Eton College King's Scholarship Examination 2022

SCIENCE 2 (Data Analysis)

(30 minutes)

Candidate Number: _____

<u>Remember to write your candidate number on every sheet in the space provided.</u>

*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.

Total Marks Available: 30

For examiners' use only.

Total [30]	

Do not turn over until told to do so.

1. Limestone is a rock composed mainly of calcium carbonate. Some students were asked to estimate the purity of the limestone from a quarry. They heated samples of the limestone, so that the calcium carbonate decomposed and the solid decreased in mass:

$$CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$$

They used a more powerful version of the normal Bunsen burner, as a very high temperature is required. Each student was given a sample of the limestone and told to follow the instructions below:

Instructions

1. Weigh your sample using a balance which measures to one decimal place in grams and record the mass of the sample.
2. Heat the sample strongly for 30 minutes to ensure that the decomposition of calcium carbonate is complete.
3. Weigh the solid which remains and record its mass.

Here are the results:

Experiment number	Initial mass of sample (g)	Final mass of solid (g)	Mass lost (g)
1	2.0	1.2	0.8
2	4.4	2.8	1.6
3	6.4	4.6	1.8
4	8.2	5.1	3.1
5	9.8	6.1	
6	12.0	7.5	

(a) Complete the final column of the results table.

[1]

(b) Look at the instructions for the experiment, and suggest why no student was given a sample with a mass of more than 12 grams.

_____

_____

[1]

(c) Look at the instructions for the experiment and suggest why no student was given a sample with a mass of less than 2 grams.

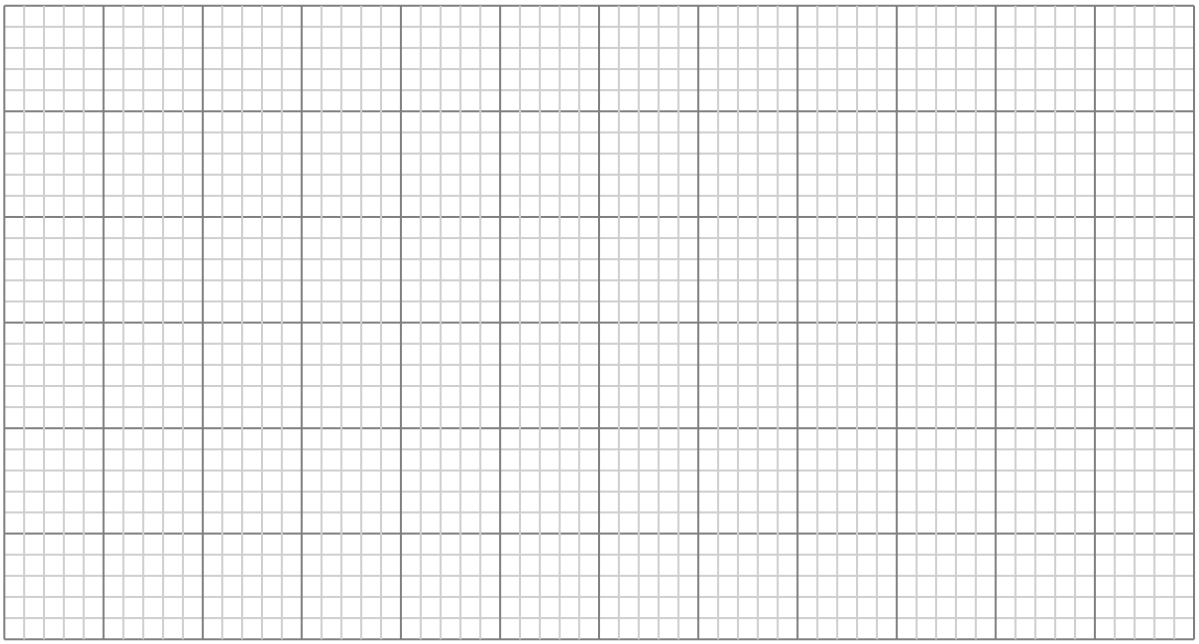
_____

_____

[1]

(d) Using the grid below, plot a graph of **mass lost** against **initial mass of sample**. Choose suitable scales, label the axes, and include the origin.

[4]



(e) One of the points from experiments 1 to 4 is anomalous. Label this point, and draw a straight line of best fit using the other five points. The line of best fit must pass through the origin.

[2]

(f) Suggest an explanation for the anomalous point you have labelled in part (e). You should assume the student did not simply make an error in recording the mass.

_____

_____

[1]

Scientists use a **relative atomic mass** scale to compare the masses of atoms of different elements. The relative atomic masses of some elements are shown below, together with the equation for the thermal decomposition of calcium carbonate.

Ca	C	O
40	12	16

$$CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$$

(g) Use this information to calculate the decrease in mass of solid if 10.0 grams of pure calcium carbonate decomposed according to the equation given. Show your working.

[4]

(h) Use the graph, and your answer to (g), to estimate the percentage of calcium carbonate in the limestone. Mark on the graph the measurement you have made, and show your working and answer in the space below. (If you were unable to complete part (g), you should assume the answer to that calculation was 4.0 grams, although this is not the correct value.)

[4]

(i) What has been assumed here about the impurities in the limestone?

[1]

2. Arabella and Beatrice were asked to investigate the reaction of calcium carbonate with hydrochloric acid:

$$CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + CO_2(g) + H_2O(l)$$

They were each given an identical sample of calcium carbonate, 100 cm^3 of hydrochloric acid, and the apparatus shown below. They were instructed to:

1. Add the acid to the flask.
2. Add the calcium carbonate to the flask and immediately fit the bung.
3. Record the volume of gas produced at suitable time intervals.
4. Plot a graph of the results and draw a line of best fit.

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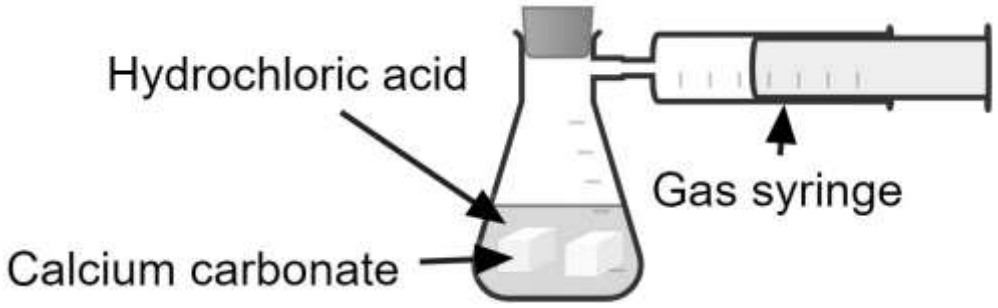
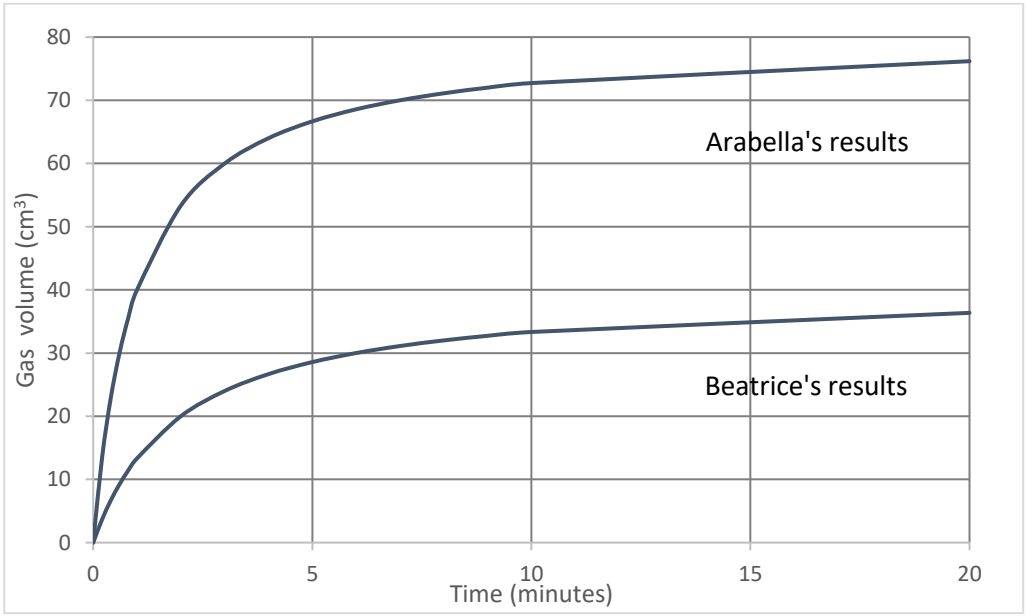


Their graphs are shown below. There was some calcium carbonate left over at the end of both experiments.



(a) Their teacher said that Arabella's acid was twice as concentrated as Beatrice's. How did the teacher deduce this from the results? **[1]**

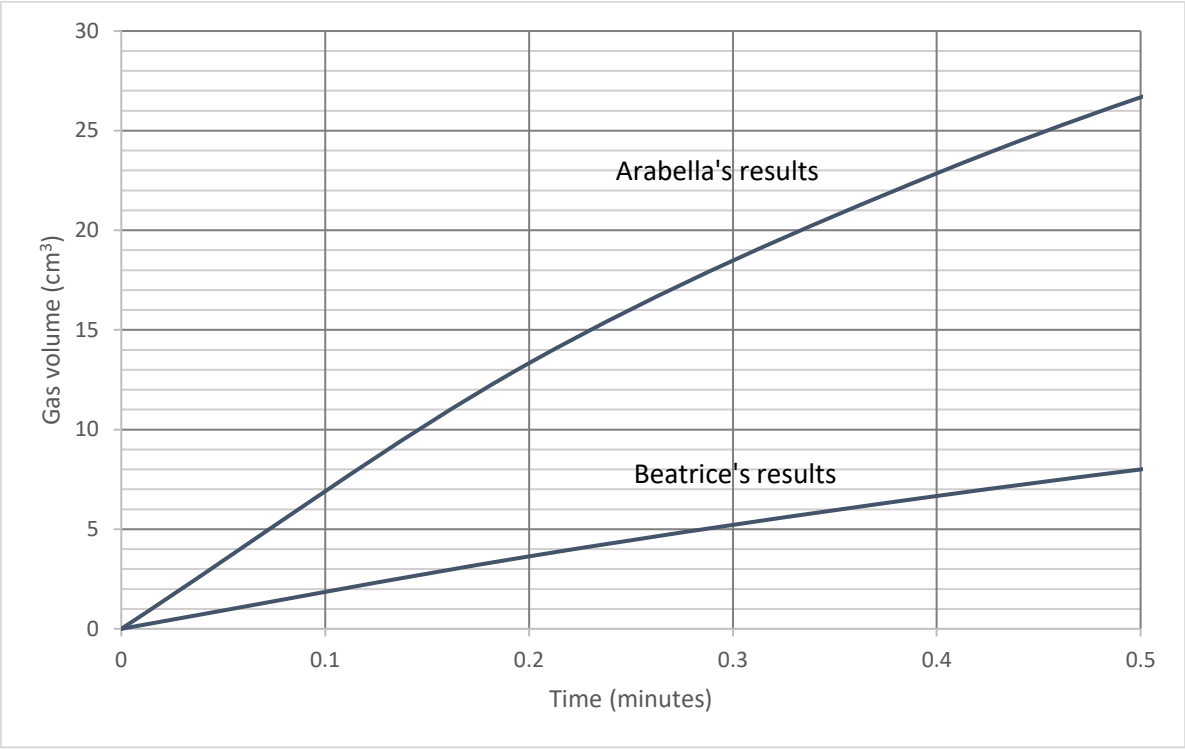
The rate of the reaction depends on the concentration of the acid. Two possibilities are:

[Rate of reaction] is proportional to [Concentration of acid]

or

[Rate of reaction] is proportional to [Concentration of acid]^{2}

To decide which is correct requires an estimate of the *initial* rate of the reaction (the rate when time=0). This can be done by measuring the rate of gas production (the gradient of the graph) during a short time interval at the start of the reaction. The graph below shows the start of each experiment in more detail.



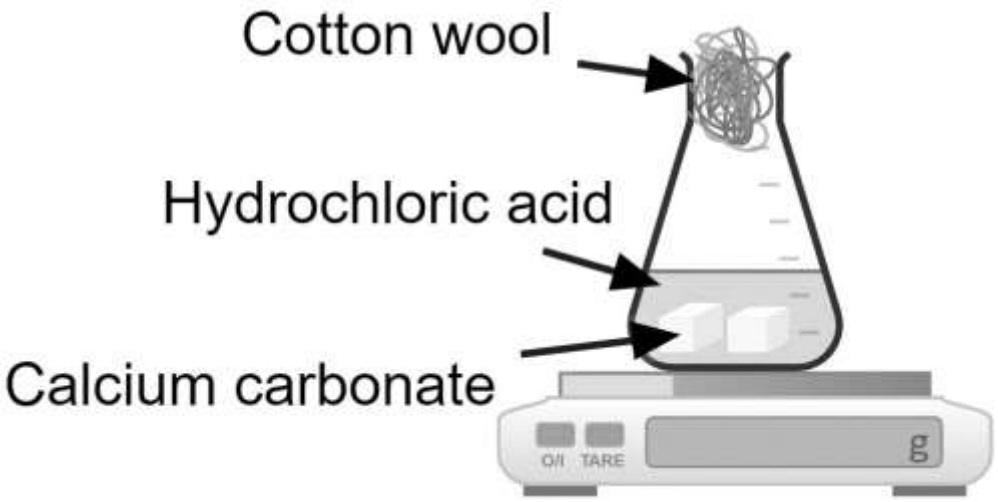
(b) Use the graph to find the volume of gas produced during the first 0.2 minutes in each experiment. Hence calculate the rate of gas production during this period for each experiment, showing your working. Remember to state the units of your answers.

[4]

(c) Your answers to (b) should represent approximately the initial rate of each reaction. Hence explain which of the two possible relationships between rate and concentration (shown at the top of the previous page) is correct.

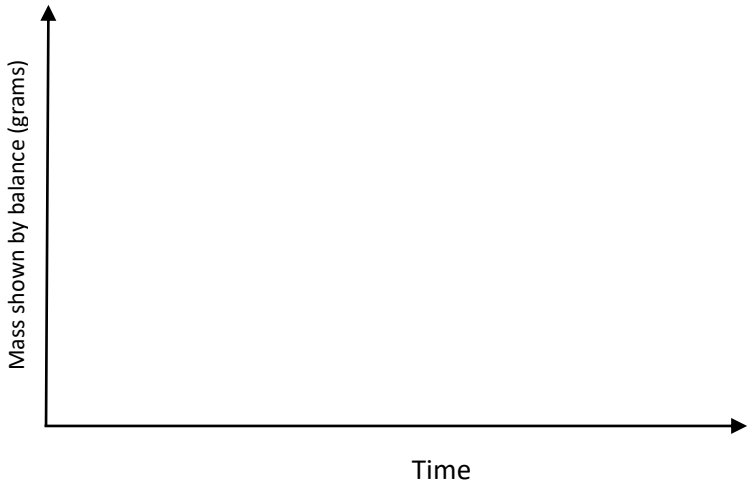
[3]

Charlotte investigated the same reaction, but using the apparatus shown below. She placed the reaction flask on a balance and recorded the mass shown by the balance at suitable time intervals.



(d) Using the axes below, sketch the form of the graph which Charlotte should obtain when she plots her results. You do not need to estimate any numerical values or add scales to the axes.

[2]



(e) What was the purpose of the cotton wool in the neck of the flask? Put a cross in the correct box.

☐ To stop carbon dioxide escaping from the flask.

☐ To stop liquid droplets escaping from the flask.

☐ To stop calcium carbonate escaping from the flask.

☐ To stop air entering the flask.

[1]

[End of Paper]