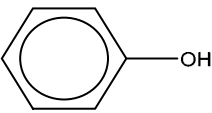
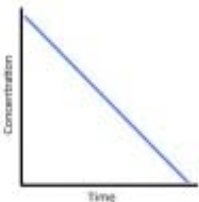


1.	measure volume / amount of oxygen formed / mass lost / and time / against time / per unit time OR measure absorbance / transmission against time / per unit time	1
	time taken for the concentration / mass / amount of a reactant to fall to half (its original value) / to halve	1
	$t_{1/2} = 150 \text{ s}$ AND evidence on graph / paper of one half-life	1
	no change	1
	M1: evidence on graph of tangent AND $4 \text{ to } 5 \times 10^{-4}$ M2: $\text{mol dm}^{-3} \text{ s}^{-1}$	2
2.	(c)(i) / $0.10 \text{ AND } \text{s}^{-1}$	1
	M1: $\text{NO}_2 + \text{O}_3 \rightarrow \text{NO}_3 + \text{O}_2$ M2: $\text{NO}_2 + \text{NO}_3 \rightarrow \text{N}_2\text{O}_5$ so it won't change / so it stays constant [1]	2 1
	constant half-life / both half-lives = 45–55 [1] two half-lives taken (evidence needed) [1]	2
	first order [1] any two rows of data quoted, effect of $[\text{H}_2]$ specified [1] effect of $[\text{I}_2]$ specified and linked to first order [1]	3
	rate = $k[\text{H}_2][\text{I}_2]$ [1]	1
	2×10^{-13} [1] $\text{mol}^{-1} \text{ dm}^3 \text{ s}^{-1}$ [1]	2
	forward reaction is faster than backward reaction and reaches equilibrium on product side / to the right [1]	1
	forward reaction is negative AND backward reaction is positive [1]	2
	equilibrium position further left at higher T [1] colorimetry / (change) in colour / less light transmission / measure absorbance	1
	Exp 1 and 2: rate $\times 1.75$ and $[\text{H}_2] \times 1.75$ (when $[\text{ICl}]$ no change) or calculation e.g.: order = $(0.007 / 0.004) / (1.75 / 1.00) = 1$ or Exp 1 and 3: rate $\times 2.5$ and $[\text{H}_2] \times 2.5$ (when $[\text{ICl}]$ no change) or Exp 2 and 3: rate $\times 10 / 7(1.43)$ and $[\text{H}_2] \times 10 / 7(1.43)$ (when $[\text{ICl}]$ no change)	1
3.	Exp 4 and 5: rate $\times 1.4$ and $[\text{ICl}] \times 1.4$ (when $[\text{H}_2]$ no change) or calculation (rate =) $k[\text{ICl}][\text{H}_2]$	1 1
	62 500 or 6.25×10^4	1
	$\text{ICl} + \text{H}_2 \rightarrow \text{HCl} + \text{HI}$ or $\text{ICl} + \text{H}_2 \rightarrow \text{IClH}_2$ or $\text{ICl} + \text{H}_2 \rightarrow \frac{1}{2}\text{I}_2 + \text{CH}_2$	1
	$\text{HI} + \text{ICl} \rightarrow \text{HCl} + \text{I}_2$ or $\text{IClH}_2 + \text{ICl} \rightarrow 2\text{HCl} + \text{I}_2$ or $\text{CH}_2 + \text{ICl} \rightarrow 2\text{HCl} + \frac{1}{2}\text{I}_2$	1

4.

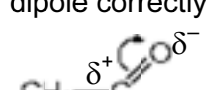
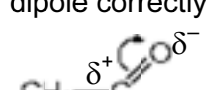
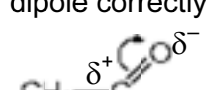
<p>part mark 1: plot a graph of concentration of $[H_2]$ against time</p> <p>part mark 2: constant half-life (showing it is 1st order)</p> <p>part mark 3: draw tangent AND determine gradient (on conc vs time graph) or draw two tangents to determine two gradients (rate) (on conc vs time graph)</p> <p>part mark 4: if conc 1 (at time 1) / conc 2 (at time 2) = gradient 1 / gradient 2</p> <p>part mark 5: plot a graph of rate against concentration of $[H_2]$</p> <p>part mark 6: gives a straight-line through the origin of graph for part mark 5</p> <p>2 parts = 1 mark 3 parts = 2 marks 4 parts = 3 marks</p>	3
[IC _l] doesn't change or [IC _l] only changes slightly	1
provides an alternative route of lower activation energy / E_a or to lower E_a and more molecules with $E \geq E_a$	1
the power to which a concentration of a reactant is raised in the rate equation / law	1
M1: (using expt 1 and 3) as $[ClO_2] \times 2.5$ rate $\times 6.25$ so 2nd order	2
M2: (using expt 1 and 2) as $[OH^-] \times 4$ rate $\times 4$ so 1st order	
rate = $k[ClO_2]^2[OH^-]$	1
M1: $k = \text{rate} / [ClO_2]^2[OH^-]$ $k = 7.20 \times 10^{-4} / (0.02)^2(0.03)$ $k = 60$ M2: $\text{mol}^{-2} \text{dm}^6 \text{min}^{-1}$	2
<div style="text-align: center;">  </div> <p>structure of phenol: C_6H_5OH OR</p>	1
tangent drawn correctly AND rate = $0.015 / 260 = 5.8 \times 10^{-5}$ ALLOW values consistent with tangent drawn at 100 sec	1
<div style="text-align: center;">  </div> <p>AND half-life decreases (1st box)</p>	1

5.

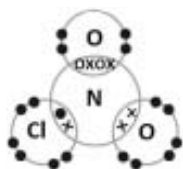
change in amount / mass / concentration of reactant / product per time	1
decrease in volume or pressure	1
$8.13 \times 10^4 / 81280 / 81300$	1
$\text{mol}^{-2} \text{dm}^6 \text{s}^{-1}$	1
$\sqrt{(0.00231 / (0.0046 \times 81280))} = 2.49 \times 10^{-3}$	1
2, 1, 3	1
2	1
the total of steps 1 and 2 / the components of 2 are two NO and one H ₂	1
time for amount or mass or concentration to halve	1
0.02 at start and 0.01 after 2 seconds	1
0.005 after 4 seconds and 0.0025 after 6 seconds	1
NO + $\frac{1}{2}$ O ₂ → NO ₂ or NO + O ₂ → NO ₂ + $\frac{1}{2}$ O ₂ AND NO ₂ + SO ₂ → NO + SO ₃	1
(NO is) regenerated / reformed	1

6.

SO ₃ + H ₂ O → H ₂ SO ₄ AND acid rain or consequence of this described	1						
<table border="1"> <tr> <td>the order of reaction with respect to [NO]</td><td>2</td></tr> <tr> <td>the order of reaction with respect to [O₂]</td><td>1</td></tr> <tr> <td>the overall order of reaction</td><td>3</td></tr> </table>	the order of reaction with respect to [NO]	2	the order of reaction with respect to [O ₂]	1	the overall order of reaction	3	1
the order of reaction with respect to [NO]	2						
the order of reaction with respect to [O ₂]	1						
the overall order of reaction	3						
ALL CORRECT [1]							
$k = (1.51 \times 10^{-4}) / (0.003^2 \times 0.00200)$ $k = \mathbf{8389}$ [1] min 2sf $\text{mol}^{-2} \text{dm}^6 \text{s}^{-1}$ [1]	2						
$8400 = (6.05 \times 10^{-5}) / (x^2 \times 0.005)$ $x = \sqrt{(6.05 \times 10^{-5}) / (8400 \times 0.005)}$ $x = \mathbf{0.00120 / 1.20 \times 10^{-3}}$ [1] min 2sf ecf from Q1bi	1						
slow(est) [1]	1						
correct RDS identified as step 1 with <u>only</u> one S ₂ O ₈ ²⁻ and one I ⁻ [1] overall mechanism adds up to chemical equation and no cancellable species on LHS / RHS in each of the equations [1] M2 DEP on one S ₂ O ₈ ²⁻ and one I ⁻ in step 1 e.g. step 1 S ₂ O ₈ ²⁻ + I ⁻ → SO ₄ ²⁻ + SO ₄ I ⁻ RDS = step 1 step 2 SO ₄ I ⁻ + I ⁻ → SO ₄ ²⁻ + I ₂	2						
no. of $t_{1/2} = 192 / 48 = 4$ $[I^-] = 0.0078 / 16 = \mathbf{4.9 \times 10^{-4}}$ [1] min 2sf	1						

7.	$\text{CH}_3\text{COCH}_3 = 1$ $\text{I}_2 = 0$ $\text{H}^+ = 1$ overall order = 2 M1 3 orders [1] M2 overall order based on their M1 [1]	2																											
	$k = 5.40 \times 10^{-3} / (1.50 \times 10^{-2} \times 7.75 \times 10^{-1})$ $k = \mathbf{0.46(452)}$ [1] $\text{dm}^3 \text{mol}^{-1} \text{s}^{-1}$ [1] 2sf min	2																											
	<table><tr><td></td><td>decreases</td><td>no change</td><td>increases</td></tr><tr><td>rate constant</td><td>✓</td><td></td><td></td></tr><tr><td>rate of reaction</td><td>✓</td><td></td><td></td></tr></table> <div>both [1]</div>		decreases	no change	increases	rate constant	✓			rate of reaction	✓			1															
	decreases	no change	increases																										
rate constant	✓																												
rate of reaction	✓																												
	draw a tangent at time, $t=0$ [1] measure the gradient / slope of the tangent [1]	2																											
	straight line graph starting at 0,0 and showing rate $\propto [\text{CH}_3\text{COCH}_3]$ [1]	1																											
	slowest step / reaction (in the mechanism) [1]	1																											
	$2\text{Ce}^{4+} + \text{Tl}^+ \rightarrow \text{Tl}^{3+} + 2\text{Ce}^{3+}$ [1] catalyst and (used in step 1 and) regenerated / reformed in step 3 / end of the reaction [1]	2																											
8.	<table><tr><td>4 (a) (i)</td><td>1st order</td><td>1</td></tr><tr><td>(ii)</td><td>1st order</td><td>1</td></tr><tr><td>(iii)</td><td>rate = $k[\text{CH}_3\text{CHO}][\text{OH}^-]$</td><td>1</td></tr><tr><td>(iv)</td><td>$\text{mol}^{-1} \text{dm}^3 \text{s}^{-1}$ (or per any suitable time unit)</td><td>1</td></tr><tr><td>(v)</td><td>calculation from candidate's answer to (iii) (expected answer = 6)</td><td>1</td></tr><tr><td>(b) (i)</td><td>rate-determining step: step 1 explanation: both reactant species are in step 1 / rate-determining step</td><td>1 1</td></tr><tr><td>(ii)</td><td>acid / proton donor / acidic behaviour</td><td>1</td></tr><tr><td>(c)</td><td>nucleophilic addition</td><td>1</td></tr><tr><td>(d)</td><td>M1: both curly arrows M2: dipole correctly shown </td><td>1 1</td></tr></table>	4 (a) (i)	1 st order	1	(ii)	1 st order	1	(iii)	rate = $k[\text{CH}_3\text{CHO}][\text{OH}^-]$	1	(iv)	$\text{mol}^{-1} \text{dm}^3 \text{s}^{-1}$ (or per any suitable time unit)	1	(v)	calculation from candidate's answer to (iii) (expected answer = 6)	1	(b) (i)	rate-determining step: step 1 explanation: both reactant species are in step 1 / rate-determining step	1 1	(ii)	acid / proton donor / acidic behaviour	1	(c)	nucleophilic addition	1	(d)	M1: both curly arrows M2: dipole correctly shown 	1 1	
4 (a) (i)	1 st order	1																											
(ii)	1 st order	1																											
(iii)	rate = $k[\text{CH}_3\text{CHO}][\text{OH}^-]$	1																											
(iv)	$\text{mol}^{-1} \text{dm}^3 \text{s}^{-1}$ (or per any suitable time unit)	1																											
(v)	calculation from candidate's answer to (iii) (expected answer = 6)	1																											
(b) (i)	rate-determining step: step 1 explanation: both reactant species are in step 1 / rate-determining step	1 1																											
(ii)	acid / proton donor / acidic behaviour	1																											
(c)	nucleophilic addition	1																											
(d)	M1: both curly arrows M2: dipole correctly shown 	1 1																											
9.	measure volume / amount of oxygen formed / mass lost / and time / against time / per unit time OR measure absorbance / transmission against time / per unit time	1																											
	time taken for the concentration / mass / amount of a reactant to fall to half (its original value) / to halve	1																											
	$t_{1/2} = 150 \text{ s}$ AND evidence on graph / paper of one half-life	1																											
	no change	1																											
	M1: evidence on graph of tangent AND 4 to 5×10^{-4} M2: $\text{mol dm}^{-3} \text{s}^{-1}$	2																											
	(c)(i) / 0.10 AND s^{-1}	1																											
	M1: $\text{NO}_2 + \text{O}_3 \rightarrow \text{NO}_3 + \text{O}_2$ M2: $\text{NO}_2 + \text{NO}_3 \rightarrow \text{N}_2\text{O}_5$	2																											

10



M1: eight electrons around N atom [N=O, N-O, N-Cl with N-O as dative]

M2: all other electrons correct

(rate =) $k[\text{ClNO}_2][\text{NO}]$

$\text{mol}^{-1} \text{dm}^3 \text{s}^{-1}$

Yes **AND** number of moles of reactants in overall equation is the same as order in rate equation

- straight line with a negative gradient
- starting at 2.0×10^{-4}
- reaches at 1.8×10^{-4} at 0.2 seconds

Award 1 mark for two points, award 2 marks for all three points

$2 \times 10^{-5} (\text{mol dm}^{-3})$

The reaction has reached equilibrium

2

1

1

1

2

1

1