

# Chem!stry

Name: ..... ( )

Class: .....

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## Rate of Reaction – Assignment One – Answers

### Question 1.

- a) Write a balanced chemical equation, including state symbols, for the reaction between zinc and dilute sulfuric acid.



- b) Give **three** ways by which the speed of the reaction between zinc and hydrochloric acid can be measured.

Measure the volume of hydrogen gas produced against time.

Measure the change in pH against time.

Measure the change in temperature against time.

Measure the change in mass of the reaction against time as  $\text{H}_2(\text{g})$  is allowed to escape.

- c) Give **three** ways in which the speed of the reaction between zinc and dilute sulphuric acid can be increased.

Increase the temperature of the reaction.

Increase the surface area (to volume ratio) of the zinc.

Increase the concentration of the sulfuric acid.

Add a catalyst to the reaction.

### Question 2.

Equal lengths of magnesium ribbon were added to  $3 \text{ mol / dm}^3$  hydrochloric acid and to  $3 \text{ mol / dm}^3$  sulfuric acid. When the reactions had stopped, some metal remained.

- a) Write the equations for the reactions.



- b) With which acid would the reaction be faster at the start? Briefly explain your answer.

Sulfuric acid,  $\text{H}_2\text{SO}_4$ . Sulfuric acid is dibasic, therefore 1 mol of sulfuric acid will ionize to produce 2 mol of hydrogen ions. Hydrochloric acid is monobasic, therefore 1 mol of hydrochloric acid will ionize to produce 1 mol of hydrogen ions. Sulfuric acid contains a greater concentration of hydrogen ions compared to the hydrochloric acid. There will be a greater frequency of effective collisions between the hydrogen ions and magnesium in the reaction using sulfuric acid.

- c) How would the speed of the reaction change if the concentration of the acids were changed to 6 mol / dm<sup>3</sup>?

The speed of the reaction would double if the concentrations were doubled.

- d) What would be the effect on the speed of reaction if the magnesium ribbon were replaced by powdered magnesium? Briefly explain your answer.

The speed of the reaction would increase. Using powdered magnesium increases the surface area of the magnesium that is in contact with the acid. This will increase the frequency of the effective collisions that take place between the hydrogen ions and magnesium.

### Question 3.

Sulfur is formed when colourless solutions of hydrochloric acid and sodium thiosulfate are mixed.



- a) What would you see during the reaction?

Solid yellow sulfur will precipitate from the solution.

- b) State two ways to make the reaction go faster.

i) Increase the temperature of the reaction.

ii) Increase the concentration of the hydrochloric acid / sodium thiosulfate.

- c) In this experiment, 50 cm<sup>3</sup> of 1.0 mol / dm<sup>3</sup> hydrochloric acid is added to 50 cm<sup>3</sup> of 1 mol / dm<sup>3</sup> sodium thiosulfate. What causes the reaction to stop?

Moles of hydrochloric acid =  $1.0 \times 50 \times 10^{-3} = 0.0500$  mol

Moles of sodium thiosulfate =  $1.0 \times 50 \times 10^{-3} = 0.0500$  mol

From the balanced chemical equation, 2 mol of hydrochloric acid react with 1 mol of sodium thiosulfate. Therefore 0.100 mol of hydrochloric acid are required to react with 0.0500 mol of sodium thiosulfate. However, only 0.0500 mol of hydrochloric acid are available.

Hydrochloric acid is the limiting reagent and the reaction stops once all of the hydrochloric acid has reacted.

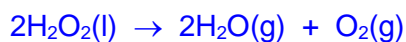
- d) Why is sulfur dioxide gas not obtained during this reaction? Suggest how gaseous sulfur dioxide can be obtained from the final reaction mixture.

Sulfur dioxide is very soluble in water and therefore dissolves in the water that is present. The solubility of a gas decreases as temperature increases. Therefore, the sulfur dioxide gas can be obtained by heating / warming the final reaction mixture.

#### Question 4.

Manganese(IV) oxide acts as a catalyst for the decomposition of hydrogen peroxide into water and oxygen.

- a) Write the balanced chemical equation for the decomposition of hydrogen peroxide.



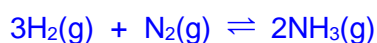
- b) State briefly the general properties associated with catalysts.

A catalyst will increase the rate / speed of a reaction by lowering the activation energy of the reaction and allowing the reaction to progress by a lower energy pathway / mechanism. Overall, the catalyst is unchanged by the reaction.

- c) Describe the experiment(s) you would carry out to confirm that manganese(IV) oxide is acting as a catalyst in this decomposition.

Using a gas syringe, measure the volume of oxygen gas produced by the reaction against time **i)** without addition of the catalyst **ii)** with addition of the catalyst. Keep all other variables, e.g. temperature, constant.

- d) **i)** Write the balanced chemical equation for the industrial manufacture of ammonia by the Haber process.



- ii)** Name the catalyst that is used for the industrial manufacture of ammonia.  
Iron.

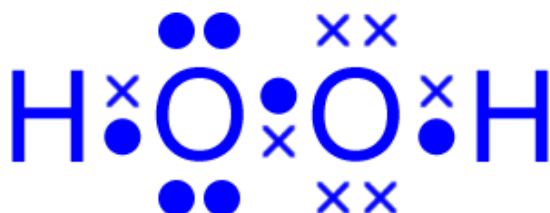
- e) Name the catalyst used by green plants for photosynthesis.

Chlorophyll.

#### Question 5.

When liquid hydrogen peroxide ( $\text{H}_2\text{O}_2$ ) is mixed with liquid hydrazine ( $\text{N}_2\text{H}_4$ ) a very fast exothermic reaction takes place which can propel a rocket into space. The reaction products are nitrogen and steam.

- a) Draw a dot-and-cross diagram to clearly show the arrangement of the electrons, and hence the bonding, in hydrogen peroxide.



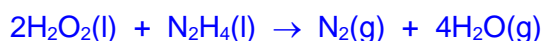
b) What is meant by “an exothermic reaction”?

A reaction that releases energy, normally in the form of heat and / or light, into the surroundings. The enthalpy change for an exothermic reaction is always negative.

c) Suggest a reason why this reaction needs to be very fast.

The reaction must fast in order to accelerate the rocket to a very high speed in a very short period of time.

d) Write the balanced chemical equation, including state symbols, for the reaction between hydrogen peroxide and hydrazine.



e) If the rocket is loaded with 680 kg of hydrogen peroxide, calculate the mass of hydrazine that will be needed to react with it.

Moles = mass in grams  $\div$  relative molecular mass

Moles of  $\text{H}_2\text{O}_2 = 680\,000 \div (1 + 1 + 16 + 16) = 20\,000$  mol

From the balanced chemical equation, 2 mol of  $\text{H}_2\text{O}_2$  react with 1 mol of  $\text{N}_2\text{H}_4$

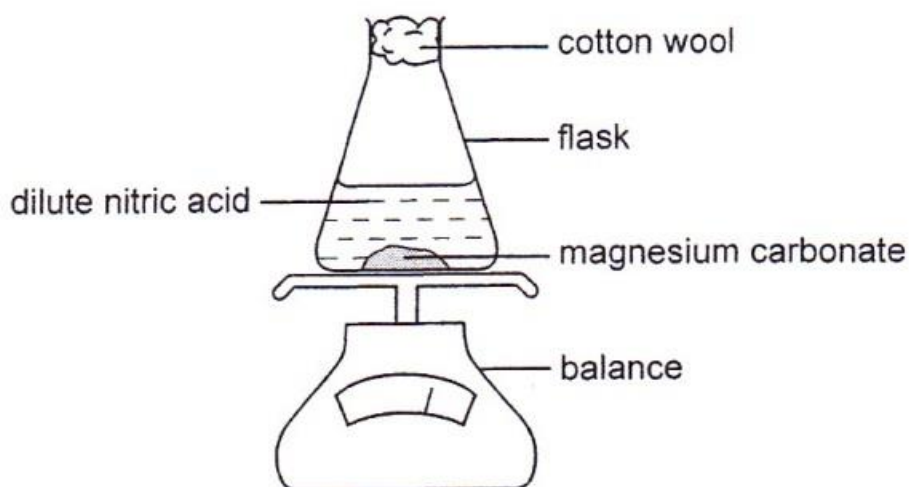
$\therefore 20\,000$  mol of  $\text{H}_2\text{O}_2$  react with  $20\,000 \times \frac{1}{2} = 10\,000$  mol of  $\text{N}_2\text{H}_4$

Mass in grams = moles  $\times$  relative molecular mass

Mass of  $\text{N}_2\text{H}_4 = 10\,000 \times (14 + 14 + (4 \times 1)) = 320\,000$  g or 320 kg

### Question 6.

Small lumps of magnesium carbonate were added to dilute nitric acid (solution **A**) in the apparatus shown in the diagram.



The balance reading was noted as soon as the lumps were added, and again after two minutes. The experiment was repeated by changing only the concentration of the nitric acid (solution **B**).

The results obtained were:

Acid Solution	Balance Reading	
	Initial	After 2 Minutes
A	120.7	116.2
B	104.9	98.8

a) Why do the balance readings decrease over the two minutes?

The reaction between nitric acid and magnesium carbonate produces carbon dioxide gas as one of the reaction products. As carbon dioxide gas escapes from the reaction flask, the mass of the reaction decreases.

b) What is the purpose of the cotton wool plug?

Cotton wool allows carbon dioxide gas to escape from the reaction flask, but prevents any of the solution being ejected / sprayed from the reaction flask as the small bubbles burst. Any change in mass is due to loss of carbon dioxide gas and not due to loss of the solution.

c) Giving reasons for your answers, explain which solution, **A** or **B**,

i) Gives the faster speed of reaction.

For acid solution **A**,  $120.7 - 116.2 = 4.50$  g

For acid solution **B**,  $104.9 - 98.8 = 6.10$  g

Acid solution **B** produces a greater mass of carbon dioxide in 2 minutes compared to acid solution **A**. Therefore acid solution **B** gives the faster speed of reaction.

ii) Has the highest concentration.

Acid solution **B** has the highest concentration. The more concentrated acid contains more hydrogen ions per unit volume and therefore has the greatest frequency of effective collisions leading to the faster speed of reaction.

d) Using ideas of collisions between particles, explain why powdered magnesium carbonate would react faster than lumps of magnesium carbonate in this experiment.

For the same mass, powdered magnesium carbonate has a larger surface area (to volume ratio) than lumps of calcium carbonate. Because there is a larger surface area over which collisions can take place, the frequency of effective collisions will be greater for the powdered magnesium carbonate compared to the lumps of magnesium carbonate.

e) Write the balanced chemical equation for another reaction for which the rate could be followed using this apparatus.

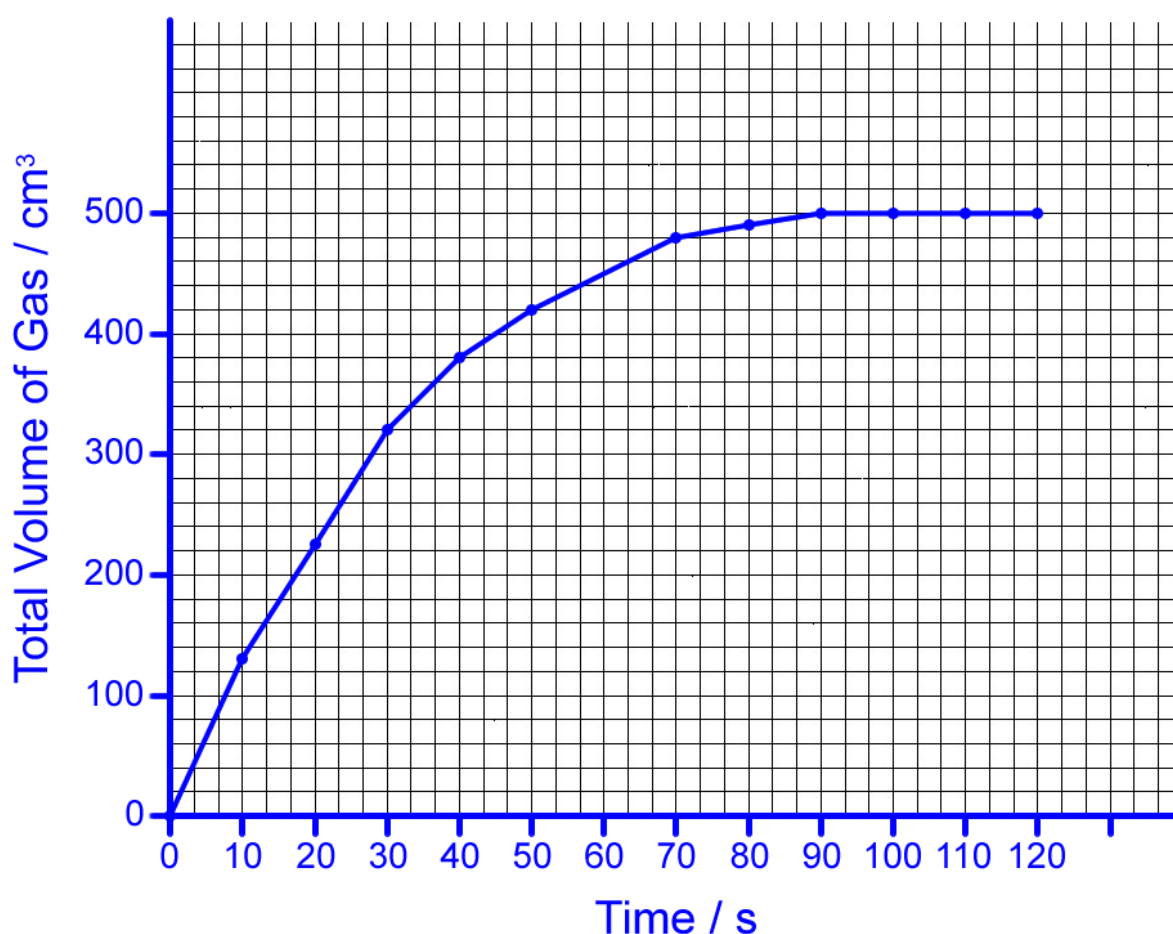


**Question 7.**

50 cm<sup>3</sup> of dilute hydrochloric acid was added to an excess of calcium carbonate contained in a flask connected to a gas syringe. The gas evolved was collected in the syringe at room temperature and pressure, and the total volume recorded at 10 second intervals. When no more gas was evolved some calcium carbonate remained unreacted in the flask. The results are shown in the table.

Time / s	10	20	30	40	50	60	70	80	90	100	110	120
Total Volume of gas / cm <sup>3</sup>	130	225	320	380	420	ca. 450	480	490	500	500	500	500

a) Plot the results on the graph paper provided below.



b) At what time does the reaction stop?

90 seconds.

c) What causes the reaction to slow down and eventually stop?

The concentration of hydrochloric acid (hydrogen ions) gradually decreases until all of the acid has reacted. Once no more hydrochloric acid (hydrogen ions) is present in the solution, the reaction will stop.

- d) Estimate, from the graph, the total volume of gas collected at 60 seconds.

450 cm<sup>3</sup>

- e) Write an equation for the reaction.



- f) Calculate the concentration, in mol / dm<sup>3</sup>, of the hydrochloric acid.

Moles of gas = volume in cm<sup>3</sup> ÷ 24 000

Moles of CO<sub>2</sub> = 500 ÷ 24 000 = 0.0208 mol

From the balanced chemical equation, 1 mol of CO<sub>2</sub> is produced by 2 mol HCl

∴ 0.0208 mol of CO<sub>2</sub> is produced by 2 × 0.0208 = 0.0416 mol of HCl

∴ There are 0.0416 mol of HCl in 50 cm<sup>3</sup> of solution

∴ There are (0.0416 ÷ 50) × 1000 = 0.832 mol of HCl in 1000 cm<sup>3</sup> = 0.832 mol / dm<sup>3</sup>

- g) On the graph paper, sketch a second curve, labelled "*Experiment 2*" to show the results you would expect to obtain if the experiment were repeated with the same quantities of materials, but with the hydrochloric acid at a higher temperature (the gas still being collected at room temperature).

[The initial gradient will be steeper. The volume of gas will reach 500 cm<sup>3</sup> in a shorter time].

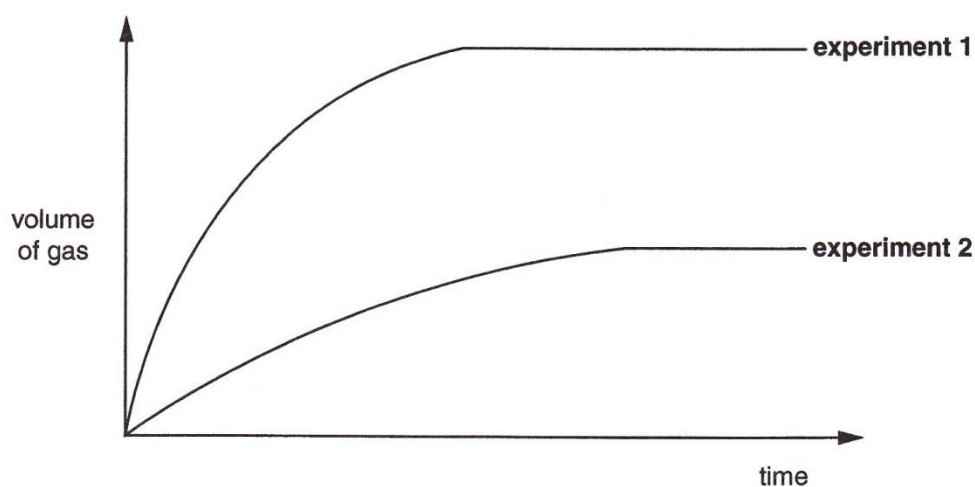
### Question 8.

An experiment was carried out to measure the rate of reaction between excess powdered calcium carbonate and dilute acids.

In **Experiment 1**, 25 cm<sup>3</sup> of 1.5 mol / dm<sup>3</sup> hydrochloric acid were used.

A further experiment using hydrochloric acid, **Experiment 2**, was carried out.

The results of **Experiments 1** and **2** are shown on the graph below.



- a) Suggest the concentration and volume of acid used for **Experiment 2**.

Concentration 0.750 mol / dm<sup>3</sup>

Volume 25.0 cm<sup>3</sup>

b) **Experiment 3** was carried out using 25 cm<sup>3</sup> of 1.5 mol / dm<sup>3</sup> sulfuric acid.

The initial rate of reaction for **Experiment 3** was faster than that for the other experiments, but the reaction stopped suddenly after only a small amount of gas had been produced.

i) Name the salt formed in **Experiment 3**.

Calcium sulfate, formula CaSO<sub>4</sub>.

ii) Explain why the reaction stops suddenly.

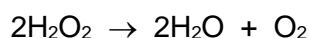
Calcium sulfate is insoluble in water. As a layer of insoluble calcium sulfate forms over the surface of the calcium carbonate, the sulfuric acid will no longer come into contact with the calcium carbonate and will not react with the calcium carbonate.

iii) Explain why the initial rate of reaction for Experiment 3 was faster than the initial rate of reaction for Experiments 1 and 2.

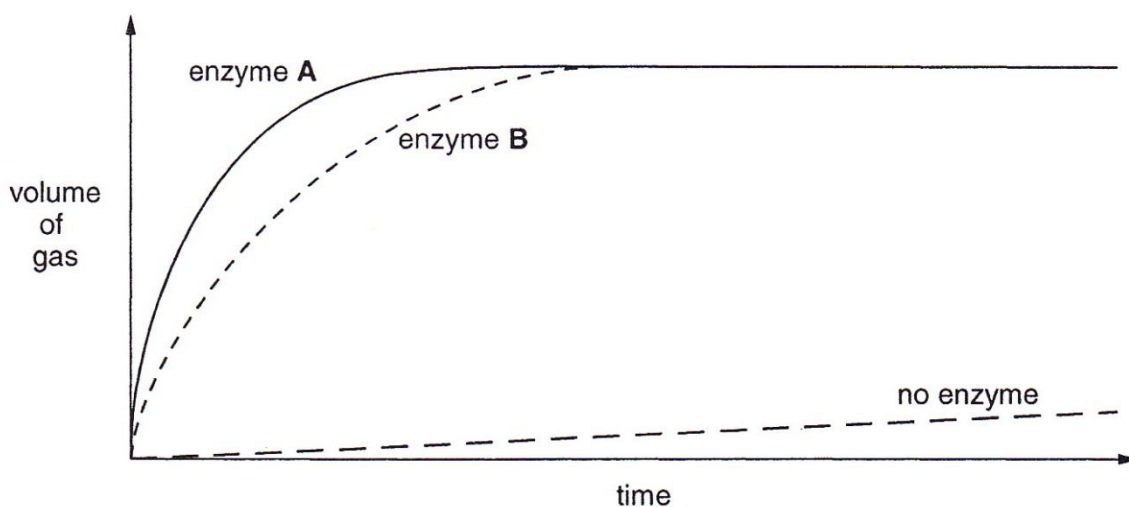
Sulfuric acid is a dibasic acid, meaning that one molecule produces two hydrogen ions. Hydrochloric acid is monobasic, meaning that one molecule produces one hydrogen ion. The concentration of hydrogen ions in the sulfuric acid is greater than the concentration of hydrogen ions in the hydrochloric acid (of the same concentration of acid). Therefore the frequency of effective collisions is greater for the sulfuric acid, leading to a faster initial rate of reaction.

### Question 9.

Hydrogen peroxide decomposes to give water and oxygen.



A student carried out three experiments to investigate the rate of reaction. She used the same volume and concentration of hydrogen peroxide each time. Her first experiment used only hydrogen peroxide. Her second and third experiments investigated the effects of adding enzyme **A** and enzyme **B** to the reaction mixture. The graph shows her results.



a) Suggest a method the student could use to follow the rate of the reaction.

Use a gas syringe to measure the volume of oxygen gas produced against time. OR Use a balance to measure the mass of oxygen gas lost against time.



- b) i) Describe the effect of each enzyme on the rate of the reaction.  
Both enzymes increase the rate of the reaction.  
The gradient for the initial reaction with enzyme **A** is greater / steeper than the gradient for the initial reaction with enzyme **B**, therefore enzyme **A** increases the rate of the reaction more than enzyme **B**.
- ii) Use ideas about activation energy to explain why the shape of the graph is so different when no enzyme is used.  
The activation energy for the reaction without an enzyme is much greater than the activation energy for the reaction with an enzyme. Without an enzyme, only a small fraction / proportion of the hydrogen peroxide molecules possess energy greater than the reaction's activation energy, and so the rate of the reaction is very slow.
- c) The student repeated the experiment for enzyme **B**. This time she used the same volume of hydrogen peroxide, but half the original concentration. She continued to measure the volume of gas until the reaction was complete. Sketch a curve on the graph to show the pattern of results for this experiment.

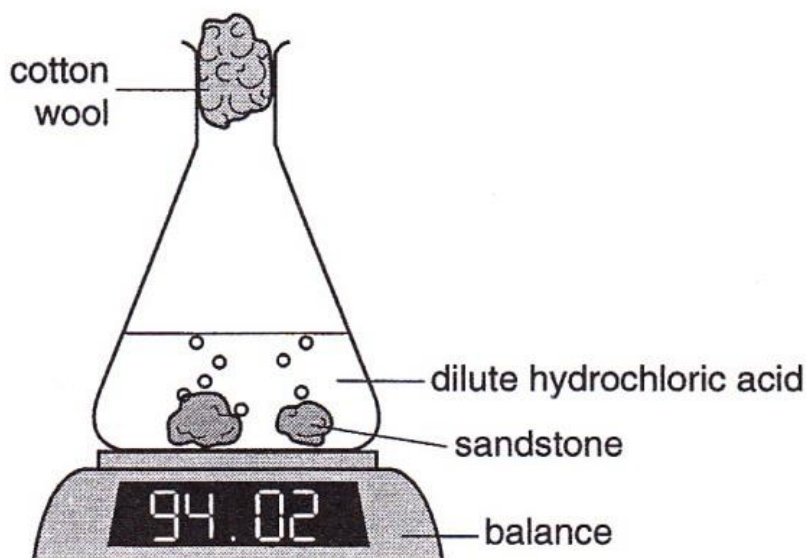
[The initial gradient is not as steep as the original reaction. The volume of oxygen gas produced will be half the volume of the original reaction].

### Question 10.

Sandstone contains sand (mainly silicon dioxide) and calcium carbonate. In an experiment, excess sandstone was reacted with dilute hydrochloric acid.



The rate of reaction was followed by measuring the mass lost during the reaction.

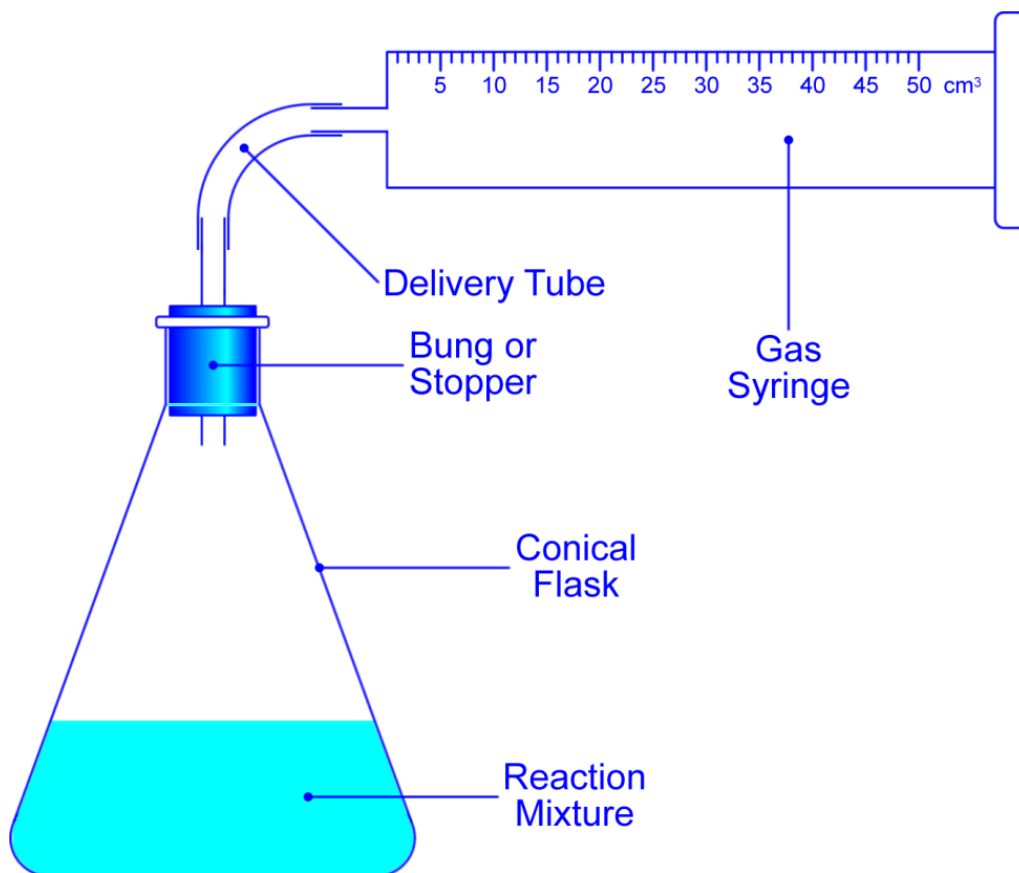


This is a table of the results.

Time / minutes	Total mass lost / g
0	0.00
4	0.18
8	0.30
12	0.38
16	0.44
20	0.48
24	0.51

- a) Use the information from the table to show that the rate of reaction decreased.  
Initial rate of reaction =  $0.18 - 0.00 = 0.18$  g of CO<sub>2</sub> produced in 4 minutes.  
Final rate of reaction =  $0.51 - 0.48 = 0.03$  g of CO<sub>2</sub> produced in 4 minutes.  
As the reaction progresses, the mass of carbon dioxide that is produced per unit time decreases, therefore the rate of reaction is decreasing.
- b) Explain, using ideas about particles colliding, why the rate of reaction decreased.  
As the hydrochloric acid reacts with the calcium carbonate, the concentration of hydrochloric acid (hydrogen ions) gradually decreases. As the concentration (number per unit volume) of the hydrogen ions decreases so the frequency of effective collisions between the hydrogen ions and calcium carbonate decreases, and the rate of the reaction decreases.

- c) Draw a labelled diagram to show a **different** method of following the rate of reaction between sandstone and hydrochloric acid.



- d) In a second experiment, 10 g of sandstone was added to excess hydrochloric acid. The total mass lost was 0.88 g. Calculate the percentage by mass of calcium carbonate in the sandstone.

Moles = mass in grams  $\div$  relative molecular mass

Moles of carbon dioxide =  $0.88 \div (12 + 16 + 16) = 0.0200$  mol

From the balanced chemical equation, 1 mol of  $\text{CO}_2$  is produced by 1 mol of  $\text{CaCO}_3$

$\therefore$  0.0200 mol of  $\text{CO}_2$  are produced by 0.0200 mol of  $\text{CaCO}_3$

Mass in grams = moles  $\times$  relative molecular mass

Mass of  $\text{CaCO}_3 = 0.0200 \times (40 + 12 + (3 \times 16)) = 2.00$  g

Percentage  $\text{CaCO}_3$  in the sandstone =  $(2 \div 10) \times 100 = 20.0\%$