GCE A LEVEL CHEMISTRY

S21-A410

Assessment Resource F

Chemistry in Practice

1. This question is about the oxides and chlorides of two elements, **X** and **Y**, which exhibit the following properties.

Element	Properties of oxide	Properties of chloride
X	White solid of melting temperature 2800 °C. It is insoluble in water but readily dissolves in dilute acid. Addition of aqueous sodium hydroxide to this solution forms a white precipitate, which is insoluble in excess aqueous sodium hydroxide.	White solid with melting temperature of 712 °C. It is readily soluble in water. Its solution gives a white precipitate with $CO_3^{2-}(aq)$ but no precipitate with $SO_4^{2-}(aq)$.
Y	White solid of melting temperature 1750 °C. It is insoluble in water and does not react with dilute acids or dilute alkalis.	Colourless liquid with boiling temperature of 58 °C. It reacts vigorously with water to give a white precipitate, an acidic solution and misty fumes. At 60 °C and 1 atm pressure, 5.000 g of the chloride of **Y** occupies a volume of 805.5 cm^3.

(a) Use **all** the information provided to suggest the identity of element **X**. Show your reasoning and include **ionic** equations to support your answer. [4]

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(b) Use **all** the information provided to suggest the identity of element **Y**. Show your reasoning and include an equation to support your answer. [6]

2. *(a)* Outline a suitable laboratory method to investigate the rate of each of the following reactions at constant temperature.

You may use a chosen method only once.

(i) $Mg(s) + H_2SO_4(aq) \longrightarrow MgSO_4(aq) + H_2(g)$ [1]

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(ii) $CH_3COCH_3(aq) + I_2(aq) \longrightarrow CH_2ICOCH_3(aq) + HI(aq)$ [2]

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(b) The kinetics of the reaction represented by the equation

$$BrO_3^-(aq) + 5Br^-(aq) + 6H^+(aq) \longrightarrow 3Br_2(aq) + 3H_2O(l)$$

can be investigated by measuring the rate at which bromine is produced using a clock reaction. The reaction mixture contains known volumes of $BrO_3^-(aq)$, $Br^-(aq)$ and $H^+(aq)$.

The reaction mixture also contains

- a known volume of aqueous phenol, which removes the bromine produced in the reaction

$$3Br_2(aq) + C_6H_5OH(aq) \longrightarrow C_6H_2Br_3OH(s) + 3H^+(aq) + 3Br^-(aq)$$

- 2–3 drops of methyl orange solution, which is bleached colourless by free bromine

$$Br_2(aq) + \underset{\text{(pink)}}{\text{methyl orange}} \longrightarrow \underset{\text{(colourless)}}{\text{bleached methyl orange}}$$

As soon as all the phenol has been used up by the bromine produced, free bromine will appear in solution and bleach the methyl orange. The time taken for the methyl orange solution to be bleached is recorded.

(i) One group of students studied the kinetics of the bromate/bromide reaction using the clock reaction described above.

They mixed different volumes of the aqueous solutions, all at a concentration of 1.0 mol dm^{-3} and a constant temperature of 298 K.

In each experiment, the total volume was made up to 500 cm^3 with deionised water. The following results were obtained.

Expt	Volume of $BrO_3^-(aq)$ / cm^3	Volume of $Br^-(aq)$ / cm^3	Volume of $H^+(aq)$ / cm^3	Volume of phenol / cm^3	Time taken for methyl orange to be bleached / s	Rate / s^{-1}
1	25.0	125.0	150.0	10.0	336	
2	25.0	125.0	300.0	10.0	84	
3	50.0	125.0	300.0	10.0	42	
4	25.0	62.5	300.0	10.0	168	

I. **Complete the table** by calculating the values of the rate in these four experiments. [1]

II. Deduce the order of reaction with respect to $BrO_3^-(aq)$, $Br^-(aq)$ and $H^+(aq)$.

Explain how you reached your conclusions. [3]

Order with respect to $BrO_3^-(aq)$ .....

Explanation .....

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Order with respect to $Br^-(aq)$ .....

Explanation .....

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Order with respect to $H^+(aq)$ .....

Explanation .....

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III. Write the rate equation for the overall reaction. [1]

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IV. With reference to this rate equation, state what is meant by the overall order of a reaction. [1]

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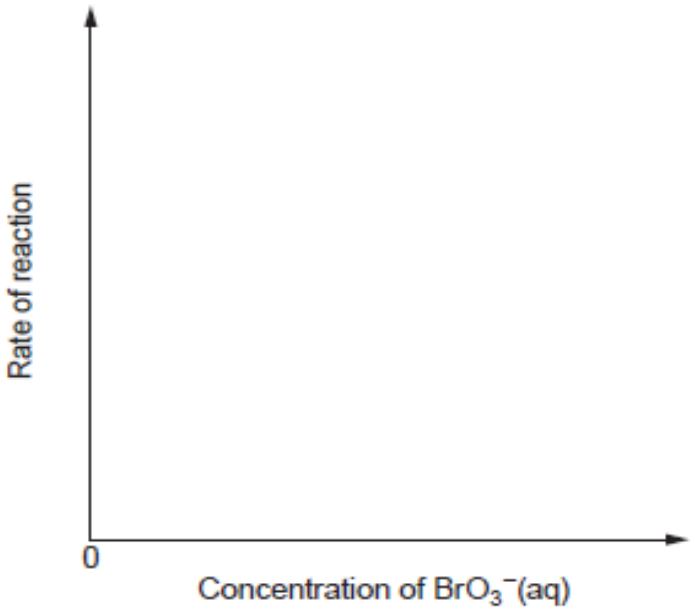
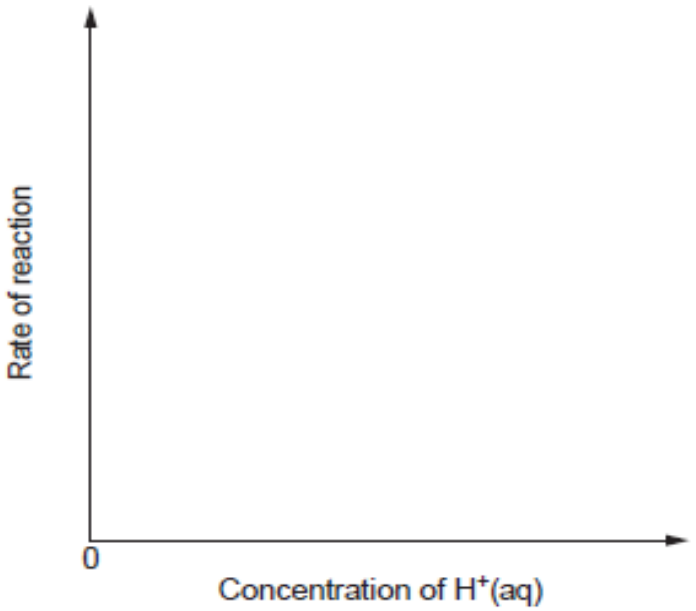
V. Calculate the value of the rate constant, giving your answer to an **appropriate** number of significant figures. [4]

Rate constant = ...

VI. On the axes below, sketch the graph of rate against concentration that would be obtained when the concentrations of $BrO_3^-(aq)$ and $H^+(aq)$ are changed in turn, whilst all other reactant concentrations remain unchanged.

Assume that the temperature remains constant. [2]

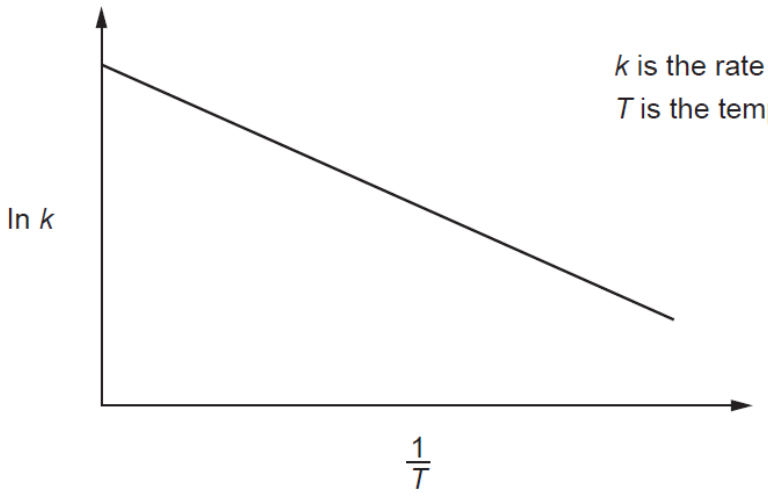




(ii) In an extension to the original work, a group of students carried out an experiment to determine the activation energy of the bromate/bromide reaction.

$$BrO_3^-(aq) + 5Br^-(aq) + 6H^+(aq) \longrightarrow 3Br_2(aq) + 3H_2O(l)$$

They collected suitable results and plotted the graph shown below.



k is the rate constant

T is the temperature (in Kelvin)

Outline the practical steps the students carried out to collect their results. Explain how their results were processed to plot the graph and how the graph would be used to determine the activation energy. [6 QER]