<table>
<tr><th colspan="3">Question</th><th>Answer</th><th>Marks</th><th>Guidance</th></tr>
<tr><td>1</td><td>(a)</td><td></td><td>
NOTE: First 3 marks are ONLY available from an expression using $[NO]^2$
Units are marked independently

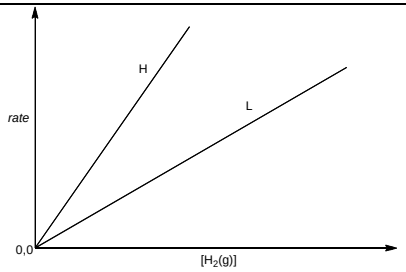
Using values ON THE CURVE in CORRECT expression 1 mark
Use of any two correct values for rate and [NO] from graph
e.g. for 5.0×10^{-4} and 4.2×10^{-4},
$k = \dfrac{4.2 \times 10^{-4}}{(2.0 \times 10^{-2}) \times (5.0 \times 10^{-4})^2}$
OR $4.2 \times 10^{-4} = k\,(2.0 \times 10^{-2}) \times (5.0 \times 10^{-4})^2$ ✓

Calculation of k 2 marks
FOR 1 MARK
k calculated correctly from values obtained from graph
BUT NOT in standard form AND/OR more than 2 SF
e.g. $k = \dfrac{6.0 \times 10^{-4}}{(2.0 \times 10^{-2}) \times (6.0 \times 10^{-4})^2} = 83333.33$ ✓
OR FOR 2 MARKS
k calculated correctly from values obtained from graph
AND in standard form AND TO 2 SF
e.g. k = 83333.33 gives 8.3×10^4 ✓

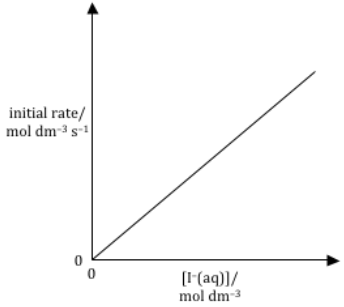
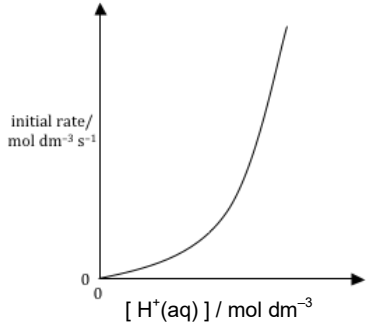
UNITS FOR 1 MARK:
$dm^6\ mol^{-2}\ s^{-1}$ ✓
</td><td>4</td><td>
Note: rate and [NO] are any correct pair of readings from the graph,
The [NO] below are the most commonly seen.
For these [NO] values, these are the ONLY rates allowed
<table>
<tr><th>[NO]</th><th>rate</th><th>k</th><th>k</th></tr>
<tr><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>
</table>
IF OTHER values are given, mark using the same principle. If any doubt, contact TL.
NOTE: IGNORE any numbers used from tangents

SPECIAL CASES that ALLOW ECF for calculation of k from ONLY ONE of the following (2 marks)
1. Powers of 10 incorrect or absent in initial k expression
2. $[H_2]^2[NO]$ used instead of $[H_2][NO]^2$
3. Any value within ±0.2 of actual values from graph

ALLOW units in any order, e.g. $mol^{-2}\ dm^6\ s^{-1}$
</td></tr>
</table>

Question			Answer	Marks	Guidance
	(b)	(i)	 One straight upward line **AND** starting at 0,0 ✓ 2nd straight upward line starting at 0,0 and steeper **AND** Steeper line labelled H **OR** less steep line labelled L ✓	**2**	**ALLOW** 1 mark for two upward sloping curves starting at origin **AND** upper curve labelled H and lower curve labelled L **NOTE: ALLOW** some leeway for lines starting from origin **ALLOW** straight line not drawn with ruler, i.e. is a straight line rather than a curve **ALLOW** similar labelling as long as it is clear which line is which
	(b)	(ii)	increases ✓	**1**	
	(c)		**MARK INDEPENDENTLY** **----------**  Downward curve ✓ Half life is constant ✓	**2**	**ALLOW** curve touching y axis **ALLOW** curve touching x axis **ALLOW** Two half lives are the same **IGNORE** 'regular' half life (not necessarily the same)

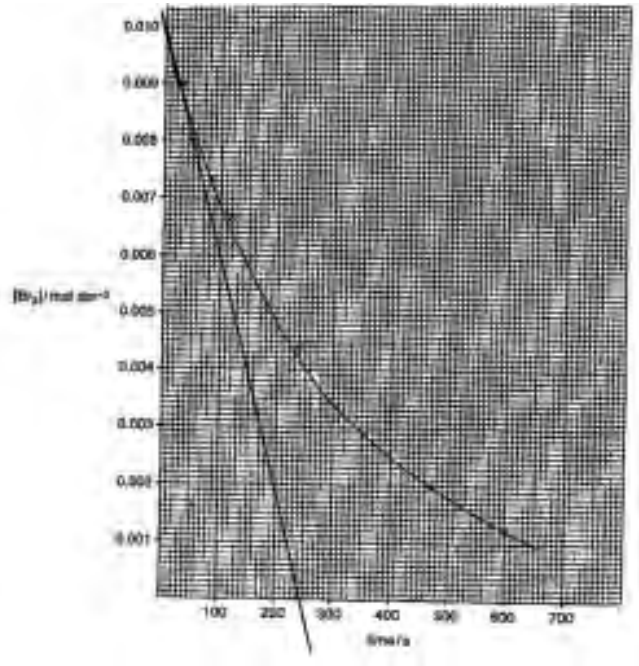
Question			Answer	Marks	Guidance
	(d)	(i)	$H_2 + N_2O \rightarrow N_2 + H_2O$ ✓	1	**ONLY** correct answer **DO NOT ALLOW** multiples
	(d)	(ii)	Steps 1 **AND** Step 2 together give $2NO + H_2$ ✓	1	**ALLOW** Step 1 **AND** Step 2 together give species in same ratio as in rate equation **ALLOW** rate-determining 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	

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.e. emphasis on particles)* **IGNORE** more reactants in overall equation **If number of species is stated, ALLOW 3–5 only** *(rate equation contains 5 ions)* **DO NOT ALLOW** negative ions would repel (*there is a mixture of positive and negative ions*) **IGNORE** more than two **reactants** collide (*not related to rate equation*)
	(b)		 Straight upward line **AND** starting at 0,0 ✓  Curve with increasing gradient, **AND** starting at 0,0 ✓	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)**	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF** answer = 6.7×10^8 **OR** 670000000 $dm^{12}\ mol^{-4}\ s^{-1}$, award **3 marks** **IF** answer = 6.7×10^8 **OR** 670000000 with incorrect units, award **2 marks** *k* to >2 SF: 666666666.7 ✓ **OR** *k* to 2 SF: 6.7×10^8 **OR** 670000000 ✓✓ units: $dm^{12}\ mol^{-4}\ s^{-1}$ ✓	**3**	**ALLOW ECF** from incorrect initial rates if 1st experimental results have **not** been used. **(Look to 4(c)(i) to check)** *i.e.* **IF** other rows have been used, then calculate the rate constant from data chosen. 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.e. 6.7×10^9 **OR** 6.7×10^7 **ALLOW** units in any order, e.g. $mol^{-4}\ dm^{12}\ s^{-1}$
	(c)	**(iii)**	(K_a =) $10^{-3.75}$ **OR** 1.78×10^{-4} ($mol\ dm^{-3}$) ✓ $[H^+]$ = $\sqrt{1.78\times10^{-4}\times0.0200}$ = 1.89×10^{-3} ($mol\ dm^{-3}$) ✓ initial rate = 6.7×10^8 x 0.01 x 0.015^2 x $(1.89 \times 10^{-3})^2$ = 5.33×10^{-3} to 5.38×10^{-3} ($mol\ dm^{-3}\ s^{-1}$) **OR** 5.3×10^{-3} to 5.4×10^{-3} ($mol\ dm^{-3}\ s^{-1}$) ✓ 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.	**3**	***FULL ANNOTATIONS MUST BE USED*** **----------** **For ALL marks, ALLOW 2 SF** up to calculator value correctly rounded $1.77827941 \times 10^{-4}$ **ALLOW** $\sqrt{10^{-3.75}\times0.0200}$ for first marking point **ALLOW** 1.88×10^{-3} ($mol\ dm^{-3}$) **ALLOW ECF** from calculated $[H^+(aq)]$ and calculated answer for *k* from **4(c)(ii)** e.g. If no square root taken, $[H^+]$ = 3.56 x 10^{-6} $mol\ dm^{-3}$ and *rate* = 1.91 x 10^{-8} **OR** 1.9 x 10^{-8} by **ECF**
			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 (≡ rate) halves
		(iii)	No change ✓	1	
	(b)	(i)	*Tangent* On graph, tangent drawn to curve at t ~ 40 s ✓ *Calculation of rate from the tangent drawn* e.g. rate = $\frac{5.2}{116}$ = 0.045 **OR** 4.5 x 10^{-2} ✓ *Units* mol dm^{-3} s^{-1} ✓ *Independent mark*	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** ±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)

Question			er	Marks	Guidance
	(b)	**(ii)**	$k = \frac{\text{answer to } \mathbf{(b)(i)}}{3.45}$ ✓ units: s^{-1} ✓ *Independent mark*	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 *Many will keep this value in calculator for **(b)(ii)*** **ALLOW** $k = \ln 2/t_{1/2} = 0.693$/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 ✓	1	**IGNORE** water does not affect the rate
			Total	**10**	

Question			er	Mark	Guidance
4			Evidence of at least two half-lives measured on graph **OR** within text (would need evidence of two half-lives) ✓ Any half-life value stated in range 180–220 s **OR** constant half-life ✓ 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* = $k[Br_2]$ Evidence of tangent on graph drawn to line at t = 0 s ✓ e.  	**4**	**ANNOTATE ALL Q3 WITH TICKS AND CROSSES, etc** **MARK ON GRAPH OR IN TEXT** **LOOK FOR STATEMENT ON GRAPH OR WITHIN TEXT** **ALLOW** almost constant half-life --- **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 mol dm^{-3} has twice the value of gradient of tangent at 0.005 mol dm^{-3} --- **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

Question			er	Mark	Guidance
			rate = $\frac{0.010}{250}$ = 0.000040 **OR** 4.0 x 10^{-5} ✓ units: mol dm^{-3} s^{-1} ✓	**2**	**ALLOW** values from 1 SF (0.00004 **OR** 4 x 10^{-5}) up to calculator value, correctly rounded **ALLOW** range ~ $\frac{0.010}{160}$ to $\frac{0.010}{300}$: i.e. **ALLOW** a calculated gradient in the range 6 x 10^{-5} – 3 x 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 = $k[Br_2]$ **OR** $k = \frac{rate}{[Br_2]}$ ✓ k = calculated result from $\frac{\text{calculated value for rate}}{0.010}$ ✓ units: s^{-1} ✓	**3**	**DO NOT ALLOW** *rate* = k[Br], *ie* Br instead of Br_2 **DO NOT ALLOW** just $k[Br_2]$, *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 x 10^{-3} 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 = $k[Br_2]^2$ k = calculated result from $\frac{\text{calculated value for rate}}{0.010^2}$ **units**: dm^3 mol^{-1} s^{-1} **OR** mol^{-1} dm^3 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**		$BrO_3^- + 5Br^- + 6H^+ \longrightarrow 3Br_2 + 3H_2O$ ✓	1	**ALLOW** multiples
	b		***graph:***	1	***ANNOTATIONS MUST BE USED*** **Both** explanation and 1st order required for mark
			Straight/diagonal line through origin **OR** 0,0 **AND** 1st order with respect to BrO_3^- ✓		**DO NOT ALLOW** diagonal line **OR** straight line **OR** constant gradient on its own (no mention of origin **OR** 0,0) **ALLOW** 'As BrO_3^- doubles, rate doubles' **AND** 1st order **ALLOW** rate is proportional to concentration **AND** 1st order
			initial rates data: When $[Br^-]$ is doubled, rate × 2 ✓ 1st order with respect to Br^- ✓ When $[H^+]$ × 2, rate × 4 (2^2) ✓ 2nd order with respect to H^+ ✓	4	Mark order and explanation independently Mark order first, then explanation
			Rate equation rate = $k\,[BrO_3^-]\,[Br^-]\,[H^+]^2$ ✓	1	**ALLOW** ECF from candidate's orders above

Question	Expected Answers	Marks	Additional Guidance
	Calculation of rate constant (3 marks)	3	***ANNOTATIONS MUST BE USED***
	$k = \frac{\text{te}}{[BrO_3^-][Br^-][H^+]^2}$		**Calculation can be from any of the experimental runs – they all give the same value of *k***
	OR $\frac{1.19 \times 10^{-5}}{(5.0 \times 10^{-2})(1.5 \times 10^{-1})(3.1 \times 10^{-1})^2}$ ✓		**ALLOW** $mol^{-3}\ dm^9\ s^{-1}$ **ALLOW** 1.6510579×10^{-2} and correct rounding to 1.7×10^{-2} **Correct numerical answer subsumes previous marking point**
	$= 1.7 \times 10^{-2}$ **OR** 1.65×10^{-2} ✓ $dm^9\ mol^{-3}\ s^{-1}$ ✓		**DO NOT ALLOW** fraction: $\frac{238}{14415}$ --- **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. --- **Example 1:** 1st order with respect to H^+ *rate* = $k\ [BrO_3^-]\ [Br^-]\ [H^+]$ $k = \frac{\text{rate}}{[BrO_3^-][Br^-][H^+]}$ **OR** $\frac{1.19 \times 10^{-5}}{(5.0 \times 10^{-2})(1.5 \times 10^{-1})(3.1 \times 10^{-1})}$ ✓ $= 5.1 \times 10^{-3}$ **OR** 5.12×10^{-3} ✓ $dm^6\ mol^{-2}\ s^{-1}$ ✓ **ALLOW** $5.11827957 \times 10^{-3}$ and correct rounding to 5.1×10^{-3} --- **Example 2:** Zero order with respect to BrO_3^- *rate* = $k\ [Br^-]\ [H^+]^2$ $k = \frac{\text{rate}}{[Br^-][H^+]^2}$ **OR** $\frac{1.19 \times 10^{-5}}{(1.5 \times 10^{-1})(3.1 \times 10^{-1})^2}$ ✓ $= 8.3 \times 10^{-4}$ **OR** 8.26×10^{-4} ✓ $dm^6\ mol^{-2}\ s^{-1}$ ✓ **ALLOW** $8.255289629 \times 10^{-4}$ and correct rounding to 8.3×10^{-4}
	Total	**10**	

Question			Expected answers	Marks	Additional guidance
6	a		***graph:*** Rate does not change with concentration **AND** zero-order with respect to I_2 ✓ ***initial rates data:*** Mark independently When $[(CH_3)_2CO]$ × 2, rate × 2 (2^1) ✓ 1st order with respect to $(CH_3)_2CO$ ✓ When [HCl] x 2.5, rate × 2.5 ✓ 1st order with respect to HCl ✓		***ANNOTATIONS MUST BE USED*** **ALLOW** (straight) line with zero gradient **AND** zero-order **ALLOW** horizontal line **AND** zero-order **IGNORE** just 'constant line' **OR** just 'straight line' *also fits 1st order* ***CARE** with comparisons in opposite direction* **ALLOW** $[(CH_3)_2CO]$ × 0.5, rate × 0.5 (0.5^1) **ALLOW** [HCl] × 0.4, rate × 0.4 (0.4^1) **ALLOW** H^+ for HCl **CARE:** Comparison of **Experiments 1** and **3** may be valid despite **BOTH** concentrations changing
			Rate equation and rate constant: rate = $k[(CH_3)_2CO(aq)]\,[HCl(aq)]$ ✓ $k = \dfrac{rate}{[(CH_3)_2CO(aq)]\,[HCl(aq)]}$ **OR** $\dfrac{2.10 \times 10^{-9}}{(1.50 \times 10^{-3}) \times (2.00 \times 10^{-2})}$ ✓ = 7(.00) × 10^{-5} **OR** 0.00007(00) ✓ units: $dm^3\ mol^{-1}\ s^{-1}$ ✓	**9**	**ALLOW ECF** from incorrect orders In rate equation, square brackets **are required** rate = $k[(CH_3)_2CO(aq)][HCl(aq)][I_2(aq)]^0$ **ALLOW** H^+ for HCl **IGNORE** state symbols, even if wrong **ALLOW ECF** for units 'correct' for incorrect expression used to calculate *k, e.g. upside down or wrong orders* $\dfrac{[(CH_3)_2CO(aq)]\,[H^+(aq)]}{rate}$ × units: mol s dm^{-3} ✓

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Question			Expected answers	Marks	Additional guidance
	b		**step 1**: $H_2(g)$ + ICl(g) ⟶ LHS of step 1 ✓ ⟶ HCl(g) + HI(g) **step 2**: HI(g) + ICl(g) ⟶ HCl(g) + $I_2(g)$ products of step 1 **AND** step 2 ✓	**2**	State symbols **NOT** required **2nd mark** can **ONLY** be awarded provided that • **1st mark** has been awarded • **step 1 AND step 2** add up to the overall equation. e.g. **ALLOW** ⟶ $H_2ICl(g)$ **step 2**: $H_2ICl(g)$ + ICl(g) ⟶ 2HCl(g) + $I_2(g)$ In **step 2**, **ALLOW** inclusion of extra species on **both** sides of the equation **only** if they cancel, e.g. HI(g) + HCl(g) + ICl(g) ⟶ 2HCl(g) + $I_2(g)$
			Total	**11**	

Question			Answer	Mark	Guidance
7	(a)		**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF** answer = 8.3×10^4 **OR** 83333 award **2 marks** **THEN IF** units are **dm^6 mol^{-2} s^{-1}**, award 1 further mark		
			$k = \frac{rate}{[H_2(g)]\,[NO(g)]^2}$ **OR** $\frac{3.6 \times 10^{-2}}{(1.2 \times 10^{-2}) \times (6.0 \times 10^{-3})^2}$ ✓		
			= 8.3×10^4 **OR** 83000 **OR** 83333 ✓	2	**ALLOW** 2 SF up to calculator value of 8.33333333×10^4 correctly rounded **ALLOW ECF** for calculated answer from incorrectly rearranged *k* expression but **not** for units (Marked independently see below)
			units: dm^6 mol^{-2} s^{-1} ✓	1	**ALLOW** dm^6, mol^{-2} and s^{-1} in any order, ***eg*** mol^{-2} dm^6 s^{-1} **DO NOT ALLOW** other units (Rate equation supplied on paper – **not** derived from data)
	(b)	(i)	*effect on rate* × 2 ✓	1	**ALLOW** 'doubles' **OR** *rate* = 7.2 x 10^{-2} (mol dm^{-3} s^{-1})
		(ii)	*effect on rate* × ¼ **OR** x 0.25 ✓	1	**ALLOW** 'a quarter' **OR** decrease by ¼ **OR** decrease by 0.25 **OR** rate decreases by 4 **OR** decrease by 75% **OR** *rate* = 0.9 × 10^{-2} (mol dm^{-3} s^{-1}) **DO NOT ALLOW** just 0.5^2 of rate **OR** rate decreases by 2^2
		(iii)	*effect on rate* × 64 ✓	1	**ALLOW** *rate* = 2.3(04) (mol dm^{-3} 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: $H_2(g) + 2\,NO(g) \longrightarrow N_2O(g) + H_2O(g)$ LHS of step one ✓ step 2: $H_2(g) + N_2O(g) \longrightarrow N_2(g) + H_2O(g)$ 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: $\longrightarrow N_2(g) + ½\,O_2(g) + H_2O(g)$ step 2: $H_2(g) + ½\,O_2(g) \longrightarrow H_2O(g)$ step 1: $\longrightarrow H_2O_2(g) + N_2(g)$ step 2: $H_2(g) + H_2O_2(g) \longrightarrow 2H_2O(l)$ There may be others with species, such as $H_2N_2O_2$ and HNO. Provided the two steps add up to give the overall equation **AND** charges balance, the 2nd mark can be awarded
			Total	**10**	