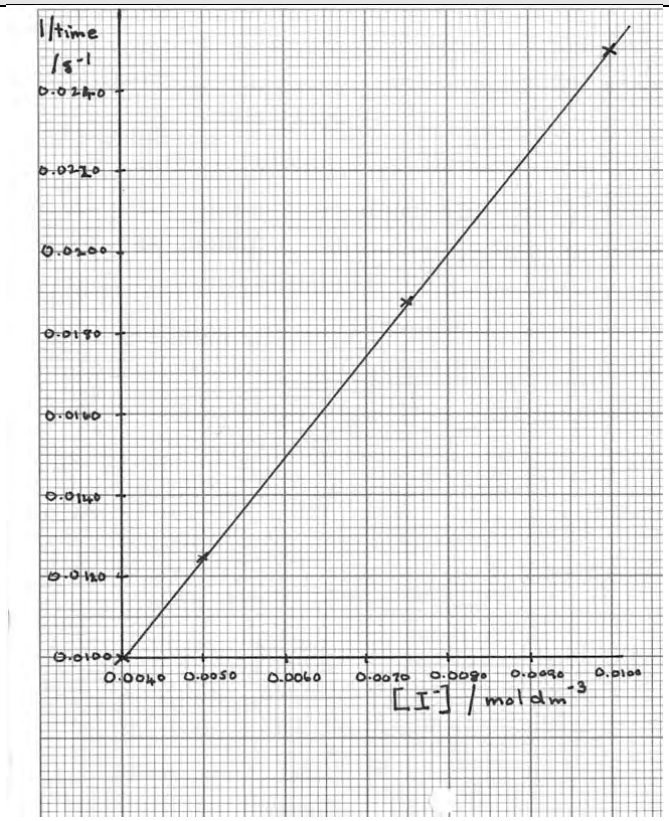
Question Number	Correct Answer	Reject	Mark
1(a)	$S_2O_8^{2-} + 2I^- \rightarrow 2SO_4^{2-} + I_2$ ALLOW multiples Ignore state symbols even if incorrect **COMMENT** 2 in front of sulfate is often missed.		1

Question Number	Correct Answer	Reject	Mark
1 (b)(i)	Blue/black /blue-black OR Colourless to blue-black/ blue/black	purple	1

Question Number	Correct Answer	Reject	Mark
1 (b)(ii)	The mixture would change colour/ go blue/black /blue-black **immediately/straight away** ALLOW …too quick(ly)/too early …quicker …no time delay		1

Question Number	Correct Answer	Reject	Mark
1 (b)(iii)	(As quickly as iodide reacts to form iodine it is) reduced/turned back to iodide by the thiosulfate ions ALLOW Persulfate reacts with thiosulfate first. OR Iodine reacts with thiosulfate.		1

Question Number	Correct Answer	Reject	Mark
1 (c)(i)	 **First mark** Correct graph of rate v concentration, with axes correct **and** values increasing on both axes labelled with quantity **and** units Note Units may be given in brackets with no slash. s/t meaning s divided by time is fine. **(1)** **Second mark** Sensible scales to use at least half the graph paper but allow graphs starting at the origin and points cover two by two big squares. Linear scales All points reasonably correct with straight line drawn **(1)** Second mark depends on correct graph of rate v concentration, but not other detail of first mark		2

Question Number	Correct Answer	Reject	Mark
1 (c)(ii)	First order This mark is independent of the graph drawn **(1)** Because the graph is a straight line (through the origin)/ rate is proportional to $[I^-]$ OR As concentration increases by (factor of) 2 rate increases by 2 (or any other numbers, including 'x') OR Rate increases linearly (with concentration) OR Gradient of line is constant **(1)** Second mark depends on first order	Just 'as concentration increases rate increases'	2

Question Number	Correct Answer	Reject	Mark
1 (c)(iii)	Rate = $k[S_2O_8^{2-}][I^-]$ **(1)** Units - $dm^3\ mol^{-1}\ s^{-1}$ **(1)** TE from (c)(ii) ALLOW Units in any order Internal TE from rate equation	Incorrect formulae	2

Question Number	Correct Answer	Reject	Mark
1 (d)(i)	**Method 1** **First mark** Gradient = $-E_a/R$ OR $E_a = -R \times$ gradient **(1)** **Second mark** (Gradient =) $\frac{-3.15-(-3.84)}{(3.20-3.31)\times10^{-3}}$ OR = -6272.7 (K) Please award this mark if -6272.7 is seen anywhere! **(1)** **Method 2** **First mark** Setting up two simultaneous equations **(1)** **Second mark** Subtracting one equation from the other or other correct methods of solution **(1)** **Third mark (applies to both methods)** (E_a) = +52126 J mol^{-1} /+52.1(26)kJ mol^{-1} Note: TE can only be given if either method 1 or method 2 has been clearly carried out. Positive sign given OR Two negative signs clearly cancel in method and no sign given **(1)** Correct answer with or without working, with sign and units **(3)** Ignore SF unless only one	Negative sign	3

Question Number	Correct Answer	Reject	Mark
1 (d)(ii)	Either Take readings at different temperatures OR Repeat at the same two temperatures ALLOW Just ‘repeat the experiment’		1

Question Number	Acceptable Answers	Reject	Mark
2(a)(i)	(Sodium thiosulfate) (rapidly) reacts with / reduces the iodine (as it is formed) **(1)** So prevents the starch-iodine colour appearing until a fixed amount of reaction has occurred ALLOW (for second mark) So prevents the starch-iodine colour appearing until all the thiosulfate has reacted OR Moles of iodine reacted / thiosulfate ÷ time is (approximately) proportional to the (initial) rate of reaction **(1)** ALLOW Use of 'thio' for thiosulfate	iodide / I^-	**2**

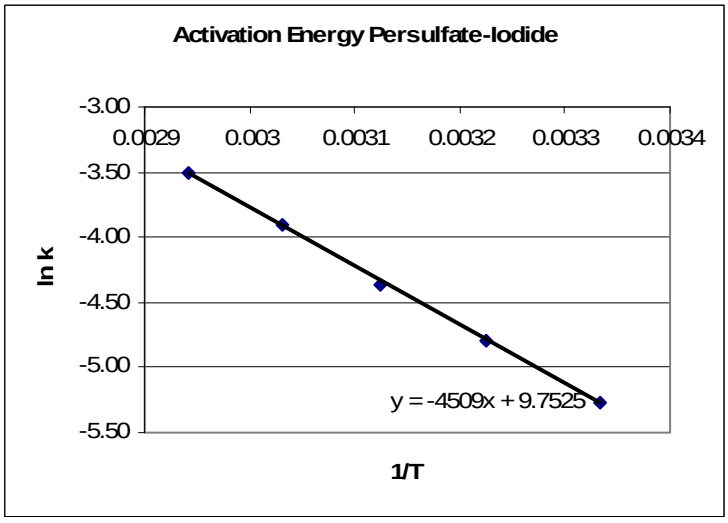
Question Number	Acceptable Answers	Reject	Mark
2(a)(ii)	(From 2 to 1) **$[S_2O_8^{2-}]$** doubles ($[I^-]$ unchanged) and rate doubles / time halves so order wrt $S_2O_8^{2-}$ = 1 **(1)** (From 3 to 1) **$[I^-]$** doubles ($[S_2O_8^{2-}]$ unchanged) and rate doubles / time halves so order **wrt I^-** = 1 OR (if first mark awarded) (From 3 to 2) **$[I^-]$** doubles ($[S_2O_8^{2-}]$ halved) and rate unchanged so order **wrt I^-** = 1 **(1)** Penalise omission of concentration/square brackets once only Rate = $k[S_2O_8^{2-}][I^-]$ **(1)** Third mark stand alone if no working & TE on incorrect orders IGNORE case of k	Rate equation =	**3**

Question Number	Acceptable Answers	Reject	Mark
2(b)(i)	**irst mark** Colorimetry /Use a colorimeter **(1)** **Second mark** Measure transmittance / absorbance (at various times) **(1)** **Third mark** (Use a calibration curve to) convert transmittance / absorbance into concentration. OR transmittance / absorbance proportional to concentration ALLOW Colorimetry may be used because iodine (solution) is coloured (and other reagents are colourless) / to measure intensity of the iodine colour **(1)** ALLOW (for the same three marks) Electrical conductivity Measured at various times / (use a calibration curve to) convert conductivity into concentration. Conductivity reduces as reaction proceeds because 3 mol ions converted to 2 mol ions / fewer ions on right hand side	Sampling methods calorimeter pH meter Just conductivity changes	**3**

Question Number	Acceptable Answers	Reject	Mark
2(b)(ii)	$[(NH_4)_2S_2O_8]$ / $[S_2O_8^{2-}]$ / [peroxodisulfate] / [persulfate] remains (approximately) unchanged during the reaction. OR [KI] / $[I^-]$ is the only variable	$(NH_4)_2S_2O_8$ in excess. $[(NH_4)_2S_2O_8]$ etc does not affect the rate Only [KI] / $[I^-]$ affects the rate	**1**

Question Number	Acceptable Answers	Reject	Mark
2(b)(iii)	Plot a graph of concentration (of iodine/I_2) (on the y axis) against time **(1)** Measure the initial gradient / gradient at t=0 **(1)** 'Plot a graph and measure the initial gradient / gradient at t=0' alone scores second mark		**2**

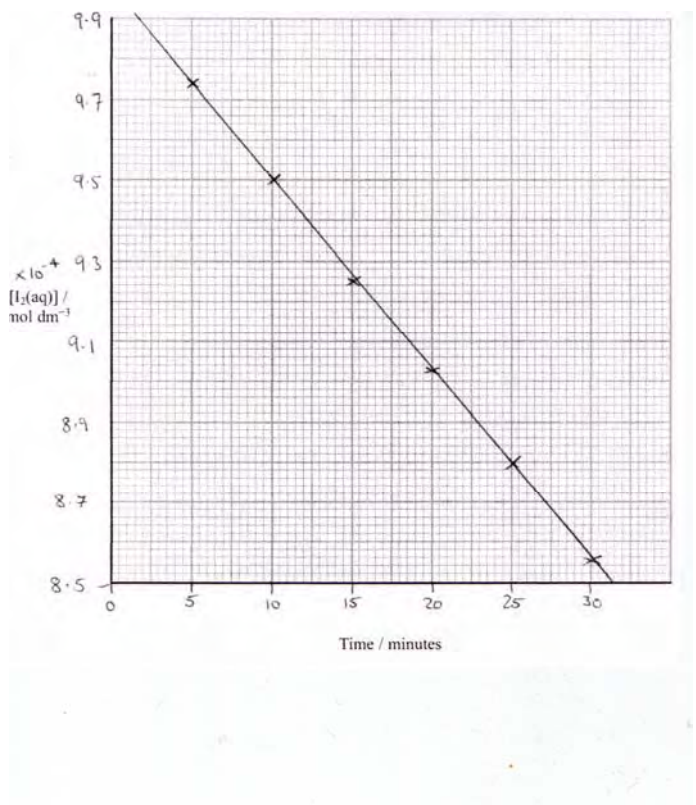
Question Number	Acceptable Answers	Reject	Mark
2(b)(iv)	TE on 20(a)(ii) on numerical answer and appropriate units $8.75 \times 10^{-5} = k \times 2.0 \times 0.025$ $k = 8.75 \times 10^{-5} / (2.0 \times 0.025)$ $= 1.75 \times 10^{-3}$ **(1)** $dm^3\ mol^{-1}\ s^{-1}$ **(1)** ALLOW units in any order Correct answer including units with no working scores 2	1 SF	**2**

Question Number	Acceptable Answers	Reject	Mark
2(c)(i)	 Use the overlay to mark the graph At least 4 points within the circles on the overlay **(1)** Best fit line on points given **(1)**		**2**

Question Number	Acceptable Answers	Reject	Mark
2(c)(ii)	Gradient = −(−3.50 − −5.27) / (0.00333 − 0.00294) = (−)4538 = (−)4500 ALLOW values from (−)4300 to (−)4700 **(1)** gradient value negative **(1)** E_a = −gradient x R = −−4538 x 8.31 = (+)37700 J mol^{-1} (= (+)38 kJ mol^{-1}) **(1)** TE on value of gradient even if it is positive −4300 gives 35.7; −4700 gives 39.1 Correct units **(1)** Correct answer from the gradient calculation with units scores final 2 marks **BUT** correct answer with units but no gradient calculation scores units mark only		**4**

Question Number	Correct Answer	Reject	Mark
3 (a)(i)	Sodium thiosulfate/$Na_2S_2O_3$ ALLOW $S_2O_3^{2-}$ or thiosulfate ions	Just thiosulfate	**1**

Question Number	Acceptable Answers	Reject	Mark
3(a)(ii)	Add (excess) sodium hydrogencarbonate/ $NaHCO_3$ **(1)** To neutralize/remove/react with acid (catalyst) **(1)** Cool in ice (water) with no reference to neutralization – allow 1 mark but ignore if either of first two marks awarded	NaOH/ sodium hydroxide/ alkali just cold water	**2**

Question Number	Acceptable Answers	Reject	Mark
3(b)(i)	Suitable graph and scale **(1)** Points plotted and line of best fit **(1)** 0 order (with respect to iodine) **(1)**  		**3**

Question Number	Acceptable Answers	Reject	Mark
3(b)(ii)	Graph is a straight line/Gradient is constant **(1)** Rate stays constant (as iodine used up)/ Concentration has no effect on rate **(1)** Stand alone marks	Half life is constant	**2**

Question Number	Acceptable Answers	Reject	Mark
3(c)	Colorimetry/use of pH meter/conductivity/titrate with $AgNO_3$/titrate with alkali (to monitor change in $[H^+]$)	C**a**lorimetry Use of starch/ Iodine clock reaction	**1**

Question Number	Acceptable Answers	Reject	Mark
4 (a)(i)	**O_2** : first order as increasing $[O_2]$ x 2 increases rate x 2 / as rate is (directly) proportional to oxygen concentration **(1)** (Experiments 1 and 2 or [NO] constant) **NO:** second order as increasing [NO] x 2 increases rate x 4/ by 2^2 **(1)** (Experiments 2 and 3 or $[O_2]$ constant) Two correct orders with no explanation **(1)** only	Two correct orders based on stoichiometry	**2**

Question Number	Acceptable Answers	Reject	Mark
4 (a)(ii)	Rate = k $[O_2][NO]^2$ Rate equation must be consistent with answer in (a)(i)	Just k $[O_2][NO]^2$ i.e. no rate/R Non square brackets	**1**

Question Number	Acceptable Answers	Reject	Mark
4 (a)(iii)	Rate = k$[O_2][NO]^2$ TE from (i) $k=((5.10 \times 10^{-4})/(0.005)(0.0125)^2) = 652.8$ / 653/650 OR $k=((10.2 \times 10^{-4})/(0.0100)(0.0125)^2) = 652.8$ / 653/650 OR $k=((40.8 \times 10^{-4})/(0.0100)(0.025)^2) = 652.8$ / 653/650 **(1)** TE for value of k from rate equation given $dm^6\ mol^{-2}\ s^{-1}$ (allow any order) **(1)**		**2**

Question Number	Acceptable Answers	Reject	Mark
4 (b)(i)	$NO_2 + CO \rightarrow NO + CO_2$ Allow multiples	Equation not cancelled down eg NO_3 on both sides.	**1**

Question Number	Acceptable Answers	Reject	Mark
4 (b)(ii)	Rate = $k[NO_2]^2$ OR Rate = $k[NO_2]^2[CO]^0$ OR Rate = $k[NO_2]^2[CO]^0\,[NO_3]^0$ **(1)** Only molecules/reactant in slow step are (2)NO_2 OR CO appears after the rate determining/slow step (and $2NO_2$ molecules in slow step) OR CO is not involved in rate determining / slow step OR Only the molecules in the slow step are in the rate equation OR Step 1 is slowest so determines rate equation **(1)** **Second mark:** **No TE on rate equation containing incorrect species. Only allow TE if k missing in correct rate equation**	Equations involving CO to power other than zero	**2**