	ALLOW time for concentration to fall by half DO NOT ALLOW concentration of product to fall by half ALLOW mass OR amount as alternative to concentration ALLOW time for reactant/substance/atoms to decrease by half
		(ii)	At least two half-lives correctly shown on graph AND half-life stated as approx. 54 s ✓ 1st order has a constant half-life ✓	2	ALLOW half-life in range 50–56 s ALLOW half-life shown on graph Care: Initial concentration is ~5.8 and NOT 6.0 For constant half-life, ALLOW 'half lives are the same', 'two half-lives are 54 s', etc. ALLOW 2 tangents drawn, one at half conc of first AND evidence that gradient (\equiv rate) halves
		(iii)	No change ✓	1	
	(b)	(i)	<i>Tangent</i> On graph, tangent drawn to curve at $t \sim 40$ s ✓ <i>Calculation of rate from the tangent drawn</i> e.g. rate = $\frac{5.2}{116} = 0.045$ OR 4.5×10^{-2} ✓ <i>Units</i> $\text{mol dm}^{-3} \text{s}^{-1}$ ✓ <i>Independent mark</i>	3	Annotate tangent on graph Note: This mark can only be awarded from a tangent ALLOW ECF for tangent drawn at different time from 40 s ALLOW $\pm 10\%$ of gradient of tangent drawn ALLOW 2 SF up to calculator value ALLOW trailing zeroes, e.g. 0.04 for 0.040 IGNORE '–' sign for rate Note: IF candidate calculates rate via ln 2 method (shown in (ii), consult with TL)



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Question		er	Marks	Guidance
(b)	(ii)	$k = \frac{\text{answer to (b)(i)}}{3.45} \checkmark$ units: $\text{s}^{-1} \checkmark$ <i>Independent mark</i>	2	From 0.045, $k = \frac{0.045}{3.45} = 0.013$ ALLOW concentration range 3.4–3.5 ALLOW use of unrounded calculator answer from (b)(i) even if different from answer given on (b)(i) answer line <i>Many will keep this value in calculator for (b)(ii)</i> ALLOW $k = \ln 2/t_{1/2} = 0.693/\text{half life}$ from (a)(iii) For 54 s, $k = 0.693/54 = 0.013$ ALLOW 2 SF up to calculator value
(c)		water is in excess OR concentration of H_2O is very large/does not change \checkmark	1	IGNORE water does not affect the rate
		Total	10	



Question	er	Mark	Guidance
4	<p>Evidence of at least two half-lives measured on graph OR within text (would need evidence of two half-lives) ✓</p> <p>Any half-life value stated in range 180–220 s OR constant half-life ✓</p> <p>1st order ✓ Note: This is only correct response for order (ie no ECF). If not stated separately, this mark can be awarded from a rate equation, e.g. $rate = k[Br_2]^1$ OR $rate = k[Br_2]$</p> <p>Evidence of tangent on graph drawn to line at $t = 0$ s ✓ e.</p> 	4	<p>ANNOTATE ALL Q3 WITH TICKS AND CROSSES, etc</p> <p>MARK ON GRAPH OR IN TEXT</p> <p>LOOK FOR STATEMENT ON GRAPH OR WITHIN TEXT ALLOW almost constant half-life</p> <p>-----</p> <p>Note: Response may use an alternative approach from half-life for the 1st two marks based on gradients of tangents: 1st mark would be awarded for evidence of two tangents drawn on graph 2nd mark would be awarded for stating that ratio of concentrations = ratio of rates, e.g. gradient of tangent at $0.010 \text{ mol dm}^{-3}$ has twice the value of gradient of tangent at $0.005 \text{ mol dm}^{-3}$</p> <p>-----</p> <p>MARK TANGENTS ON GRAPH ALLOW some leeway but tangent must coincide with part of curve that is 'straight' (ie between $[Br_2] = 0.010$–0.009 and MUST NOT cross the curve</p>



Question	er	Mark	Guidance
	$rate = \frac{0.010}{250} = 0.000040$ OR 4.0×10^{-5} ✓ units: $\text{mol dm}^{-3} \text{ s}^{-1}$ ✓	2	ALLOW values from 1 SF (0.00004 OR 4×10^{-5}) up to calculator value, correctly rounded ALLOW range $\sim \frac{0.010}{160}$ to $\frac{0.010}{300}$: i.e. ALLOW a calculated gradient in the range $6 \times 10^{-5} - 3 \times 10^{-5}$ from a tangent drawn at $t = 0$ IF tangent is drawn on graph at a different time or incorrectly (e.g. crossing curve), then mark rate calculation by ECF using the gradient of the tangent drawn by the candidate (ie not the range above). IF no tangent is drawn ALLOW a value in the range above ONLY Credit only attempts at tangents, not just a random straight line IGNORE a '- sign'
	$rate = k[\text{Br}_2]$ OR $k = \frac{rate}{[\text{Br}_2]}$ ✓ $k =$ calculated result from $\frac{\text{calculated value for rate}}{0.010}$ ✓ units: s^{-1} ✓	3	DO NOT ALLOW $rate = k[\text{Br}]$, ie Br instead of Br_2 DO NOT ALLOW just $k[\text{Br}_2]$, ie 'rate = ' OR 'r = ' must be present Calculation of k is from candidate's calculated initial rate From 0.00004 , $k = \frac{0.000040}{0.010} = 4 \times 10^{-3} \text{ s}$ Note: IF order with respect to Br_2 has been shown as 2nd order, then mark this part by ECF , e.g. if Br_2 shown to be 2nd order, $rate = k[\text{Br}_2]^2$ $k =$ calculated result from $\frac{\text{calculated value for rate}}{0.010^2}$ units: $\text{dm}^3 \text{ mol}^{-1} \text{ s}^{-1}$ OR $\text{mol}^{-1} \text{ dm}^3 \text{ s}^{-1}$ Note: Units mark must correspond to the candidate's stated rate equation, NOT an incorrectly rearranged k expression
	Total	9	



Question		Expected Answers	Marks	Additional Guidance
5	a	$\text{BrO}_3^- + 5\text{Br}^- + 6\text{H}^+ \longrightarrow 3\text{Br}_2 + 3\text{H}_2\text{O}$ ✓	1	ALLOW multiples
	b	<p>graph:</p> <p>Straight/diagonal line through origin OR 0,0 AND 1st order with respect to BrO_3^- ✓</p> <p>initial rates data:</p> <p>When $[\text{Br}^-]$ is doubled, rate $\times 2$ ✓ 1st order with respect to Br^- ✓</p> <p>When $[\text{H}^+] \times 2$, rate $\times 4$ (2^2) ✓ 2nd order with respect to H^+ ✓</p> <p>Rate equation rate = $k [\text{BrO}_3^-] [\text{Br}^-] [\text{H}^+]^2$ ✓</p>	1 4 1	<p>ANNOTATIONS MUST BE USED</p> <p>Both explanation and 1st order required for mark</p> <p>DO NOT ALLOW diagonal line OR straight line OR constant gradient on its own (no mention of origin OR 0,0)</p> <p>ALLOW 'As BrO_3^- doubles, rate doubles' AND 1st order ALLOW rate is proportional to concentration AND 1st order</p> <p>Mark order and explanation independently Mark order first, then explanation</p> <p>ALLOW ECF from candidate's orders above</p>



Question	Expected Answers	Marks	Additional Guidance
	<p>Calculation of rate constant (3 marks)</p> $k = \frac{te}{[\text{BrO}_3^-][\text{Br}^-][\text{H}^+]^2}$ <p>OR $\frac{1.19 \times 10^{-5}}{(5.0 \times 10^{-2})(1.5 \times 10^{-1})(3.1 \times 10^{-1})^2} \checkmark$</p> $= 1.7 \times 10^{-2} \text{ OR } 1.65 \times 10^{-2} \checkmark \text{ dm}^9 \text{ mol}^{-3} \text{ s}^{-1} \checkmark$	3	<p>ANNOTATIONS MUST BE USED</p> <p>Calculation can be from any of the experimental runs – they all give the same value of k</p> <p>ALLOW $\text{mol}^{-3} \text{ dm}^9 \text{ s}^{-1}$</p> <p>ALLOW 1.6510579×10^{-2} and correct rounding to 1.7×10^{-2}</p> <p>Correct numerical answer subsumes previous marking point</p> <p>DO NOT ALLOW fraction: $\frac{238}{14415}$</p> <p>-----</p> <p>ALLOW ECF from incorrect rate equation. Examples are given below for 1st line of initial rates data. IF other rows have been used, then calculate the rate constant from data chosen.</p> <p>Example 1: 1st order with respect to H^+ $\text{rate} = k [\text{BrO}_3^-] [\text{Br}^-] [\text{H}^+]$ $k = \frac{\text{rate}}{[\text{BrO}_3^-][\text{Br}^-][\text{H}^+]}$</p> <p>OR $\frac{1.19 \times 10^{-5}}{(5.0 \times 10^{-2})(1.5 \times 10^{-1})(3.1 \times 10^{-1})} \checkmark$</p> $= 5.1 \times 10^{-3} \text{ OR } 5.12 \times 10^{-3} \checkmark \text{ dm}^6 \text{ mol}^{-2} \text{ s}^{-1} \checkmark$ <p>ALLOW $5.11827957 \times 10^{-3}$ and correct rounding to 5.1×10^{-3}</p> <p>-----</p> <p>Example 2: Zero order with respect to BrO_3^- $\text{rate} = k [\text{Br}^-] [\text{H}^+]^2$ $k = \frac{\text{rate}}{[\text{Br}^-][\text{H}^+]^2}$</p> <p>OR $\frac{1.19 \times 10^{-5}}{(1.5 \times 10^{-1})(3.1 \times 10^{-1})^2} \checkmark$</p> $= 8.3 \times 10^{-4} \text{ OR } 8.26 \times 10^{-4} \checkmark \text{ dm}^6 \text{ mol}^{-2} \text{ s}^{-1} \checkmark$ <p>ALLOW $8.255289629 \times 10^{-4}$ and correct rounding to 8.3×10^{-4}</p>
	Total	10	



Question	Expected answers	Marks	Additional guidance
6 a	<p>graph: Rate does not change with concentration AND zero-order with respect to I₂ ✓</p> <p>initial rates data: Mark independently</p> <p>When [(CH₃)₂CO] × 2, rate × 2 (2¹) ✓ 1st order with respect to (CH₃)₂CO ✓</p> <p>When [HCl] × 2.5, rate × 2.5 ✓ 1st order with respect to HCl ✓</p>		<p>ANNOTATIONS MUST BE USED</p> <p>ALLOW (straight) line with zero gradient AND zero-order ALLOW horizontal line AND zero-order IGNORE just 'constant line' OR just 'straight line' <i>also fits 1st order</i></p> <p>CARE with comparisons in opposite direction ALLOW [(CH₃)₂CO] × 0.5, rate × 0.5 (0.5¹)</p> <p>ALLOW [HCl] × 0.4, rate × 0.4 (0.4¹) ALLOW H⁺ for HCl</p> <p>CARE: Comparison of Experiments 1 and 3 may be valid despite BOTH concentrations changing</p>
	<p>Rate equation and rate constant:</p> <p>rate = k[(CH₃)₂CO(aq)] [HCl(aq)] ✓</p> $k = \frac{\text{rate}}{[(\text{CH}_3)_2\text{CO}(\text{aq})] [\text{HCl}(\text{aq})]} \text{ OR}$ $\frac{2.10 \times 10^{-9}}{(1.50 \times 10^{-3}) \times (2.00 \times 10^{-2})} \checkmark$ <p>= 7(.00) × 10⁻⁵ OR 0.00007(00) ✓</p> <p>units: dm³ mol⁻¹ s⁻¹ ✓</p>	9	<p>ALLOW ECF from incorrect orders In rate equation, square brackets are required</p> $\text{rate} = k[(\text{CH}_3)_2\text{CO}(\text{aq})][\text{HCl}(\text{aq})][\text{I}_2(\text{aq})]^0$ <p>ALLOW H⁺ for HCl IGNORE state symbols, even if wrong</p> <p>ALLOW ECF for units 'correct' for incorrect expression used to calculate k, e.g. <i>upside down or wrong orders</i></p> $\frac{[(\text{CH}_3)_2\text{CO}(\text{aq})] [\text{H}^+(\text{aq})]}{\text{rate}} \times \text{units: mol s dm}^{-3} \checkmark$



Question	Expected answers	Marks	Additional guidance
b	<p>step 1: $\text{H}_2(\text{g}) + \text{ICl}(\text{g}) \longrightarrow$ LHS of step 1 ✓</p> <p>$\longrightarrow \text{HCl}(\text{g}) + \text{HI}(\text{g})$</p> <p>step 2: $\text{HI}(\text{g}) + \text{ICl}(\text{g}) \longrightarrow \text{HCl}(\text{g}) + \text{I}_2(\text{g})$ products of step 1 AND step 2 ✓</p>	2	<p>State symbols NOT required</p> <p>2nd mark can ONLY be awarded provided that</p> <ul style="list-style-type: none">• 1st mark has been awarded• step 1 AND step 2 add up to the overall equation. <p>e.g. ALLOW $\longrightarrow \text{H}_2\text{ICl}(\text{g})$</p> <p>step 2: $\text{H}_2\text{ICl}(\text{g}) + \text{ICl}(\text{g}) \longrightarrow 2\text{HCl}(\text{g}) + \text{I}_2(\text{g})$</p> <p>In step 2, ALLOW inclusion of extra species on both sides of the equation only if they cancel, e.g. $\text{HI}(\text{g}) + \text{HCl}(\text{g}) + \text{ICl}(\text{g}) \longrightarrow 2\text{HCl}(\text{g}) + \text{I}_2(\text{g})$</p>
	Total	11	



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Question	Answer	Mark	Guidance
7 (a)	<p>FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = 8.3×10^4 OR 83333 award 2 marks THEN IF units are $\text{dm}^6 \text{mol}^{-2} \text{s}^{-1}$, award 1 further mark</p> $k = \frac{\text{rate}}{[\text{H}_2(\text{g})][\text{NO}(\text{g})]^2} \text{ OR } \frac{3.6 \times 10^{-2}}{(1.2 \times 10^{-2}) \times (6.0 \times 10^{-3})^2}$ <p>✓</p> $= 8.3 \times 10^4 \text{ OR } 83000 \text{ OR } 83333 \checkmark$ <p>units: $\text{dm}^6 \text{mol}^{-2} \text{s}^{-1}$ ✓</p>	2 1	<p>ALLOW 1 mark for 8.3×10^x with no working (power of 10 is error)</p> <p>ALLOW 2 SF up to calculator value of 8.33333333×10^4 correctly rounded</p> <p>ALLOW ECF for calculated answer from incorrectly rearranged k expression but not for units (Marked independently see below)</p> <p>ALLOW dm^6, mol^{-2} and s^{-1} in any order, eg $\text{mol}^{-2} \text{dm}^6 \text{s}^{-1}$ DO NOT ALLOW other units (Rate equation supplied on paper – not derived from data)</p>
(b) (i)	effect on rate $\times 2$ ✓	1	ALLOW 'doubles' OR rate = $7.2 \times 10^{-2} (\text{mol dm}^{-3} \text{s}^{-1})$
(ii)	effect on rate $\times \frac{1}{4}$ OR $\times 0.25$ ✓	1	ALLOW 'a quarter' OR decrease by $\frac{1}{4}$ OR decrease by 0.25 OR rate decreases by 4 OR decrease by 75% OR rate = $0.9 \times 10^{-2} (\text{mol dm}^{-3} \text{s}^{-1})$ DO NOT ALLOW just 0.5^2 of rate OR rate decreases by 2^2
(iii)	effect on rate $\times 64$ ✓	1	ALLOW rate = $2.3(04) (\text{mol dm}^{-3} \text{s}^{-1})$ DO NOT ALLOW just 'increases by 4 and then by 16 / 4^2 OR increases by 4^3



Question		Answer	Mark	Guidance
(c)	(i)	(initial) rate increases AND more frequent collisions OR more collisions per second/time ✓	1	BOTH points required for mark ALLOW rate increases AND concentration increases For concentration increases, ALLOW particles closer together OR less space between particles DO NOT ALLOW just more collisions OR collisions more likely
	(ii)	rate constant does not change ✓	1	
(d)		step 1: $\text{H}_2(\text{g}) + 2 \text{NO}(\text{g}) \longrightarrow \text{N}_2\text{O}(\text{g}) + \text{H}_2\text{O}(\text{g})$ LHS of step one ✓ step 2: $\text{H}_2(\text{g}) + \text{N}_2\text{O}(\text{g}) \longrightarrow \text{N}_2(\text{g}) + \text{H}_2\text{O}(\text{g})$ rest of equations for step 1 AND step 2 ✓	2	State symbols NOT required For 'rest of equations', This mark can only be awarded if 1st mark can be awarded ALLOW other combinations of two steps that together give the overall equation (shown above part in scoris window), eg step 1: $\longrightarrow \text{N}_2(\text{g}) + \frac{1}{2} \text{O}_2(\text{g}) + \text{H}_2\text{O}(\text{g})$ step 2: $\text{H}_2(\text{g}) + \frac{1}{2} \text{O}_2(\text{g}) \longrightarrow \text{H}_2\text{O}(\text{g})$ step 1: $\longrightarrow \text{H}_2\text{O}_2(\text{g}) + \text{N}_2(\text{g})$ step 2: $\text{H}_2(\text{g}) + \text{H}_2\text{O}_2(\text{g}) \longrightarrow 2\text{H}_2\text{O}(\text{l})$ There may be others with species, such as $\text{H}_2\text{N}_2\text{O}_2$ and HNO . Provided the two steps add up to give the overall equation AND charges balance, the 2nd mark can be awarded
Total			10	