Eton College King's Scholarship Examination 2019

SCIENCE 2 (Data Analysis)

(30 minutes)

Candidate Number:_____

Remember to write your candidate number on every sheet in the space provided.

*You should attempt **ALL** the questions. Write your answers in the spaces provided.*

The maximum mark for each question or part of a question is shown in square brackets.

Calculators are allowed. In questions involving calculations, all your working must be shown.

For examiners' use only.

Total [30]	

Do not turn over until told to do so.

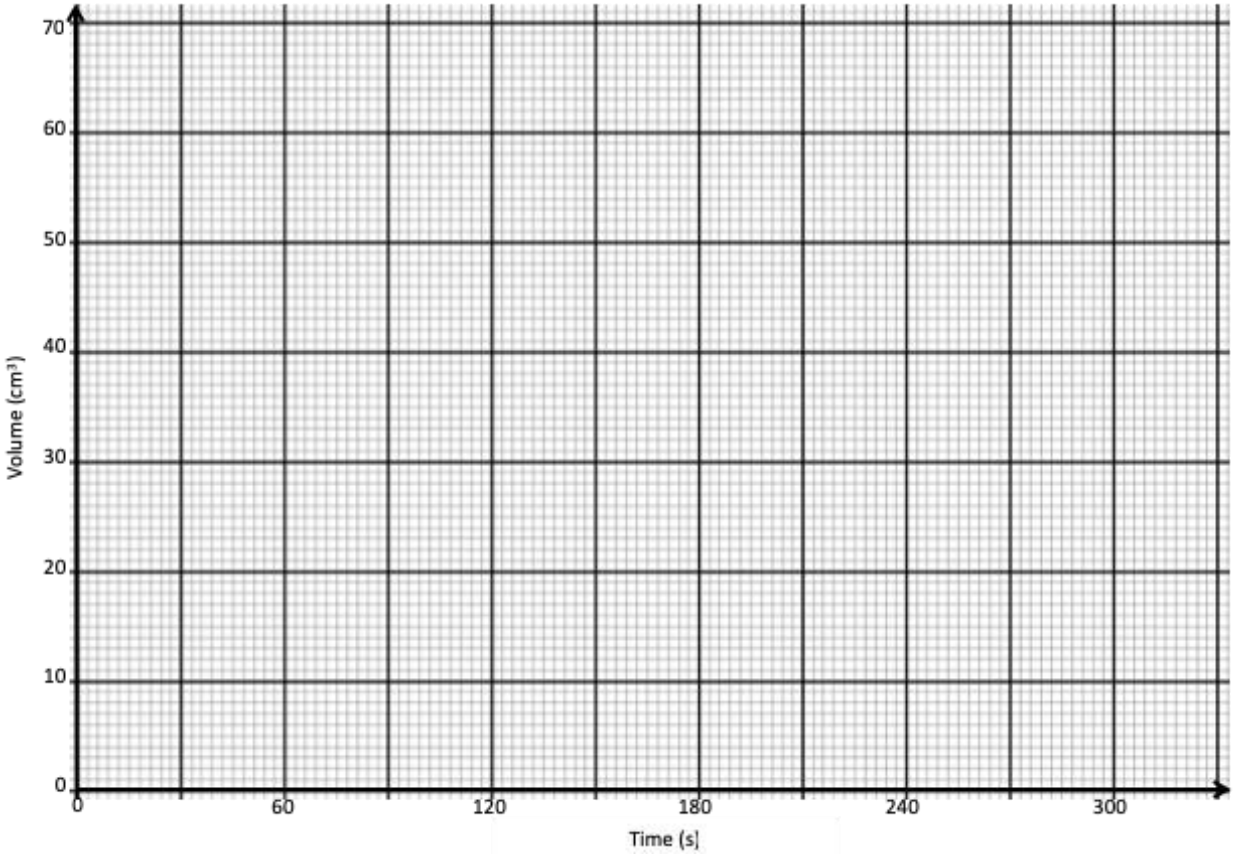
1. Hydrogen peroxide undergoes a decomposition reaction to form water and oxygen according to the following equation:

$$2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g)$$

A manganese (IV) oxide catalyst is also used, which is a purple, insoluble solid. For this experiment 20 cm^3 of hydrogen peroxide was mixed with 30 cm^3 of water and 0.20 g of manganese (IV) oxide. All the chemicals were at room temperature. The volume of gas produced was recorded every 60 seconds using a gas syringe. The results are shown in the table below:

Time (s)	0	60	120	180	240	300
Volume (cm^3)	0	30	48	57	60	60

(a) Plot a graph of these results and draw a suitable line of best fit. **[3]**



(b) Use your graph to estimate how long it would take to produce 50 cm^3 of gas.

_____ **[2]**

(c) Explain why the graph becomes horizontal after 240 seconds.

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_____ **[2]**

(d) The experiment was repeated using the same quantities of everything, except this time it was placed in a warm water bath at 40 °C. On the same axis, sketch the graph you would expect to get from this reaction and label it D. **[2]**

(e) The experiment was repeated at room temperature, but this time 10 cm^3 of hydrogen peroxide was mixed with 40 cm^3 of water and 0.20 g of manganese (IV) oxide. On the same axis, sketch the graph you would expect to get from this reaction and label it E. **[2]**

(f) A catalyst is a substance that speeds up the rate of reaction and is chemically unchanged at the end of the reaction. How could you demonstrate that the manganese (IV) oxide is indeed a catalyst in this reaction?

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_____ **[2]**

2. Nitrogen dioxide reacts with ozone according to the following equation:

$$2NO_2(g) + O_3(g) \rightarrow N_2O_5(g) + O_2(g)$$

Three separate experiments were performed using varying concentrations of reactants, as shown in the table below. The rate of each reaction was measured and is recorded in the table below.

Experiment	**Concentration of NO_2 (g) / mol dm^{-3}**	**Concentration of O_3(g) / mol dm^{-3}**	**Rate / mol dm^{-3} s^{-1}**
1	1.0	2.5	0.000032
2	2.0	2.5	0.000064
3	2.0	5.0	0.000128

(a) How does doubling the concentration of nitrogen dioxide affect the rate of reaction?

_____ **[1]**

(b) How is the rate of reaction affected when the concentration of ozone is doubled?

_____ **[1]**

(c) Predict the rate of reaction if the experiment is repeated using 0.5 mol dm^{-3} of nitrogen dioxide and 2.5 mol dm^{-3} of ozone?

_____

_____ **[1]**

(d) Predict the rate of reaction if the experiment is repeated using 4.0 mol dm^{-3} of nitrogen dioxide and 7.5 mol dm^{-3} of ozone?

_____

_____ **[1]**

(e) In chemistry, we can write an equation to express how the reaction rate is related to the concentration of the reactants; the rate equation for this particular reaction is written below. The rate constant, k, is a numerical value which links the rate with the concentrations of reactants. Square brackets are used around the reactants to show we are referring to the concentration values.

$$\text{Rate} = k\,[NO_2(g)][O_3(g)]$$

Using the data from the experiment 1, rearrange the equation to find the numerical value of k and state the units of the value you calculate. Show your working.

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_____ **[3]**

3. Chemical reactions do not always go to completion and often there is unreacted starting material left over. This means we achieve a lower mass of product than we expected. We can calculate the percentage yield of product from an experiment using the following equation:

$$\% \text{ yield} = \frac{\text{Actual mass}}{\text{Predicted mass}} \times 100$$

Silver nitrate solution reacts with sodium chloride solution (which is in excess) to form silver chloride and sodium nitrate according to the following equation:

Silver nitrate + sodium chloride → silver chloride + sodium nitrate

The silver chloride is insoluble in water whereas sodium nitrate is soluble. If the reaction had gone to completion and all of the silver nitrate had reacted, we would expect to obtain 7.90 g of silver chloride. However, only 6.22 g of silver chloride was actually collected from this reaction.

(a) Calculate the percentage yield of silver chloride in this reaction. Give your answer to the nearest whole number.

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_____ **[2]**

(b) The experiment was repeated using the same amounts as described above. This time the percentage yield was calculated to be 107 %. What was the actual mass of silver chloride that was collected? Give your answer to 2 decimal places.

_____

_____ **[2]**

(c) Assuming that the correct quantities of reagents were used, give a possible reason for this result.

_____

_____ **[1]**

Some chemical reactions may be reversible, where both the forwards and reverse reactions are possible. Some reversible reactions can exist in a state of *dynamic equilibrium*, where the rate of the forwards reaction is equal to the rate of the reverse reaction, so that the concentrations of the reactants and products remain constant.

$$A + B \rightleftharpoons C$$

(d) Imagine 10 molecules of A were placed in a container with 10 molecules of B and the reaction was left to reach dynamic equilibrium. When the reaction was in dynamic equilibrium, there were 4 molecules of A remaining. Complete the table below by filling in the blanks. **[3]**

	A	**B**	**C**
Number of molecules initially	10	10	
Number of molecules that have reacted / formed			6
Number of molecules remaining at dynamic equilibrium	4	4	

(e) Assuming molecules of A are yellow in colour, molecules of B are colourless and molecules of C are blue, explain what colour you would expect the reaction mixture to appear when it is in dynamic equilibrium.

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_____ **[2]**

[End of paper]