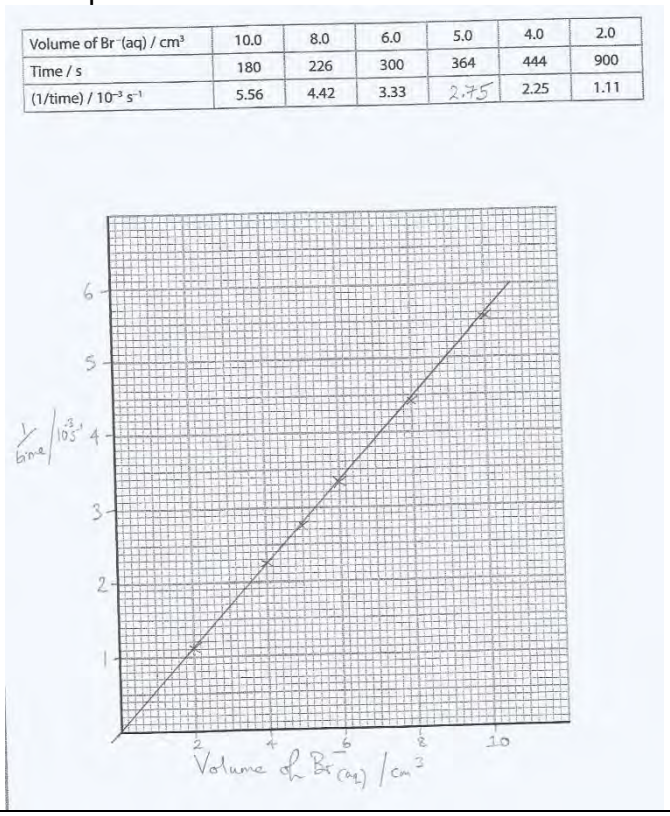
Question Number	Acceptable Answers	Reject	Mark
1(a)	So that the phenol is used up / methyl orange is bleached before the rate changes (significantly) OR So that the phenol is used up / methyl orange is bleached during the initial rate period OR So that the concentration of bromide/bromate/reactants does not fall significantly before all the phenol is used up / the methyl orange is bleached OR Within this region/period/time the average rate of reaction approximates to the initial rate	bromine	**(1)**

Question Number	Acceptable Answers	Reject	Mark
1(b)(i)	So that only the **concentration** of bromide ions varies (significantly) during the course of the reaction / so that the **concentration** of the bromide ions is the limiting factor / so that the **concentration** of bromide ions is the only variable ALLOW So their **concentrations** / the BrO_3^- and H^+ **concentrations** do not change OR So their **concentrations** / the BrO_3^- and H^+ **concentrations** are not the limiting factor		**(1)**

Question Number	Acceptable Answers	Reject	Mark
1(b)(ii)	**M1:** **Completed table** 2.75 **(1)** **M2:** Axes correct with sensible scales so at least half of the graph paper on both axes is covered **(1)** **M3:** Axes labels fully correct, with units **(1)** **M4:** All points plotted correctly (allow ± 1 small square) and straight line drawn **through (0,0)** and through all appropriate points **(1)** Exemplar:  		**(4)**

Question Number	Acceptable Answers	Reject	Mark
1(b)(iii)	**M1:** First order This mark is independent of the graph drawn **(1)** **M2:** Because the graph is a straight line (through the origin) OR rate is proportional to $[Br^-]$ / rate is proportional to volume of Br^- OR As concentration / volume increases by (factor of) 2, rate increases by 2 (or any other numbers, including 'x') OR Rate increases linearly (with concentration) ALLOW Gradient of line is constant **(1)** **M2** can only be awarded if **M1** correct		**(2)**

Question Number	Acceptable Answers	Reject	Mark
1(b)(iv)	Rate = $k\ [Br^-][BrO_3^-][H^+]^2$ ALLOW 'r =' instead of "rate =" Allow TE on their order wrt Br^- from (b)(iii) **(1)** $dm^9\ mol^{-3}\ s^{-1}$ Allow the units in any order Allow TE for M2 on candidate's stated rate equation **(1)** e. if rate = $k\ [BrO_3^-][H^+]$ then TE on units for $dm^6\ mol^{-2}\ s^{-1}$		**(2)**

Question Number	Acceptable Answers	Reject	Mark
1(c)(i)	They are spectator ions OR They are unchanged (on both sides of the equation) OR They do not take part in the reaction / they do not play any part in the reaction ALLOW “They cancel out”		**(1)**

Question Number	Acceptable Answers	Reject	Mark
1(c)(ii)	Blue-black colour appears / turns blue-black ALLOW blue or black / shades of blue or black **IGNORE** Any INITIAL colour Any reference to precipitate / solid	Black from blue Purple Bluer Blacker	**(1)**

Question Number	Acceptable Answers	Reject	Mark
1 (d)(i)	Measure the time taken (for the blue-black colour to appear) and temperature		**(1)**

Question Number	Acceptable Answers	Reject	Mark
1(d)(iii)	Temperature converted to kelvin OR K^{-1} given as units on the *x*-axis of the graph **(1)** **M2** The vertical axis should be ln rate / ln 1/t **Note** ALLOW ln *k* for this mark **(1)** **M3** The horizontal axis should be 1/T **(1)** **M4** **Straight** line (with a negative gradient) OR Can be shown by candidate in a sketch graph of a **straight** line with a negative gradient **(1)** **M5** Any mention of **gradient** (of the line) **(1)** **M6** Rearranges expression so: E_a = **−**gradient x *R* OR 'Multiply gradient by –R' Negative sign MUST be shown or mentioned specifically **(1)** **NOTE:** Plot "ln rate **against** 1/T" scores both M2 and M3 If axes clearly the wrong way round max (4) – namely only marks M1, M4, M5 and M6 are possible	1/**T** 1/**t**	**(6)**

Question Number	Correct Answer	Reject	Mark
2 (a)	**1st mark:** Take **samples** (of reaction mixture) at various times OR Using of different mixtures (e.g. in separate conical flasks) **(1)** THEN: **EITHER** Quench (with ice) / remove the catalyst **(1)** **Titrate** with **acid of known concentration/standard** (using a suitable indicator) **(1)** **OR** Quench with acid **(1)** **Titrate** with **alkali of known concentration** (using a suitable indicator) **(1)** If no quenching, M3 can only be awarded if titrate with acid of known concentration	$NaHCO_3$ $NaHCO_3$	**3**

Question Number	Correct Answer	Reject	Mark
2 (b) (i)	(As) rate is (directly) proportional to concentration / as [A] doubles so does rate / rate ∞ concentration / rate ∞ [A] ALLOW Just 'straight line through origin/(0,0)' IGNORE References just to a 'constant gradient' References to **just** 'it is a straight line' References to positive correlation		**1**

Question Number	Correct Answer	Reject	Mark
2 (b) (ii)	**1st mark:** Rate higher than expected / rate unusually high / higher rate (for the anomalous points on the graph) **(1)** **2nd mark:** Reaction is exothermic / (heat) energy is released during the reaction **(1)** **3rd mark:** **EITHER** (So) there are more particles/collisions with energy > E_a ALLOW Higher **proportion of** successful collisions / just more successful collisions **IGNORE** **Just** 'more collisions' / 'more frequent collisions' **OR** At higher concentrations of **A**, the effect of the reaction being exothermic is greater **(1)**		**3**

Question Number	Correct Answer	Reject	Mark
2 (c) (i)	Increases reliability / improves validity (of the data obtained) / confirms the initial results / to check for anomalous results IGNORE References to average / precision / accuracy **OR** To determine order w.r.t. B and X / to see the effect of B and X (on the rate) / enables order of other reagents to be determined / to determine order w.r.t. B / find overall order / determine rate equation / to calculate *k*		**1**

Question Number	Correct Answer	Reject	Mark
2 (c) (ii)	0 order w.r.t. B **(1)** 1st order w.r.t. X **(1)** Rate = k [A][X] OR Rate = k [A][X][B]^0 ALLOW TE for CQ correct rate equation on incorrect order(s) **(1)** **Correct** reasoning **using data from table** to deduce the **CORRECT** order w.r.t. B NOTE that there must be reference to **TWO** relevant concentrations changing Eg (Expt 1 & 3) [A] triples, so does rate **AND** [B] d ubles so order w.r.t. B is 0 (Expt 2 & 3) [A] x 1.5, rate x 1.5 **AND** [B] d ubles so order w.r.t. B is 0 This mark can only be awarded if the reasoning shows that order w.r.t B is zero. **(1)** Not enough **just** to say 'as [B] doubles, rate unchanged' **Correct** reasoning **using data from table** to		**5**

	deduce the **CORRECT** order w.r.t. X NOTE that there must be reference to **TWO** relevant concentrations changing E.g. (Expt 1 & 4) [A] x 4 (and [B] x 2) **AND** [X] ÷ 2 rate doubles so order w.r.t. X is 1 (Expt 2 & 4) [A] x 2 (and [B] x 2) **AND** [X] ÷ 2 rate stays the same so order w.r.t. X is 1 (Expt 3 & 4) [A] x 4/3 (and [B] stays the same) **AND** [X] ÷ 2 rate decreases by 2/3, so order w.r.t. X is 1 This mark can only be awarded if the reasoning shows that order w.r.t X is one. Not enough **just** to say 'as [X] doubles, rate doubles' **(1)** IGNORE Any justification not concluded from data in the table Working to confirm order w.r.t. A = 1 (already given in question) NOTE Correct rate equation **alone** scores M1, M2 and M3		

Question Number	Correct Answer	Reject	Mark
2 (c) (iii)	k = rate / [A][X] = 4.2 x 10^{-3} ÷ (0.08 x 0.25) = 0.21 **(1)** $dm^3\ mol^{-1}\ s^{-1}$ / $mol^{-1}\ dm^3\ s^{-1}$ ALLOW units in any order **(1)** Comment Unit mark is independent of the value **Allow use of data from experiments 1, 2 & 3** Allow TE from an incorrect rate equation given in answer to Q14(c)(ii) or a 'new' rate equation given at the start of answer to Q14(c)(iii), if of the form rate = k …		**2**

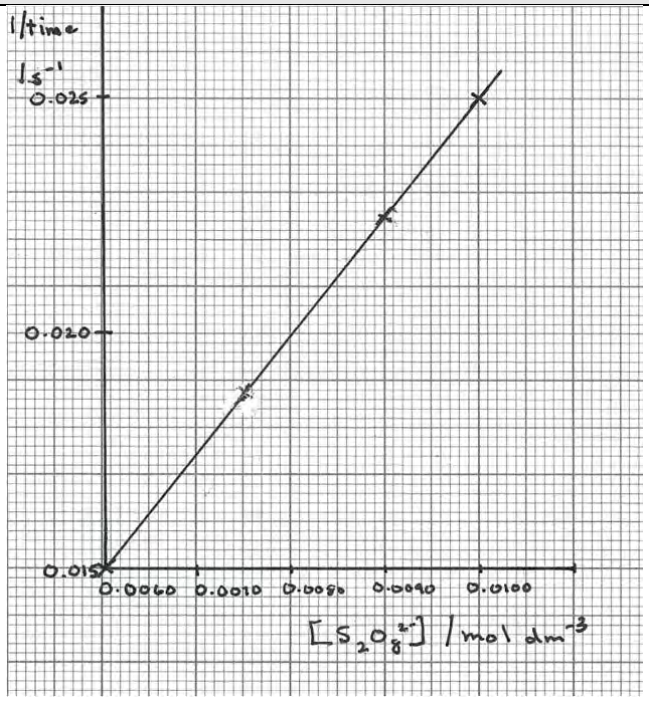
Question Number	Correct Answer	Reject	Mark
2 (d)	**Correct feature** **ANY <u>one</u> of:** First step does involve carbocation formation / carbocation is correct / two electrons taken by Br atom in C–Br bond / C–Br bond breaks (heterolytically) (Second step does involve) attack of hydroxide ion First order wrt the halogenoalkane / 1st order wrt 2-bromomethylpropane (S_N1) is a two-step process Curly arrow**<u>s</u>** are correct **(1)** **Incorrect features** **ANY <u>two</u> of:** • Should be S_N1 (not S_N2) • First step is slow • Second step is fast • (It is not) S_N2 • $C^{\delta+} - Br^{\delta-}$ not shown / dipole on C–Br bond not shown **(2)**		**3**

Question Number	Correct Answer	Reject	Mark
3(a)	$S_2O_8^{2-} + 2I^- \rightarrow 2SO_4^{2-} + I_2$ ALLOW multiples Ignore state symbols even if incorrect		**1**

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

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

Question Number	Correct Answer	Reject	Mark
3 (d)(i)	**Method 1** **First mark** Gradient = $-E_a/R$ OR $E_a = -R \times$ gradient **(1)** **Second mark** (Gradient =) $\frac{-3.0-(-3.69)}{(3.30-3.41) \times 10^{-3}}$ 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
3 (d)(ii)	Either Take readings at different temperatures OR Repeat at the same two temperatures ALLOW Just ‘repeat the experiment’		**1**