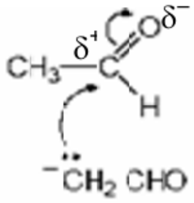
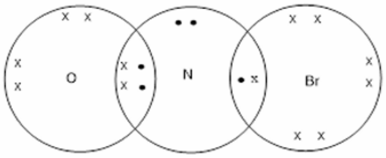
1.

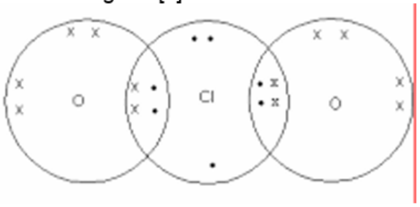
Question	Answer	Mark
4 (a) (i)	1st order	**1**
(ii)	1st order	**1**
(iii)	rate = $k[CH_3CHO][OH^-]$	**1**
(iv)	$mol^{-1}\,dm^3\,s^{-1}$ (or per any suitable time unit)	**1**
(v)	calculation from candidate's answer to **(iii)** (expected answer = 6)	**1**
(b) (i)	rate-determining step: step 1 explanation: 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**

2.

Question	Answer	Marks
1(a)	N +2 to +3 (and oxidised)	**1**
	Br_2 / Br 0 to –1 (and reduced)	**1**
1(b)		
	3 bonding pairs around N (in a structure involving NOBr)	**1**
	rest of molecule correct	**1**
1(c)(i)	the **power** to which a concentration of a reactant is raised in the **rate equation**	**1**
1(c)(ii)	using expt. 2 and 3 a = 2 **or** [NO] 2nd order **and** conc × 3 rate × 9 **or** $6.1 \times 10^{-2} / 6.8 \times 10^{-3} = (0.09 / 0.03)^a$	**1**
	using expt. 1 and 2 b = 1 **or** $[Br_2]$ 1st order **and** conc × 2 rate × 2 **or** $6.8 \times 10^{-3} / 3.4 \times 10^{-3} = (0.04 / 0.02)^b$	**1**
(c)(iii)	initial rate = 0.16(32)	**1**
1(c)(iv)	$(0.0034 = k(0.03)^2(0.02))$ k **= 188.9**	**1**
	$mol^{-2}\,dm^6\,s^{-1}$	**1**
1(c)(v)	*k* decreases (as rate decreases)	**1**

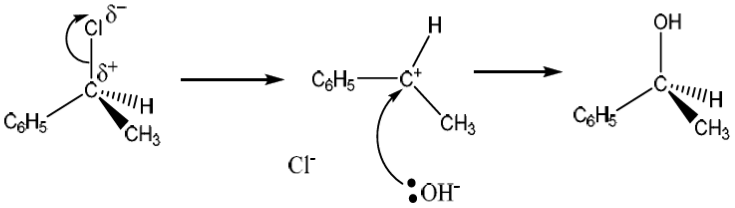
Question	Answer	Marks
1(d)	m = 2 **and** n = 0	**1**

3.

Question	Answer	Marks
1(a)	Cl +3 to +4 (and oxidised)	**1**
	Cl 0 to –1 (and reduced)	**1**
1(b)	19 electrons total [1] correct diagram [1] 	**2**
1(c)(i)	the exponent / power to which a concentration is raised in the rate equation	**1**
1(c)(ii)	(0.0022 = k (0.01) × (0.06)) k = 3.7 (3.67)	**1**
	$mol^{-1}\ dm^{3}\ s^{-1}$	**1**
1(c)(iii)	initial rate = 5.50×10^{-3}	**1**
	[ClO_2] = 0.048	**1**
1(d)(i)	slowest step (in a multi-step reaction)	**1**
1(d)(ii)	1 mole of F_2 and 1 mole ClO_2 reacting in the rate-determining step	**1**
	1st step is rate-determining step **and** a balanced mechanism consistent with overall equation e.g. $ClO_2 + F_2 \rightarrow ClO_2F_2$ $ClO_2 + ClO_2F_2 \rightarrow 2ClO_2F$ **or** $ClO_2 + F_2 \rightarrow ClO_2F + F$ $ClO_2 + F \rightarrow ClO_2F$	**1**
1(e)	k increases (as rate increases)	**1**

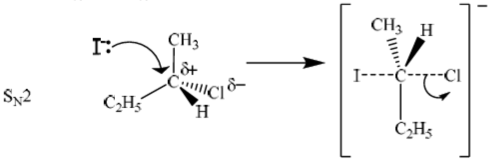
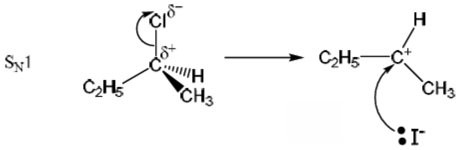
4.

Question	Answer	Marks
6(a)	Any of the three methods possible. Any 4 of the 5 points for each method available for maximum 4 marks. Method 1 1 Ensure both solutions (**A** and **B)** at 40 °C before mixing 2 mix known volumes of **A** and **B** and start the clock 3 at known time take out a sample / **X** and add it to ice-cold solvent 4 titrate against HCl 5 repeat at time at known time intervals Method 2 1 Ensure both solutions (**A** and **B)** at 40 °C before mixing 2 mix known volumes of **A** and **B** and start the clock 3 at known time pour into ice-cold solvent or pour ice-cold solvent in 4 titrate against HCl 5 repeat with different concentrations of either A or B, or repeat using different times Method 3 1 Ensure both solutions (**A** and **B)** at 40 °C before mixing 2 mix known volumes of **A** and **B** and start the clock and add pH meter 3 at a known time . . . . 4 . . . . record the pH 5 repeat pH readings at known time intervals	**4**
6(b)(i)	from 1 and 3: when [RCl] is trebled, so is rate, so order w.r.t. [RCl] = 1	**1**
	from 1 and 2: when both concentrations are doubled, rate doubles so [OH^-] has no effect on rate, so order w.r.t.[OH^-] = 0	**1**
6(b)(ii)	rate = k[RCl] AND units: sec^{-1} 1 / s	**1**
6(b)(iii)	relative rate = 2.0	**1**

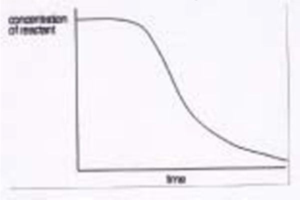
Question	Answer	Marks
6(c)(i)	 C-C*l* dipole and first curly arrow	1
	intermediate cation	1
	OH^- with lone pair and curly arrow	1
6(c)(ii)	Beginning with candidate's mechanism in (c)(i): **If S_N1:** racemate / mixture of / two optical isomers will be formed, because: the intermediate is planar / has a plane of symmetry / OH^- can approach from top or bottom or from any direction **If S_N2:** one optical isomer because attack always from fixed direction / from same side / the "configuration" always inverts / there is an asymmetric transition state	1

5.

2(c)(i)	[R-C*l*]: rate increases by 5 / 3 when concentration increases by 10 / 6 (5 / 3), so order = 1	1
	$[I^-]$: rate increases by 5 / 3 when concentration increases by 5 / 3, so order = 1	1
2(c)(ii)	rate = $k[I^-][CH_3CH_2CHClCH_3]$ AND units of k = $dm^3\ mol^{-1}\ s^{-1}$	1
2(c)(iii)	relative rate = 5 / 5.3	1

Question	Answer	Marks
2(d)(i)	either S_N1 or S_N2 mechanism  	
	C-C*l* dipole AND C-C*l* curly arrow	1
	intermediate cation OR 5-valent transition state (charge essential)	1
	I^- with lone pair AND other curly arrow	1
2(d)(ii)	If S_N1 in 2(d)(i) **mixture of / two** optical isomers will be formed, AND the intermediate can be formed by the I^- approaching from top or bottom plane If S_N2 in 2(d)(i) **one optical isomer** AND attack always from fixed direction / opposite side	1

6.

<table>
<tr><th>Question</th><th>Answer</th><th>Marks</th></tr>
<tr><td rowspan="3">4(a)(i)</td><td>experiments 1 and 2: doubling [ClO_2] quadruples the rate, so second order</td><td>**1**</td></tr>
<tr><td>experiments 2 and 3: doubling [OH^-] doubles the rate, so first order</td><td>**1**</td></tr>
<tr><td>rate equation = $k[ClO_2]^2[OH^-]$</td><td>**1**</td></tr>
<tr><td rowspan="2">4(a)(ii)</td><td>from experiment t 2: $9.34 \times 10^{-4} = k(2.50 \times 10^{-2})^2 \times 1.30 \times 10^{-3}$
$k = 1.15 \times 10^3$</td><td>**1**</td></tr>
<tr><td>units: $mol^{-2} dm^6 s^{-1}$</td><td>**1**</td></tr>
<tr><td>4(b)(i)</td><td>heterogeneous catalysts are in different physical state from the reactants **AND** homogeneous catalysts are in the same physical state as the reactants</td><td>**1**</td></tr>
<tr><td>4(b)(ii)</td><td>
<table>
<tr><th>catalysed reaction</th><th>heterogeneous</th><th>homogeneous</th></tr>
<tr><td>manufacture of ammonia in the Haber process</td><td>✓</td><td></td></tr>
<tr><td>removal of nitrogen oxides from car exhausts</td><td>✓</td><td></td></tr>
<tr><td>oxidation of sulfur dioxide in the atmosphere</td><td></td><td>✓</td></tr>
</table>
</td><td>**2**</td></tr>
<tr><td>4(c)(i)</td><td>$2MnO_4^- + 6H^+ + 5(CO_2H)_2 \rightarrow 2Mn^{2+} + 10\ CO_2 + 8\ H_2O$
correct Mn : $(CO_2H)_2$ ratio
rest of equation</td><td>**2**
1
1</td></tr>
<tr><td>4(c)(ii)</td><td>first section: flatter
second section: steeper, before flattening

</td><td>**2**
1
1</td></tr>
</table>

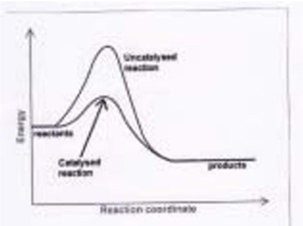
<table>
<tr><th>Question</th><th>Answer</th><th>Marks</th></tr>
<tr><td>,4(d)(i)</td><td>

diagram
catalyst lowers E_a for both the forward and reverse reactions
so the process requires less energy / can occur at a lower temperature</td><td>**3**
1
1
1</td></tr>
<tr><td rowspan="2">4(d)(ii)</td><td>$K_p = (pNH_3)^2/(pN_2)(pH_2)^3$
$1.45 \times 10^{-5} = (pNH_3)^2 / 20 \times 60 \times 60 \times 60$</td><td>**1**</td></tr>
<tr><td>$pNH_3 = 7.91$</td><td>**1**</td></tr>
</table>

7.

Question	Answer	Marks
2(a)	change in amount / mass / concentration of reactant / product per time	**1**
2(b)	decrease in volume or pressure	**1**
2(c)	8.13×10^4 / 81280 / 81300	**1**
	$mol^{-2}\ dm^6\ s^{-1}$	**1**
2(d)	$\sqrt{}(0.00231 / (0.0046 \times 81280))\ = 2.49 \times 10^{-3}$	**1**
2(e)	2, 1, 3	**1**
2(f)(i)	2	**1**
2(f)(ii)	the total of steps 1 and 2 / the components of 2 are two NO and one H_2	**1**
2(g)(i)	time for amount or mass or concentration to halve	**1**
2(g)(ii)	0.02 at start and 0.01 after 2 seconds	**1**
	0.005 after 4 seconds and 0.0025 after 6 seconds	**1**
2(h)(i)	$NO + \frac{1}{2} O_2 \rightarrow NO_2$ **or** $NO + O_2 \rightarrow NO_2 + \frac{1}{2} O_2$ **AND** $NO_2 + SO_2 \rightarrow NO + SO_3$	**1**
2(h)(ii)	(NO is) regenerated / reformed	**1**
2(h)(iii)	$SO_3 + H_2O \rightarrow H_2SO_4$ **AND** acid rain or consequence of this described	**1**

8.

Question	Answer	Marks
2(a)	colorimetry / (change) in colour / less light transmission / measure absorbance	**1**
2(b)	Exp 1 and 2: rate × 1.75 and [H_2] × 1.75 (when [$\mathrm{IC}l$] no change) **or** calculation e.g.: order = (0.007 / 0.004) / (1.75 / 1.00) = 1 **or** Exp 1 and 3: rate × 2.5 and [H_2] × 2.5 (when [$\mathrm{IC}l$] no change) **or** Exp 2 and 3: rate × 10 / 7(1.43) and [H_2] × 10 / 7(1.43) (when [$\mathrm{IC}l$] no change)	**1**
2(c)	Exp 4 and 5: rate × 1.4 and [$\mathrm{IC}l$] × 1.4 (when [H_2] no change) **or** calculation	**1**
2(d)	(rate=) k[$\mathrm{IC}l$][H_2]	**1**
2(e)	62 500 **or** 6.25×10^4	**1**
2(f)	$\mathrm{IC}l + H_2 \rightarrow \mathrm{HC}l + \mathrm{HI}$ **or** $\mathrm{IC}l + H_2 \rightarrow \mathrm{IC}lH_2$ **or** $\mathrm{IC}l + H_2 \rightarrow \frac{1}{2}I_2 + \mathrm{C}lH_2$	**1**
	$\mathrm{HI} + \mathrm{IC}l \rightarrow \mathrm{HC}l + I_2$ **or** $\mathrm{IC}lH_2 + \mathrm{IC}l \rightarrow 2\mathrm{HC}l + I_2$ **or** $\mathrm{C}lH_2 + \mathrm{IC}l \rightarrow 2\mathrm{HC}l + \frac{1}{2}I_2$	**1**

Question	Answer	Marks
2(g)(i)	part mark 1: plot a graph of concentration of $[H_2]$ against time part mark 2: constant half-life (showing it is 1st order) 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) part mark 4: if conc 1 (at time 1) / conc 2 (at time 2) = gradient 1 / gradient 2 part mark 5: plot a graph of rate against concentration of $[H_2]$ part mark 6: gives a straight-line through the origin of graph for part mark 5 2 parts = 1 mark 3 parts = 2 marks 4 parts = 3 marks	**3**
2(g)(ii)	$[ICl]$ doesn't change ***or*** $[ICl]$ only changes slightly	**1**
2(h)	provides an alternative route of lower activation energy / E_a **or** to lower E_a and more molecules with $E \geqslant E_a$	**1**

9.

Question	Answer	Marks
2(a)	change in amount / mass / concentration of reactant / product per time	**1**
2(b)	decrease in volume or pressure	**1**
2(c)	8.13×10^4 / 81280 / 81300	**1**
	$mol^{-2}\,dm^6\,s^{-1}$	**1**
2(d)	$\sqrt{}(0.00231 / (0.0046 \times 81280)) = 2.49 \times 10^{-3}$	**1**
2(e)	2, 1, 3	**1**
2(f)(i)	2	**1**
2(f)(ii)	the total of steps 1 and 2 / the components of 2 are two NO and one H_2	**1**
2(g)(i)	time for amount or mass or concentration to halve	**1**
2(g)(ii)	0.02 at start and 0.01 after 2 seconds	**1**
	0.005 after 4 seconds and 0.0025 after 6 seconds	**1**
2(h)(i)	$NO + \frac{1}{2} O_2 \rightarrow NO_2$ **or** $NO + O_2 \rightarrow NO_2 + \frac{1}{2} O_2$ **AND** $NO_2 + SO_2 \rightarrow NO + SO_3$	**1**
2(h)(ii)	(NO is) regenerated / reformed	**1**
2(h)(iii)	$SO_3 + H_2O \rightarrow H_2SO_4$ **AND** acid rain or consequence of this described	**1**

10.

Question	Answer	Marks
2(a)	 **M1:** eight electrons around N atom [N=O, N-O, N-Cl with N-O as dative] **M2:** all other electrons correct	**2**
2(b)(i)	(rate =) k[ClNO$_2$][NO]	**1**
2(b)(ii)	mol^{-1} dm^3 s^{-1}	**1**
2(b)(iii)	Yes **AND** number of moles of reactants in overall equation is the same as order in rate equation	**1**
2(c)(i)	• 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**
2(c)(ii)	2×10^{-5} (mol dm^{-3})	**1**
2(c)(iii)	The reaction has reached equilibrium	**1**

11.

Question	Answer	Marks
2(a)	**M1:** the time taken for the amount/concentration or a reactant to halve **M2:** the slowest step	**2**
2(b)	• Use an excess of CH_3Br • (Several experiments with) different initial [OH] • control / equilibrate temperatures • measure time • find [OH$^-$] by sample and titrate or use of pH probe **or** find [Br$^-$] by sample and reference to use of Ag$^+$. • processing of results – plot graph of [OH$^-$] vs rate or evaluate rate is proportional to [OH$^-$] numerically Alternative approach: • Use an excess of CH_3Br • One experiment with known initial [OH$^-$] • control / equilibrate temperatures • measure time • find [OH$^-$] by sample and titrate or use of pH probe **or** find [Br$^-$] by sample and reference to use of Ag$^+$ and describes how to calculate [OH$^-$] . • processing of results – plot graph of [OH$^-$] vs time and look for constant half-life Award 1 mark for each correctly identified point.	**4**

Question	Answer	Marks
2(c)	**M1:** rate = k[ester][OH$^-$] **M2:** value of k = 0.206 **M3:** units mol^{-1}dm^{3}s^{-1}	**3**

12.

Question	Answer	Marks
5(a)(i)	**M1**: using expt 2 and 3, $[NH_3]$ × 2, rate × 4 so order with respect to $[NH_3]$ = 2 **M2**: using expt 1 and 2, $[ClO^-]$ × 2 and $[NH_3]$ × 2, as rate × 8 (=2^2 * x) so order with respect to $[ClO^-]$ = 1	**2**
5(a)(ii)	rate = $k[NH_3]^2[ClO^-]$	**1**
5(a)(iii)	**M1:** $k = 0.256 / (0.200 \times 0.100^2)$ $k = 128$ **M2:** Units dm^6 mol^{-2} s^{-1}	**2**

Question	Answer	Marks
5(a)(iv)	curve / line showing *k* increasing as temperature increases	**1**
5(b)(i)	**M1:** plot a graph of $[I^-]$ against time **M2:** constant half-lives	**2**
5(b)(ii)	$ClO^- + I^- \rightarrow IO^- + Cl^-$	**1**
5(b)(iii)	step 2 **and** Cl is reduced / oxid no. decreases / oxid no. +1 → –1 ***or*** step 2 **and** I is oxidised / oxid no. increases / oxid no. –1 → +1	**1**

13.

<table>
<tr><th>Question</th><th>Answer</th><th>Marks</th></tr>
<tr><td>4(a)</td><td>CH_3COCH_3 = 1
I_2 = 0
H^+ = 1
overall order = 2 M1 3 orders [1] M2 overall order based on their M1 [1]</td><td>2</td></tr>
<tr><td>4(b)(i)</td><td>k = $5.40 \times 10^{-3} / (1.50 \times 10^{-2} \times 7.75 \times 10^{-1})$
k = 0.46(452) [1] dm^3 mol^{-1} s^{-1} [1] 2sf min</td><td>2</td></tr>
<tr><td>4(b)(ii)</td><td><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>
both [1]</td><td>1</td></tr>
<tr><td>4(c)</td><td>draw a tangent at time, t=0 [1]
measure the gradient / slope of the tangent [1]</td><td>2</td></tr>
<tr><td>4(d)</td><td>straight line graph starting at 0,0 and showing rate α $[CH_3COCH_3]$ [1]</td><td>1</td></tr>
<tr><td>4(e)(i)</td><td>slowest step / reaction (in the mechanism) [1]</td><td>1</td></tr>
<tr><td>4(e)(ii)</td><td>$2Ce^{4+} + Tl^{+} \rightarrow Tl^{3+} + 2Ce^{3+}$ [1]
catalyst and (used in step 1 and) regenerated / reformed in step 3 / end of the reaction [1]</td><td>2</td></tr>
</table>

14.

1(d)(i)	**M1** from 3rd and 1st rows as [NO] × 2 , rate increases × 4, so order = 2 **M2** from 3rd and 2nd rows as $[O_2]$ × 2, rate also × 2, so order = 1	**2**
1(d)(ii)	rate = $k[NO]^2[O_2]$ k = rate / ($[NO]^2[O_2]$) = 3.5 / (0.01 × 0.05) = 7000 units: mol^{-2} dm^6 s^{-1}	**3**

15.

<table>
<tr><th>Question</th><th>Answer</th><th>Marks</th></tr>
<tr><td>1(a)</td><td><table><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>
ALL CORRECT [1]</td><td>**1**</td></tr>
<tr><td>1(b)(i)</td><td>$k = (1.51 \times 10^{-4}) / (0.003^2 \times 0.00200)$
k = **8389** [1] min 2sf

$mol^{-2}\ dm^6\ s^{-1}$ [1]</td><td>**2**</td></tr>
<tr><td>1(b)(ii)</td><td>$8400 = (6.05 \times 10^{-5}) / (x^2 \times 0.005)$
$x = \sqrt{}\ (6.05 \times 10^{-5}) / (8400 \times 0.005)$
x = **0.00120** / **1.20** × $\mathbf{10^{-3}}$ [1] min 2sf ecf from Q1bi</td><td>**1**</td></tr>
<tr><td>1(c)</td><td>slow(est) [1]</td><td>**1**</td></tr>
<tr><td>1(d)(i)</td><td>**correct RDS identified** as step 1 with **only one** $\mathbf{S_2O_8^{2-}}$ and **one** $\mathbf{I^-}$ [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 $S_2O_8^{2-}$ and one I^- in step 1
e.g. step 1 $S_2O_8^{2-} + I^- \rightarrow SO_4^{2-} + SO_4I^-$ RDS = step 1
step 2 $SO_4I^- + I^- \rightarrow SO_4^{2-} + I_2$</td><td>**2**</td></tr>
<tr><td>1(d)(ii)</td><td>no. of $t_{1/2}$ = 192 / 48 = 4
$[I^-]$ = 0.0078 / 16 = **4.9** × $\mathbf{10^{-4}}$ [1] min 2sf</td><td>**1**</td></tr>
</table>

16.

Question	Answer	Marks
1(a)(i)	so it won't change / so it stays constant [1]	**1**
1(a)(ii)	constant half-life / both half-lives = 45–55 [1] two half-lives taken (evidence needed) [1]	**2**
1(b)(i)	first order [1] any two rows of data quoted, effect of $[H_2]$ specified [1] effect of $[I_2]$ specified and linked to first order [1]	**3**
1(b)(ii)	rate = $k[H_2][I_2]$ [1]	**1**
1(b)(iii)	2×10^{-13} [1] $mol^{-1}\ dm^3\ s^{-1}$ [1]	**2**
1(c)(i)	forward reaction is faster than backward reaction **and** reaches equilibrium on product side / to the right [1]	**1**
1(c)(ii)	forward reaction is negative **AND** backward reaction is positive [1] equilibrium position further left at higher T [1]	**2**

17.

9(c)(i)	slowest step in overall reaction	**1**
9(c)(ii)	$H_2O_2 + 2H^+ + 2I^- \rightarrow I_2 + 2H_2O$ **OR** $H_2O_2 + 2HI \rightarrow I_2 + 2H_2O$	**1**
9(c)(iii)	H_2O_2 = 1 **AND** I^- = 1 **AND** H^+ = 0	**1**

18.

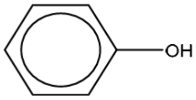
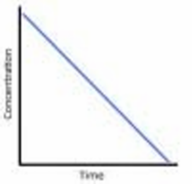
Question	Answer	Marks
3(b)(i)	$2AuCl_3 + 3H_2O_2 \rightarrow 2Au + 3O_2 + 6HCl$	**1**
3(b)(ii)	**M1** 1st order w.r.t. $AuCl_3$ because rate ×2 / doubles when concentration ×2 / doubles **M2** First order H_2O_2 × 2; $AuCl_3$ × 3 rate × 6 so order = 1 for H_2O_2 **M3** rate = $k\ [AuCl_3]\ [H_2O_2]$	**3**
3(b)(iii)	$k = 1.53 \times 10^{-1} / (0.10 \times 0.50) = 3.06$ $dm^9\ mol^{-2}\ minute^{-1}$	**2**

19.

Question	Answer	Marks
5(a)	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**
5(b)(i)	time taken for the concentration / mass / amount of a reactant to fall to half (its original value) / to halve	**1**
5(b)(ii)	$t_{1/2} = 150$ s **AND** evidence on graph / paper of one half-life	**1**
5(b)(iii)	no change	**1**
5(c)(i)	**M1:** evidence on graph of tangent **AND** 4 to 5 × 10^{-4} **M2:** $mol\ dm^{-3}\ s^{-1}$	**2**
5(c)(ii)	**(c)(i)** / 0.10 **AND** s^{-1}	**1**
5(d)	**M1:** $NO_2 + O_3 \rightarrow NO_3 + O_2$ **M2:** $NO_2 + NO_3 \rightarrow N_2O_5$	**2**

20.

Question	Answer	Marks
7(a)(i)	the power to which a concentration of a reactant is raised in the rate equation / law	**1**
7(a)(ii)	**M1:** (using expt 1 and 3) as $[ClO_2]$ × 2.5 rate × 6.25 so 2nd order **M2:** (using expt 1 and 2) as $[OH^-]$ × 4 rate × 4 so 1st order	**2**
7(a)(iii)	rate = $k[ClO_2]^2[OH^-]$	**1**
7(a)(iv)	**M1:** $k = rate / [ClO_2]^2[OH^-]$ $k = 7.20 \times 10^{-4} / (0.02)^2(0.03)$ k = 60 **M2:** $mol^{-2}\ dm^6\ min^{-1}$	**2**

Question	Answer	Marks
7(b)(i)	structure of phenol: C_6H_5OH **OR** 	**1**
7(b)(ii)	tangent drawn correctly **AND** rate = 0.015 / 260 = 5.8×10^{-5} **ALLOW** values consistent with tangent drawn at 100 sec	**1**
7(c)	 **AND** half-life decreases (1st box)	**1**

21.

3(d)(i)	**M1:** first order w.r.t. H_2O_2 **AND** change in conc. × 1.5 gives increase rate × 1.5 (expts 3 / 4) **M2:** first order w.r.t. IO_3^- **AND** change in conc. × 2 gives increase rate × 2 (as reaction first order w.r.t. H_2O_2) (expts 1 / 3) **M3:** zeroth order w.r.t. H^+ **AND** change in conc. has no effect on rate (expts 1 / 3 / 4 and 2)	**3**
3(d)(ii)	rate = $k[H_2O_2][IO_3^-]$ ecf	**1**
3(d)(iii)	**M1:** $k = 8.82 \times 10^{-5} \div (0.150 \times 0.140) = 4.20 \times 10^{-3}$ min 2sf ecf **M2:** $mol^{-1}\,dm^3\,s^{-1}$ ecf	**2**

22.

Question	Answer	Marks
2(a)(i)	(homogeneous is in the) same phase / state as reactants **AND (**heterogeneous is in a) different phase / state to reactants	**1**
2(a)(ii)	1 $S_2O_8^{2-} + 2Fe^{2+} \rightarrow 2Fe^{3+} + 2SO_4^{2-}$ [1] *2* $2I^- + 2Fe^{3+} \rightarrow 2Fe^{2+} + I_2$ [1]	**2**
2(a)(iii)	reactants are **both anions / negatively charged** **AND** so they **repel** each other **OWTTE**	**1**
2(b)(i)	rate = $k[NO]^2[O_2]$ **OR** rate = $8.6 \times 10^6\,[NO]^2[O_2]$	**1**
2(b)(ii)	rate = $8.6 \times 10^6 \times (7.2 \times 10^{-4})^2 \times 1.9 \times 10^{-3}$ rate = 8.47×10^{-3} ($mol\,dm^{-3}\,s^{-1}$) min 2sf	**1**
2(c)(i)	(reaction is) first order wrt cisplatin / overall **OR** rate is directly proportional to concentration of cisplatin	**1**
2(c)(ii)	$0.693 / 2.50 \times 10^{-5} = (2.77 \times 10^4$ s) **OR** $\ln 2 / 2.50 \times 10^{-5} = (2.77 \times 10^4$ s)	**1**

Question	Answer	Marks
2(c)(iii)	initial concentration is 8.0×10^{-5} $mol\,dm^{-3}$ – five half-life periods have elapsed [1] time = 5 × 27720 = 1.39×10^5 s [1] min 2 sf	**2**

23.

Question	Answer	Marks
2(a)(i)	rate = $k[NO][O_3]$	**1**
2(a)(ii)	1.66×10^{-8} [1] mol dm^{-3} s^{-1} [1]	**2**
2(a)(iii)	not constant **AND** overall second order / not overall first order	**1**
2(b)(i)	graph is straight line clearly parallel to *x*-axis	**1**
2(b)(ii)	graph is straight line with negative gradient	**1**
2(b)(iii)	adsorption of reactants onto catalyst surface [1] bonds in reactants weaken [1] reaction occurs followed by desorption of products [1]	**3**
2(b)(iv)	all active sites on catalyst surface are occupied	**1**

24.

Question	Answer	Marks
3(a)(i)	evidence of tangent drawn at t = 40 s and calculation of gradient = 0.000170 (mol dm^{-3} s^{-1}) min 2sf	**1**
3(a)(ii)	**M1** evidence of construction lines and calculation of two $t_{1/2}$ **OR** evidence of construction lines and times for halving of concentration **M2** deduction: constant half-life / constant time between halving of concentration → 1st order	**2**
3(b)	**M1** two half-lives in 320 s so $t_{1/2}$ = 160 s **M2** $k = 0.693 / 160 = 0.00433$ s^{-1} ecf min 2sf	**2**