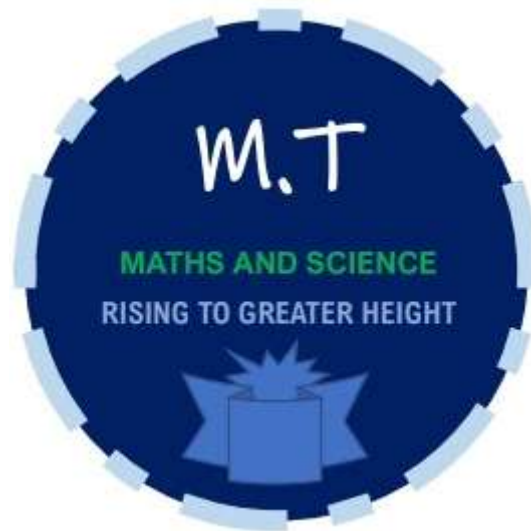




**PHYSICAL SCIENCES**  
**GRADE 12**



**PHYSICAL SCIENCES**  
**GRADE 12**

**TOPIC:**

**REACTION**  
**RATES**



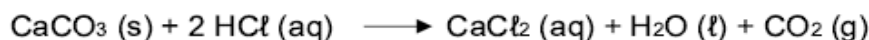
## REACTION RATES

### ACTIVITY 1 ES25

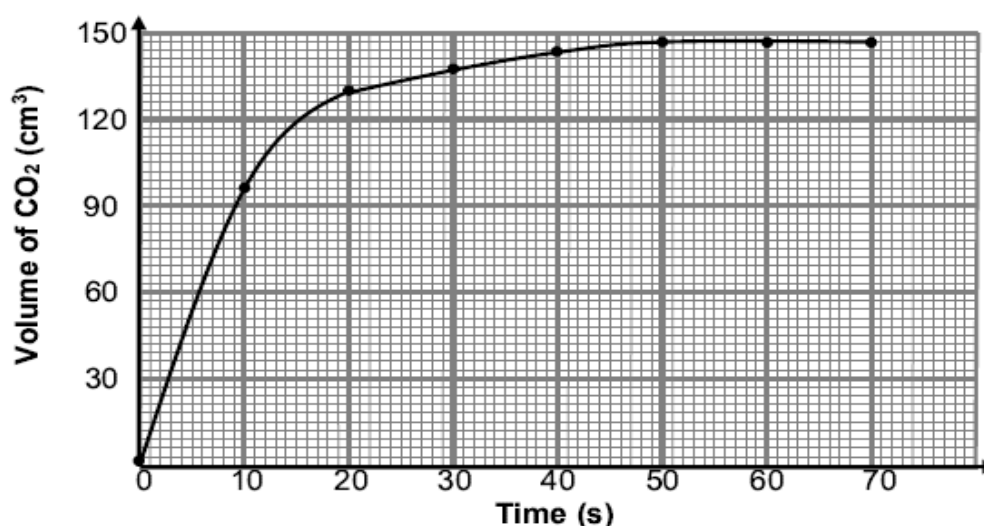
5.1 Define the term *reaction rate*.

(2)

A group of learners want to determine the percentage purity of a sample that contains calcium carbonate ( $\text{CaCO}_3$ ). They react 2,5 g sample of impure calcium carbonate ( $\text{CaCO}_3$ ) with EXCESS dilute hydrochloric acid ( $\text{HCl}$ ) according to the balanced equation.



They measure the volume of carbon dioxide gas produced over time and obtained the graph below.



5.2 How will the learners know that the reaction has reached completion?

(1)

5.3 Calculate the:

5.3.1 Average rate at which  $\text{CO}_2$  is produced in  $\text{cm}^3 \cdot \text{s}^{-1}$

(3)

5.3.2 Percentage purity of  $\text{CaCO}_3$  if the molar volume of  $\text{CO}_2$  is  $24\,000 \text{ cm}^3 \cdot \text{mol}^{-1}$  at  $25^\circ\text{C}$

(5)

5.4 The experiment is repeated by using powdered sample of calcium carbonate instead of chunked sample of calcium carbonate.

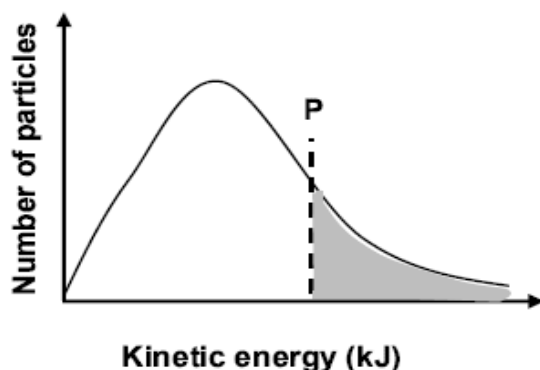
5.4.1 Will the reaction rate INCREASE, DECREASE or REMAIN THE SAME?

(1)

5.4.2 Explain the answer to QUESTION 5.4.1 by referring to the collision theory.

(3)

- 5.5 The graph below represents the Maxwell-Boltzmann distribution curve for  $\text{CO}_2(\text{g})$  at  $25^\circ\text{C}$ .



5.5.1 What does the shaded area to the right of line **P** represents? (1)

5.5.2 How will an increase in temperature affect the shaded area?

Choose from INCREASES, DECREASES or NO EFFECT.

Give a reason for the answer.

(2)  
[18]

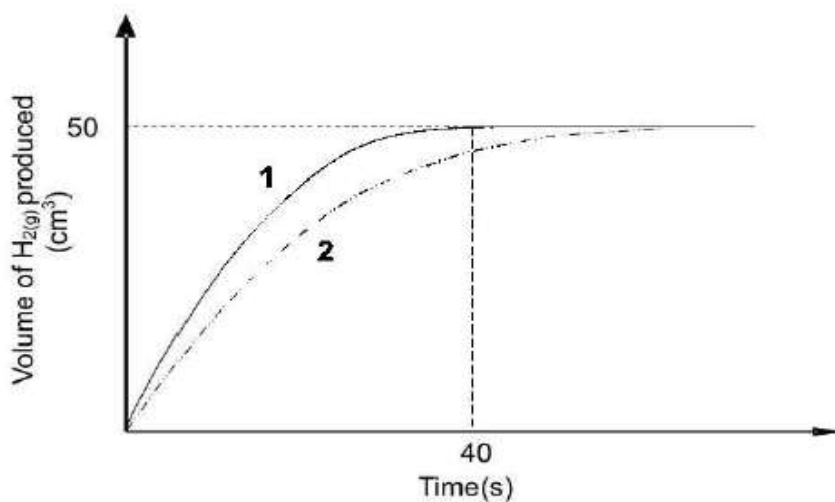
### ACTIVITY 2 F25T

A factor influencing the rate of a chemical reaction is investigated by conducting two experiments, **1** and **2**, in which the following reaction occurs:

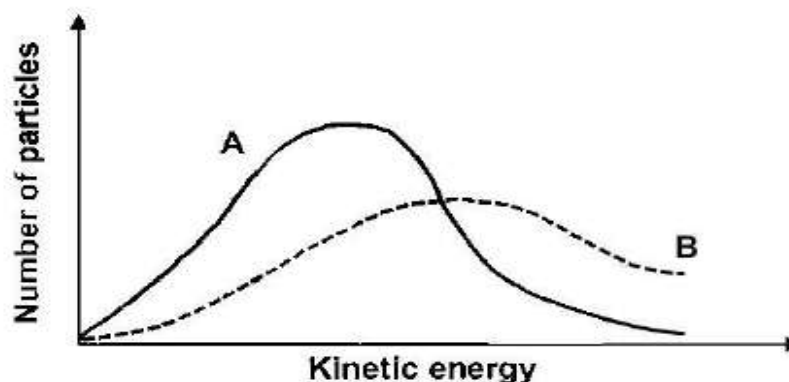


In both experiments, the same mass of magnesium(Mg) is added to an EXCESS hydrochloric acid(HCl) solution with the same concentration in an open flask at STP.

The graph below shows the changes in the amount of gas collected during the reaction in experiments **1** and **2**.



- 5.1 Write down the **name** of the apparatus used for collecting the gas. (1)
- 5.2 Define the term **rate of reaction**. (2)
- 5.3 Calculate the average rate (in  $\text{dm}^3 \cdot \text{s}^{-1}$ ) at which hydrogen is produced in experiment 1. (3)
- 5.4 If 2 g of magnesium was used for this investigation, calculate the percentage purity of the magnesium. (7)
- 5.5 The Maxwell-Boltzmann distribution curves for the reaction in experiment 1 and 2 are given below.



- 5.5.1 Which factor affecting the reaction rate is being investigated? (1)
- 5.5.2 Which curve (**A** or **B**) represents the reaction in experiment 2? (1)
- 5.5.3 Explain the answer to QUESTION 5.5.2 by referring to the collision theory. (2)

[17]



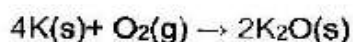
# PHYSICAL SCIENCES

## GRADE 12

### ACTIVITY 3 NWT25

Two experiments, I and II, are conducted to investigate one of the factors that affects the rate of reaction using the reaction between potassium, K(s) and EXCESS oxygen O<sub>2</sub>(g) at a certain temperature.

The balanced equation for the reaction is:



The reaction conditions used for each experiment are as follows:

#### EXPERIMENT I

6,92 g of potassium granules react with 4,28g oxygen at 30 °C.

#### EXPERIMENT II

6,92 g of potassium powder react with 4,28g oxygen at 30 °C.

5.1 Define the term *reaction rate*. (2)

5.2 Write down the independent variable for the reaction. (1)

5.3 In which experiment is the reaction rate higher?

Write only Experiment I or Experiment II. (1)

5.4 Use the COLLISION THEORY to explain the answer in QUESTION 5.3. (3)

7,36 g of potassium oxide is produced when the reaction reaches its completion in EXPERIMENT II in 5,2 s.

5.5 Calculate the:

5.5.1 Average rate of production of potassium oxide in g·s<sup>-1</sup> (3)

5.5.2 Percentage purity of potassium (6)

5.6 Is ΔH for the experiments POSITIVE or NEGATIVE?

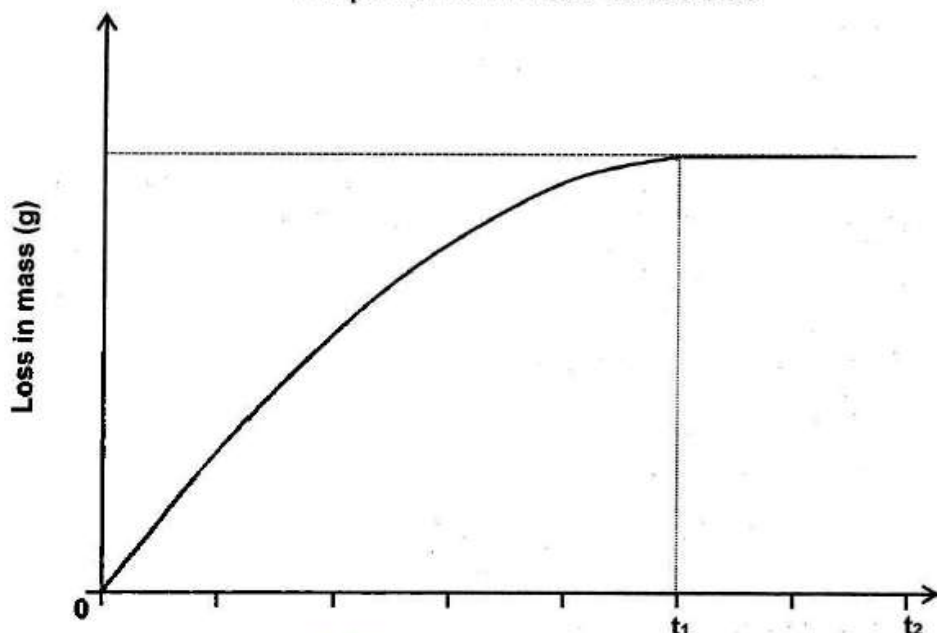
Explain the answer. (2)  
[18]



### ACTIVITY 4 25KT

The loss in mass of the flask and its contents is recorded. The results obtained are shown in the graph below.

Graph of loss in mass versus time



The average gradient of the above graph for the time interval 0 to  $t_1$  minutes is  $1,37 \text{ g} \cdot \text{min}^{-1}$ .

- 5.2 Define the term *reaction rate*. (2)
- 5.3 Explain the shape of the graph for the time interval  $t_1$  to  $t_2$  minutes. (2)
- 5.4 Apart from concentration and temperature changes, write down TWO other changes that can be made to increase the rate of this reaction. (2)
- 5.5 Calculate the value of  $t_1$  in minutes. (8)
- 5.6 The experiment is now repeated using hydrochloric acid of a higher concentration.  
How would a higher concentration of hydrochloric acid affect the following:  
(Write down only INCREASES, DECREASES or REMAINS THE SAME.)
  - 5.6.1 Loss in mass per unit time. (1)
  - 5.6.2 Total loss in mass.  
Give a reason for the answer. (2)
- 5.7 Use the collision theory to explain the answer to question 5.6.1 (3)

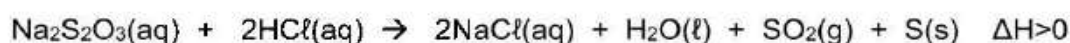
[21]

### ACTIVITY 5 GT25

- 5.1 Define the term *heat of reaction*. (2)
- 5.2 The reaction between sodium thiosulfate and hydrochloric acid is investigated. A conical flask is placed over a cross on a piece of paper. The time is measured from the moment the acid is added to the sodium thiosulfate until the cross disappears.



The equation of the reaction is given:



The reaction is carried out with solutions of different concentrations of sodium thiosulfate.

The table below shows the data collected.

| CONCENTRATION OF<br>$\text{Na}_2\text{S}_2\text{O}_3$<br>( $\text{mol}\cdot\text{dm}^{-3}$ ) | TIME TAKEN UNTIL THE CROSS COULD<br>NOT BE SEEN (IN SECONDS) |         |         |         |
|----------------------------------------------------------------------------------------------|--------------------------------------------------------------|---------|---------|---------|
|                                                                                              | TRIAL 1                                                      | TRIAL 2 | TRIAL 3 | AVERAGE |
| 0,040                                                                                        | 71                                                           | 67      | 69      | 69      |
| 0,060                                                                                        | 42                                                           | 45      | 45      | 44      |
| 0,080                                                                                        | 31                                                           | 41      | 33      | X       |

- 5.2.1 Identify the independent variable. (1)
- 5.2.2 Calculate the average rate of reaction, in  $\text{mol}\cdot\text{dm}^{-3}\cdot\text{s}^{-1}$ , for the highest concentration used. (3)
- 5.2.3 Give the reason for the disappearance of the cross. (1)
- 5.2.4 Use the collision theory and explain the trend observed in this experiment. (3)
- 5.3 The activation energy for this reaction is 27,3 kJ.
- 5.3.1 Define the term *activation energy*. (2)
- 5.3.2 Draw a fully-labelled sketch graph of the potential energy graph for this reaction. (2)

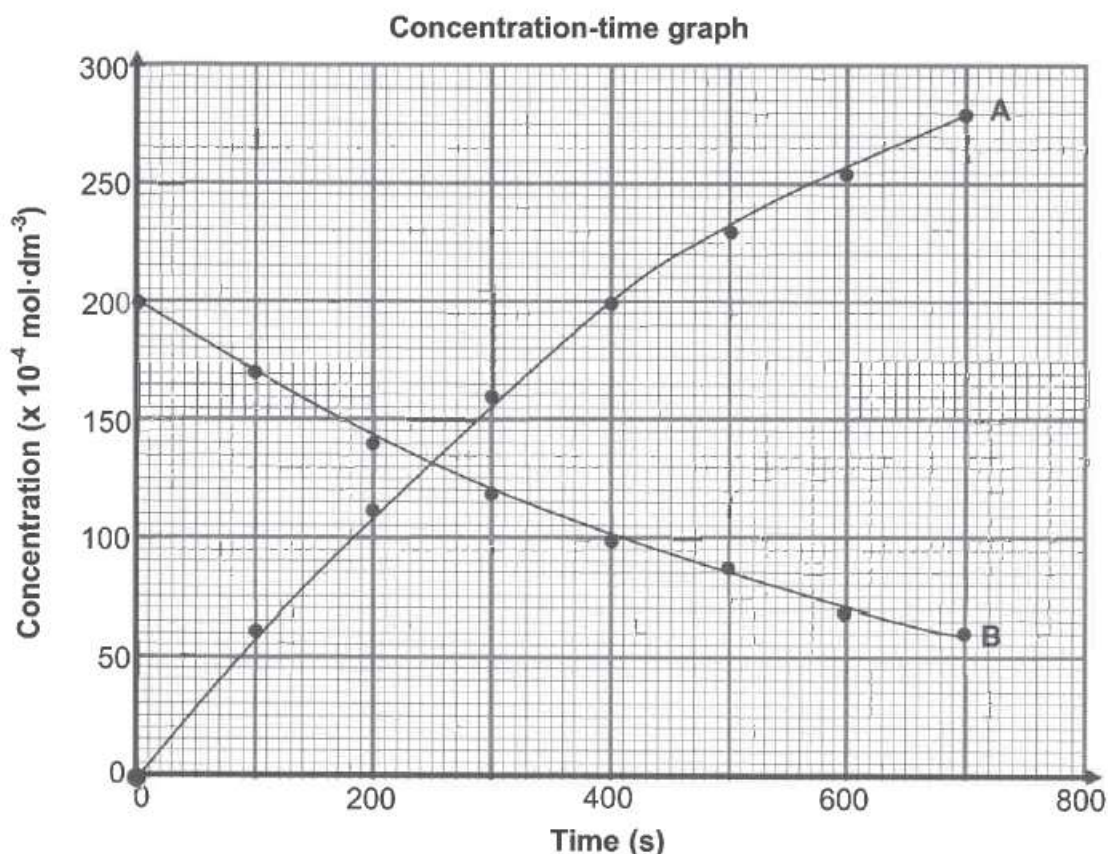
[14]

### ACTIVITY 6 G2J3

Consider the following decomposition reaction that takes place in a sealed 2 dm<sup>3</sup> container:



The graph below shows how the concentrations of N<sub>2</sub>O<sub>5</sub>(g) and NO<sub>2</sub>(g) change with time.



5.1 Refer to the graph above and give a reason why curve **A** represents the change in the concentration of NO<sub>2</sub>(g). (1)

5.2 Consider the statement below:

The rate of decomposition of N<sub>2</sub>O<sub>5</sub>(g) is half the rate of formation of NO<sub>2</sub>(g).

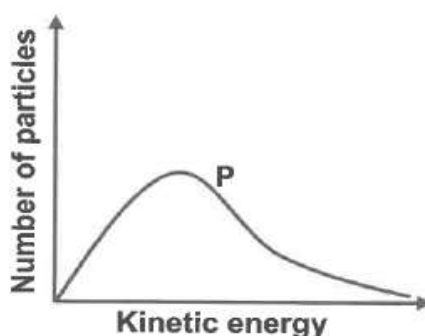
Is this statement TRUE or FALSE? Give a reason for the answer. (2)



## PHYSICAL SCIENCES

### GRADE 12

- 5.3 Calculate the:
- 5.3.1 Mass of  $\text{NO}_2(\text{g})$  present in the container at 400 s (4)
- 5.3.2 Average rate of production of  $\text{O}_2(\text{g})$  in  $\text{mol}\cdot\text{dm}^{-3}\cdot\text{s}^{-1}$  in 700 s (4)
- 5.4 The Maxwell-Boltzmann distribution curve for the  $\text{N}_2\text{O}_5(\text{g})$  initially present in the container is shown below.

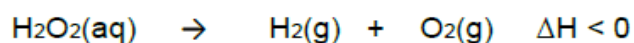


The initial concentration of the  $\text{N}_2\text{O}_5(\text{g})$  is now INCREASED.

- 5.4.1 Redraw the distribution curve above in the ANSWER BOOK and label this curve as **P**.  
  
On the same set of axes, sketch the curve that will be obtained for the higher concentration of  $\text{N}_2\text{O}_5(\text{g})$ . Label this curve as **Q**. (2)
- 5.4.2 Will the rate of decomposition of  $\text{N}_2\text{O}_5(\text{g})$  at the higher concentration be HIGHER THAN, LOWER THAN or EQUAL TO the original rate of decomposition? Explain the answer using the collision theory. (3)
- [16]

### ACTIVITY 7 ECJ22

The decomposition of hydrogen peroxide represented by the balanced equation below is used to investigate the factors that influence reaction rate.

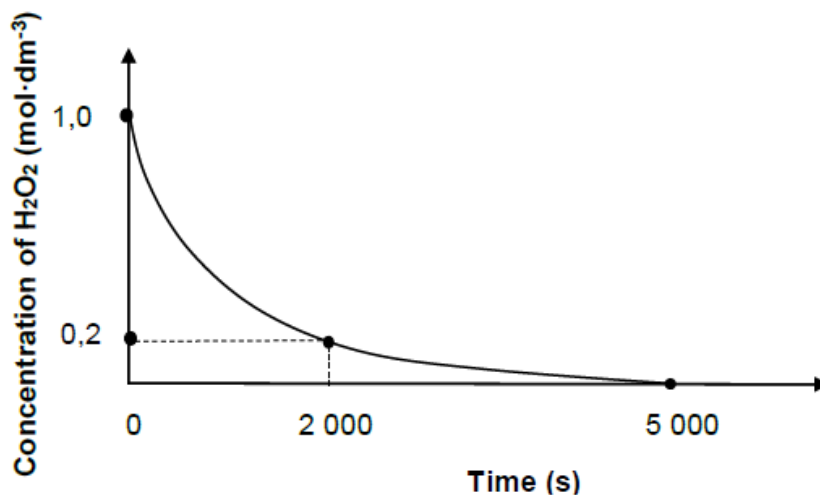


- 5.1 Define *reaction rate*. (2)
- 5.2 Besides temperature, write down TWO factors that affect the rate of this reaction. (2)



- 5.3 During an experiment (**experiment 1**),  $150 \text{ cm}^3$  of  $\text{H}_2\text{O}_2$  decomposes at  $30^\circ\text{C}$  in a flask.

The graph below shows the results of **experiment 1**.



- 5.3.1 Give a reason why the rate of reaction decreases between  $t = 2\,000 \text{ s}$  and  $t = 5\,000 \text{ s}$ . (2)

- 5.3.2 How long (in seconds) did the reaction take to reach completion? (1)

Calculate the:

- 5.3.3 Average rate of reaction (3)

- 5.3.4 Volume of oxygen produced during the interval  $t = 0$  to  $t = 2\,000 \text{ s}$ . Assume that the molar gas volume at  $30^\circ\text{C}$  is  $25\,000 \text{ cm}^3\cdot\text{mol}^{-1}$ .

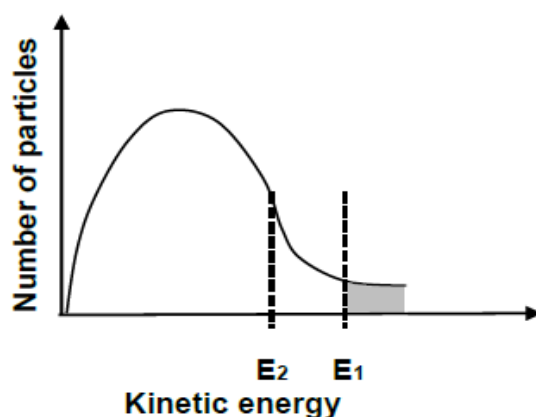
ASSUME THAT THE VOLUME OF THE SOLUTION REMAINS CONSTANT. (5)

- 5.4 How will the following be affected if the volume of hydrogen peroxide ( $\text{H}_2\text{O}_2$ ) used in **experiment 1** is doubled?

Choose from INCREASES, DECREASES or REMAINS THE SAME.

- 5.4.1 Average rate of reaction (1)
- 5.4.2 Total volume of oxygen produced (1)
- 5.5 In **experiment 2** hydrogen peroxide decomposes under the same conditions as in **experiment 1**, but a small amount of manganese dioxide is added.

The Maxwell-Boltzmann distribution curve for the reaction in **experiment 1** and **experiment 2** is shown below.



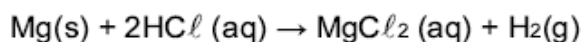
$E_1$  and  $E_2$  represent activation energies for the reaction in **experiments 1** and **2**.

- 5.5.1 Define *activation energy*. (2)
- 5.5.2 Describe what is represented by the shaded area in the graph. (1)
- 5.5.3 Which ONE of  $E_1$  or  $E_2$  would yield a higher reaction rate? Explain the answer by referring to the collision theory. (4)

[24]

### ACTIVITY 8 G24J

A group of learners use the reaction between excess hydrochloric acid and magnesium ribbon to investigate one of the factors that influences the rate of a chemical reaction. The reaction that takes place is:



The learners follow the method shown below to conduct the investigation at room temperature. A diagram of the apparatus is given below.

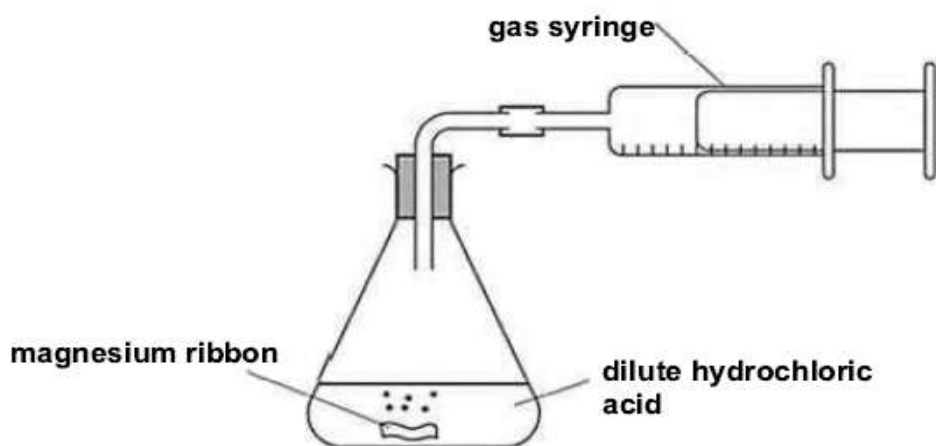
#### Method – Experiment 1:

- Step 1: Place a piece of magnesium ribbon in a conical flask and add 50 cm<sup>3</sup> HCl (aq) of known concentration.
- Step 2: Simultaneously start the stopwatch and close the flask with the rubber stopper containing the delivery tube.
- Step 3: Measure the volume of the H<sub>2</sub>(g) formed in time intervals of 20 seconds.

#### Method – Experiment 2:

Repeat steps 1 to 3 above, but use only 15 cm<sup>3</sup> of the same HCl (aq) diluted with 50 cm<sup>3</sup> distilled water.

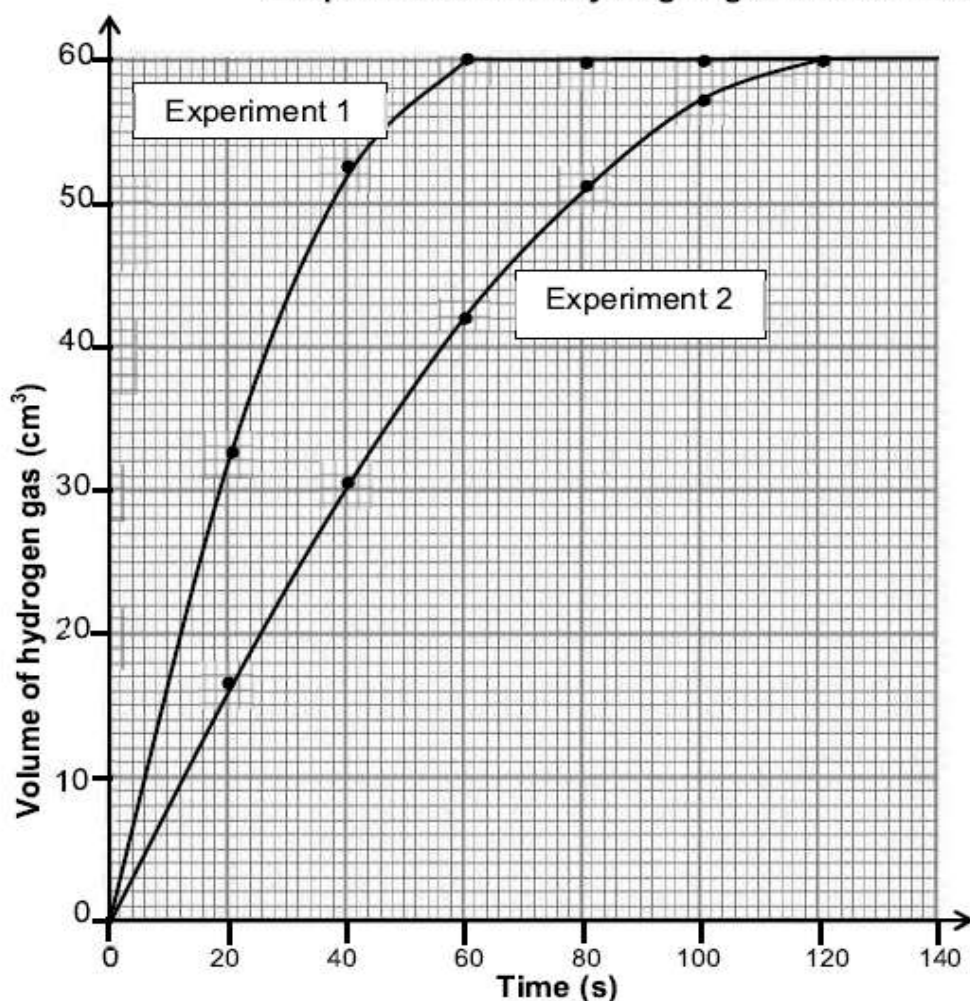
#### Apparatus:



- 5.1 Define the term *reaction rate*. (2)
- 5.2 Write down a conclusion for this investigation. (2)
- 5.3 The concentration of the hydrochloric solution is 2 mol·dm<sup>-3</sup>.  
Calculate the concentration used in Experiment 2. (3)
- 5.4 Name TWO conditions that learners had to keep the same to ensure that this is a fair test. (2)

After completing the investigation, the learners represented the results obtained during each experiment on the graph below.

**Graph of volume of hydrogen gas versus time**



- 5.5 Give a reason why the same volume of hydrogen gas is formed in both experiments. (1)
- 5.6 Write down the volume of hydrogen gas formed during the first minute in:
- 5.6.1 Experiment 1 (1)
- 5.6.2 Experiment 2 (1)
- 5.7 Which ONE of the experiments (Experiment 1 or Experiment 2) took place at a faster rate? Use the graph to explain the choice. (3)
- 5.8 Calculate the average reaction rate with respect to the magnesium, in  $\text{g}\cdot\text{s}^{-1}$ , in Experiment 1 if the molar volume at room temperature is  $24 \text{ dm}^3$ . (5)

[20]



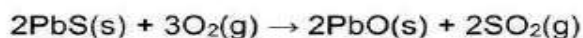
# PHYSICAL SCIENCES

## GRADE 12

### ACTIVITY 9 MJ25

A student is asked to design an industrial process to produce sulphuric acid.

- 5.1 One of the reactions in the production of sulphuric acid is the roasting (heating in oxygen) of a metal ore that contains lead(II) sulphide:

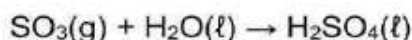


The student does a test experiment in which 36,8 g of  $\text{O}_2$  gas completely reacts with 800 g of the metal ore. All of the PbS in the ore reacts, and ONLY the PbS in the ore reacts with the oxygen.

- 5.1.1 Calculate the amount (in moles) of  $\text{O}_2$  that reacted. (3)
- 5.1.2 Calculate the mass of pure PbS in the metal ore. (3)
- 5.1.3 Calculate the percentage mass of the PbS in the metal ore. (2)

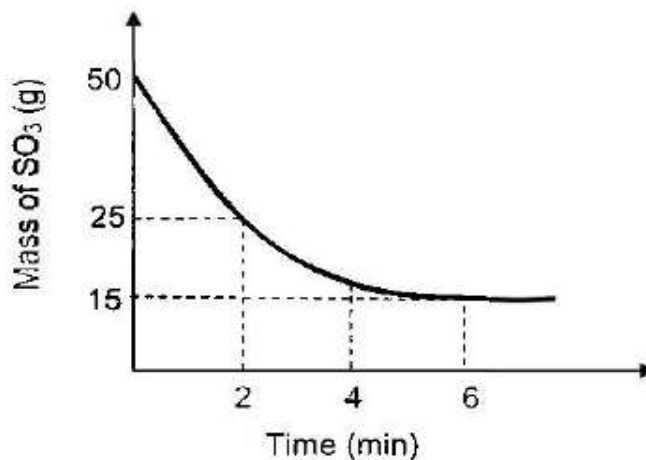


5.2 In another experiment, 50 g of sulphur trioxide reacts with water:



The amount of sulphur trioxide present in the container is monitored over time.

The following graph is plotted:

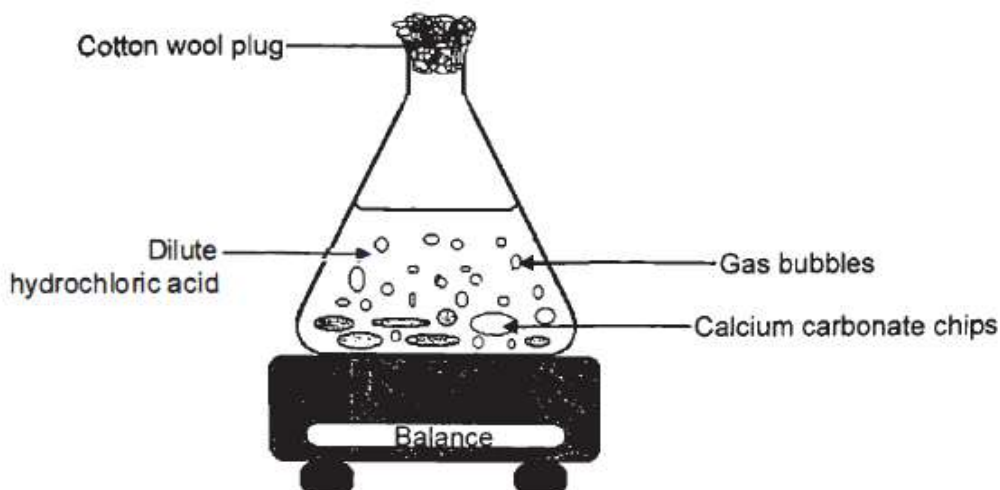


- 5.2.1 Write down the formula of the limiting reactant. (1)
- 5.2.2 At what time on the graph was the reaction rate the fastest. (1)
- 5.2.3 What happened at 6 minutes. (1)
- 5.2.4 Define the term *reaction rate*. (2)
- 5.2.5 Calculate the rate of the reaction in (g·s<sup>-1</sup>) during the first 2 minutes. (3)
- 5.2.6 Copy the above graph in your answer book. On the same set of axes, use a DOTTED LINE to show the curve that will be obtained when the temperature increases. No numerical values are required. (2)
- 5.2.7 In terms of the COLLISION THEORY, explain why the rate of a chemical reaction increases with increasing temperature. (3)

**[23]**

### ACTIVITY 10 K23J

Calcium carbonate chips are added to excess dilute hydrochloric acid solution in a flask placed on a balance as illustrated below.



The cotton wool plug placed in the mouth of the flask prevents spillage of reactants and products, while simultaneously allowing the formed gas to escape. The balanced equation for the reaction that takes place is:



The mass of the flask and its contents is recorded in intervals of 30 seconds. The results obtained are shown in the table below.

| Time in seconds (s) | Mass of the flask and its contents in grams (g) |
|---------------------|-------------------------------------------------|
| 0                   | 217,50                                          |
| 30                  | 215,00                                          |
| 60                  | 212,95                                          |
| 90                  | 211,05                                          |
| 120                 | 209,20                                          |
| 150                 | 207,40                                          |
| 180                 | X                                               |
| 210                 | 203,95                                          |
| 240                 | 203,95                                          |
| 270                 | Y                                               |

- 5.1 Define *reaction rate*. (2)
- 5.2 Write down the evidence from the table that suggests that the rate of the above reaction DECREASES with time. (2)
- 5.3 Use the collision theory to explain why the rate of the reaction decreases with time. Assume that the temperature remains constant. (3)



## PHYSICAL SCIENCES

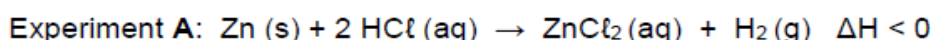
### GRADE 12

- 5.4 How will an increase in the volume of the hydrochloric acid used affect the rate of this reaction? Choose from INCREASES, DECREASES or REMAINS THE SAME (1)
- 5.5 The average rate of the reaction for the first 180s is  $6,58 \times 10^{-2} \text{ g.s}^{-1}$ . Calculate the value of X in the table. (4)
- 5.6 Write down the mass, in grams, represented by Y. Give a reason for the answer. (2)
- 5.7 Calculate the total volume of carbon dioxide gas produced during the above reaction at S.T.P. (6)
- 5.8 It is observed that when a catalyst is added to the above reaction, the reaction reaches completion in a shorter time.  
Use the collision theory to explain the observation. (3)
- 5.9 The  $\text{CaCO}_3$  chips are replaced with an equal mass of  $\text{CaCO}_3$  powder. How will each of the following be affected by this change? (Choose from INCREASES, DECREASES or REMAINS THE SAME)
- 5.9.1 The mass in grams represented by Y. (1)
- 5.9.2 Time taken to reach the mass represented by X. (1)
- [25]

### ACTIVITY 11 E21J

A group of learners conduct experiments to investigate a factor that affects the rate of reactions.

In the experiments, the learners use the reaction between zinc granules and EXCESS hydrochloric acid of concentration  $0,5 \text{ mol}\cdot\text{dm}^{-3}$  at  $20^\circ\text{C}$  as shown below:

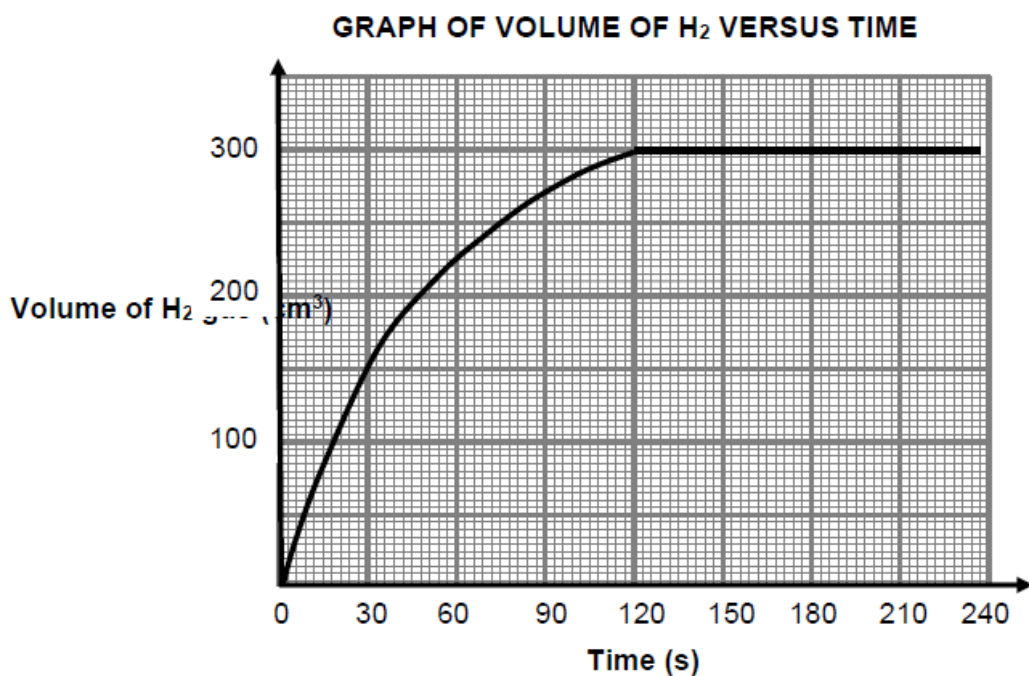


- 5.1 Define *reaction rate*. (2)
- 5.2 Is net energy ABSORBED or RELEASED during the reaction?  
Give a reason for the answer. (2)
- 5.3 How will the rate of reaction in experiment A be affected by the following changes?  
Choose from INCREASES, DECREASES or NO EFFECT.
- 5.3.1 Using  $\text{H}_2\text{SO}_4$  solution of concentration  $0,5 \text{ mol}\cdot\text{dm}^{-3}$  in place of the HCl. (1)
- 5.3.2 Pressure is increased. (1)



- 5.4 In experiment **A**,  $50 \text{ cm}^3$  of hydrochloric acid ( $\text{HCl}$ ) solution of concentration  $0,5 \text{ mol} \cdot \text{dm}^{-3}$  reacts with  $7,15 \text{ g}$  of zinc ( $\text{Zn}$ ) granules.

The volume gas formed versus time for the reaction in experiment **A** is shown below.



- 5.4.1 How many seconds did the reaction take to reach completion? (1)

It is observed that the rate of reaction is **HIGHEST** during the interval 0 to 30 s.

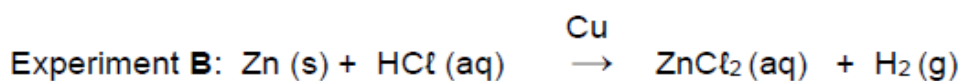
- 5.4.2 Write down **TWO** factors that influence reaction rate that explains this observation. (2)

- 5.5 Calculate the:

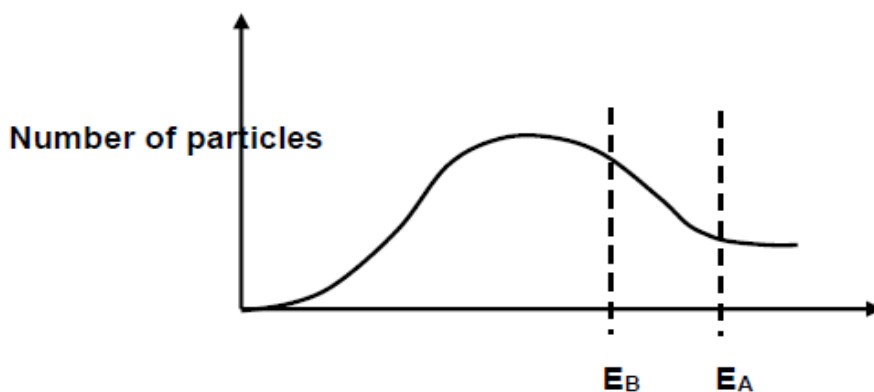
- 5.5.1 Average rate of reaction (in  $\text{cm}^3 \cdot \text{s}^{-1}$ ) for the first 120 s (3)

- 5.5.2 Mass of the **EXCESS** reactant remaining in the flask if the molar volume of hydrogen gas at  $20^\circ \text{C}$  is  $24 \text{ dm}^3 \cdot \text{mol}^{-1}$  (7)

- 5.6 In experiment **B**, the reaction in experiment **A** is repeated under the same conditions, but copper is also added to the reaction mixture.



The Maxwell-Boltzman distribution curve for the reaction in experiment **A** and in experiment **B** is shown below:



$E_A$  and  $E_B$  represent the activation energy for the reaction in experiments **A** and **B** respectively.

- 5.6.1 What is the function of copper in experiment **B**? (1)
- 5.6.2 Explain how the addition of copper in reaction **B** affects the rate of reaction by referring to the collision theory. (4)
- [24]

### ACTIVITY 12 2N4WJ

- 5.1 A group of learners uses the reaction of hydrochloric acid with magnesium ribbon to investigate the factors that influence rate of reaction.

The balanced equation for the reaction is given below:

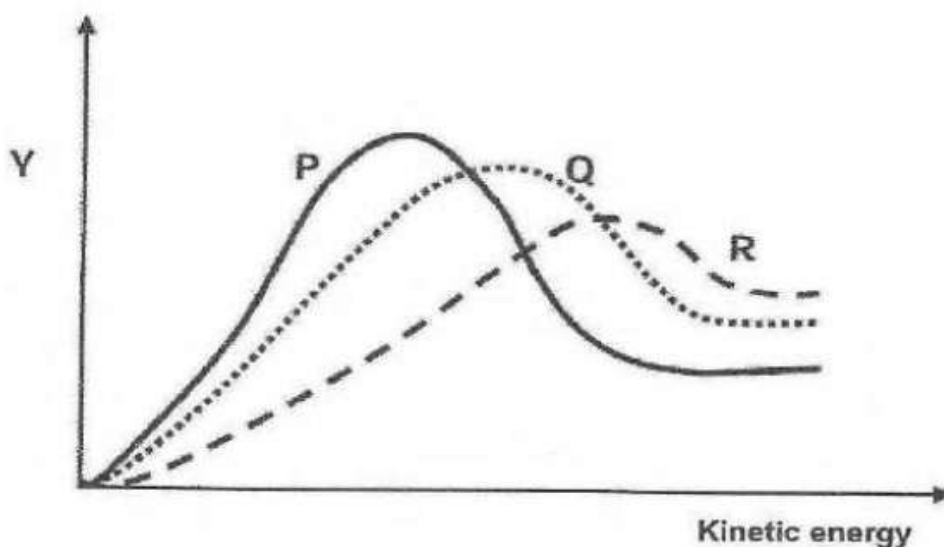


The hydrochloric acid is in EXCESS, and the same mass of magnesium is used in ALL the experiments.

| Experiment | REACTION CONDITIONS                             |                  |       |                                      |
|------------|-------------------------------------------------|------------------|-------|--------------------------------------|
|            | Concentration of HCl(aq)(mol.dm <sup>-3</sup> ) | Temperature (°C) |       | State of division of 0,24g Magnesium |
|            |                                                 | Before           | After |                                      |
| 1          | 2                                               | 35               | 57    | Powder                               |
| 2          | 2                                               | 30               | 48    | Ribbon                               |
| 3          | 2                                               | 20               | 33    | Ribbon                               |
| 4          | 1,5                                             | 30               | 45    | Ribbon                               |

- 5.1.1 Define the term *rate of reaction*. (2)
- 5.1.2 In which experiment is the reaction rate HIGHEST? Explain your answer. (3)
- 5.2 The reaction in Experiment 2 is compared to the reaction in Experiment 4.
- 5.2.1 Write down ONE control variable for this comparison. (1)
- 5.2.2 How does the amount of hydrogen gas produced in Experiment 2 compare to the amount produced in Experiment 4 if the same volume of acid is used in both experiments?
- Write down only HIGHER THAN, SMALLER THAN or EQUAL TO.
- Give a reason for your answer. (2)
- 5.3 Give a reason why it is not a fair test to compare the rate of reaction of Experiment 1 with that of Experiment 3. (1)

- 5.4 Calculate the mass of hydrochloric acid that remains in the flask at the completion of the reaction in Experiment 1 if the initial volume of the hydrochloric acid is  $80 \text{ cm}^3$ . (7)
- 5.5 The Maxwell-Boltzmann distribution curves labelled P, Q and R for the reactions in experiments 1, 2 and 3 in random order are shown below.



- 5.5.1 Write down the name of the label, Y, on the vertical axis. (1)
- 5.5.2 Which curve (Q, P or R) represents the results of Experiment 3? (1)
- 5.5.3 With the aid of the collision theory explain the effect of TEMPERATURE on reaction rate. (4)  
[22]

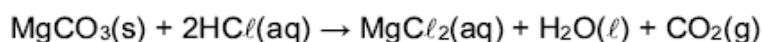


# PHYSICAL SCIENCES

## GRADE 12

### ACTIVITY 13 GJ25

Three different experiments are performed using the reaction between magnesium carbonate and hydrochloric acid:



#### EXPERIMENT I

In this experiment, magnesium carbonate reacts with EXCESS hydrochloric acid in a closed container at 23 °C. The reaction is monitored by measuring the volume of carbon dioxide gas produced over time. The molar gas volume at 23 °C is 24 dm<sup>3</sup>. The data collected is shown in the table below.

| TIME (s) | VOLUME OF CO <sub>2</sub> (cm <sup>3</sup> ) |
|----------|----------------------------------------------|
| 0        | 0                                            |
| 10       | 180                                          |
| 20       | 300                                          |
| 30       | 410                                          |
| 40       | 470                                          |
| 50       | 500                                          |
| 60       | 500                                          |

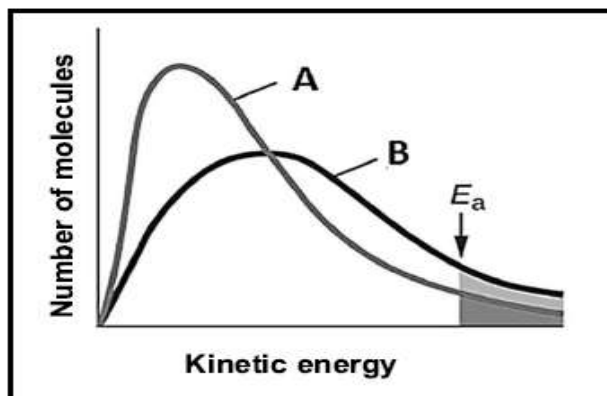
- 5.1 Define the term *reaction rate*. (2)
- 5.2 Use the collision theory to explain the effect on the reaction rate as time progresses. (4)
- 5.3 Calculate the reaction rate for the production of CO<sub>2</sub>(g) during the first 20 seconds, in dm<sup>3</sup>·s<sup>-1</sup>. (3)
- 5.4 Calculate the mass of MgCO<sub>3</sub> required for this experiment. (4)



### EXPERIMENT II

5.5 Experiment I is repeated, but this time at 30 °C.

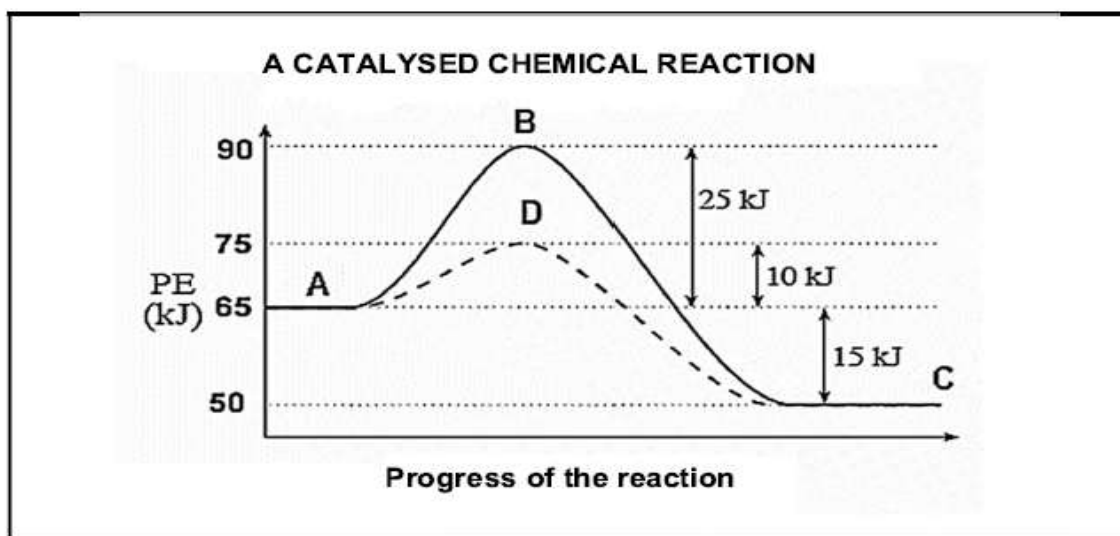
The following Maxwell-Boltzmann distribution curve was produced.



- 5.5.1 Which graph, **A** or **B**, best represents Experiment II? (1)
- 5.5.2 Explain the answer to QUESTION 5.5.1. (2)
- 5.5.3 If a catalyst was added, would the line representing the activation energy ( $E_a$ ) be drawn to the **LEFT** or the **RIGHT** of the current line? (1)

### EXPERIMENT III

5.6 Experiment I is repeated, but a catalyst is added, and the following graph is obtained.

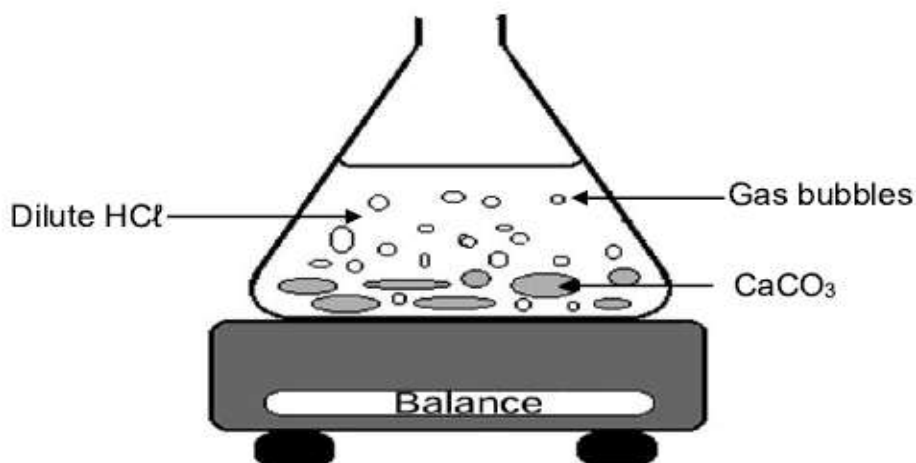
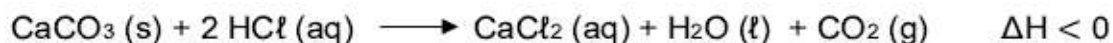


- 5.6.1 Is the reaction **EXOTHERMIC** or **ENDOTHERMIC**? (1)
- 5.6.2 Which letter represents the activated complex? (1)
- 5.6.3 Give the value of the activation energy for the forward catalysed reaction. (1)

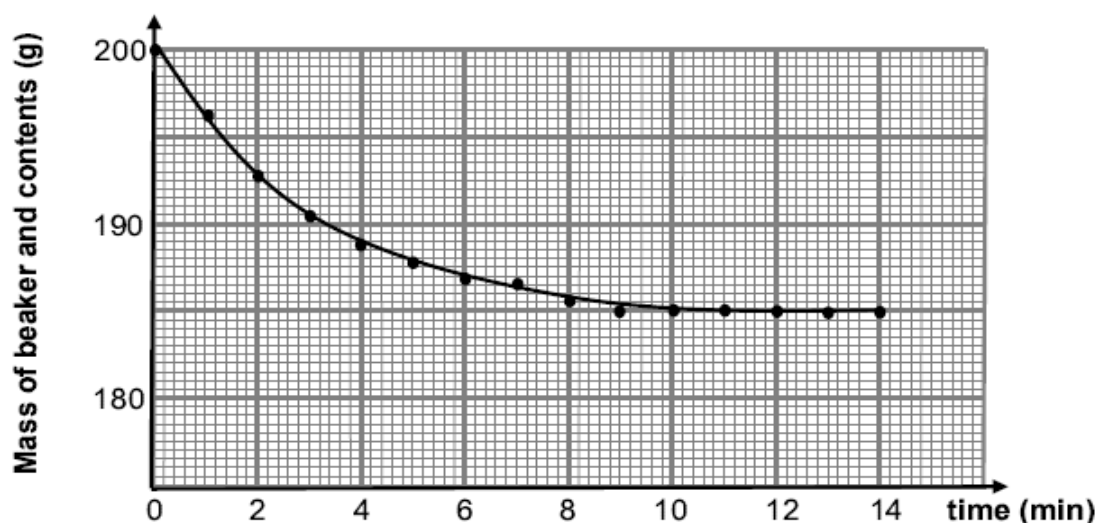
[20]

### ACTIVITY 14 EJ25

Calcium carbonate ( $\text{CaCO}_3$ ) chunks are added to EXCESS dilute hydrochloric acid ( $\text{HCl}$ ) solution in an Erlenmeyer flask that is placed on an electronic scale, as shown below. The balanced equation for the reaction that takes place is:

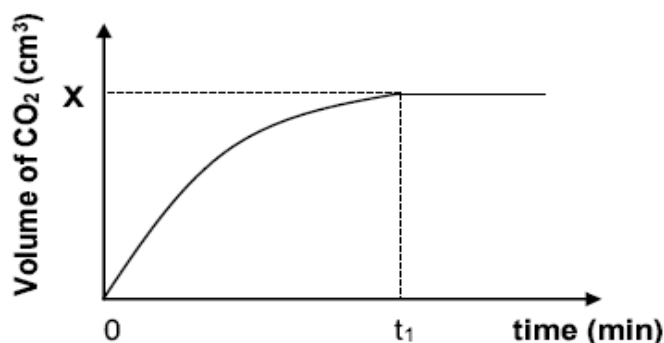


The change in mass of the flask and its contents are recorded in 1-minute intervals. The results obtained are shown in the graph below.



- 5.1 Is the reaction EXOTHERMIC or ENDOTHERMIC? Give a reason for the answer. (2)
- 5.2 Give a reason why the mass of the flask and its contents does not remain constant. (2)
- 5.3 Write down the reading on the scale balance on 4 minutes. (1)

- 5.4 The sketch graph below shows the change in volume of  $\text{CO}_2$  gas produced for this experiment.



- 5.4.1 Write down the value of  $t_1$ . (1)

- 5.4.2 How does the rate at which the amount  $\text{CO}_2$  is produced compared to the rate at which the amount  $\text{CaCO}_3$  is consumed?

Choose from HIGHER THAN, SMALLER THAN or EQUAL TO.

Give a reason for the answer. (3)

Calculate the:

- 5.4.3 Value of  $X$   
Take the molar volume as  $24\,000\text{ cm}^3\cdot\text{mol}^{-1}$  (5)

- 5.4.4 Average rate in  $\text{g}\cdot\text{min}^{-1}$  at which calcium carbonate was consumed after 11 minutes (4)

- 5.5 The experiment is repeated by increasing the temperature of the reaction mixture. The results of the two experiments are compared.

- 5.5.1 Write down a hypothesis for this comparison. (2)

- 5.5.2 How would reaction rate be affected by this change?

Choose from INCREASES, DECREASES or REMAINS THE SAME. (1)

- 5.5.3 Explain the answer to QUESTION 5.5.2 by referring to the collision theory. (3)

[24]

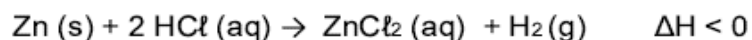


# PHYSICAL SCIENCES

## GRADE 12

### ACTIVITY 15 24ES

The reaction between EXCESS hydrochloric acid (HCl) with zinc (Zn) is used to investigate factors that influences the reaction rate. The balanced equation for this reaction is:



Three experiments are carried out and one factor is changed in each experiment. The same volume of hydrochloric acid and the same mass of zinc granules are used in each experiment. The hydrochloric acid completely covers the zinc in each experiment.

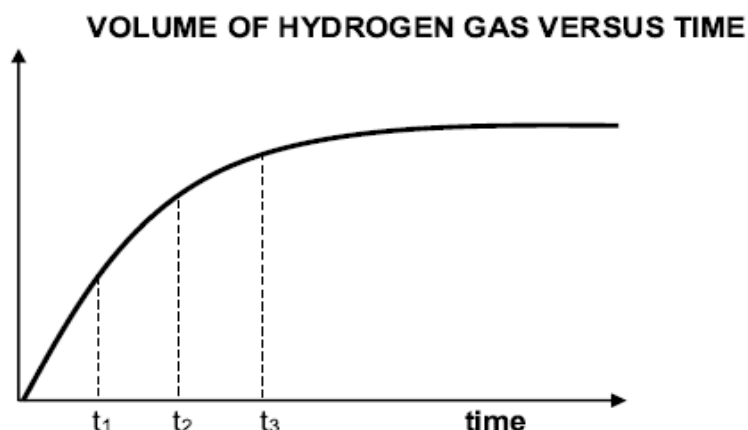
The table below shows the reaction conditions.

| EXPERIMENT | CONCENTRATION OF HCl<br>(mol·dm <sup>-3</sup> ) | Cu (s) PRESENT |
|------------|-------------------------------------------------|----------------|
| 1          | 0,5                                             | No             |
| 2          | 0,8                                             | No             |
| 3          | 0,5                                             | Yes            |

- 5.1 Define *reaction rate*. (2)
- 5.2 Write down an investigative question when comparing experiments 1 and 2. (2)



- 5.3 The curve, not drawn to scale, is obtained for the volume of hydrogen gas,  $H_2$  (g) produced over time for experiment 1.



- 5.3.1 How does the rate at which hydrogen gas is produced between  $t_1$ – $t_2$  compare to that at  $t_2$ – $t_3$ ?

Write down only HIGHER THAN, LOWER THAN or EQUAL TO. (1)

- 5.3.2 Redraw the graph in the ANSWER BOOK. Clearly label the curve as **A**.

On the same set of axes, sketch the curve that will be obtained for experiment 3. Label this curve as **B**. (2)

- 5.4 The reaction in experiment 1 takes 58 s to reach completion and the average reaction rate at which hydrogen gas,  $H_2$  is produced is  $8,39 \text{ cm}^3 \cdot \text{s}^{-1}$ .

Calculate the initial mass of zinc used in each experiment.

The molar volume for hydrogen gas ( $H_2$ ) at  $25^\circ \text{C}$  is  $24\,000 \text{ cm}^3 \cdot \text{mol}^{-1}$ .

Experiment 4 is now conducted by increasing the temperature of the reaction mixture in experiment 1. (5)

- 5.5 How will this change affect the reaction rate?

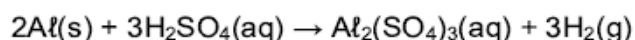
Choose from INCREASES, DECREASES or REMAINS THE SAME. (1)

- 5.6 Explain the answer to QUESTION 5.5 by referring to the collision theory. (3)

[16]

### ACTIVITY 16 M/24J

The reaction between aluminium and EXCESS sulphuric acid is used to investigate factors affecting rates of reactions.

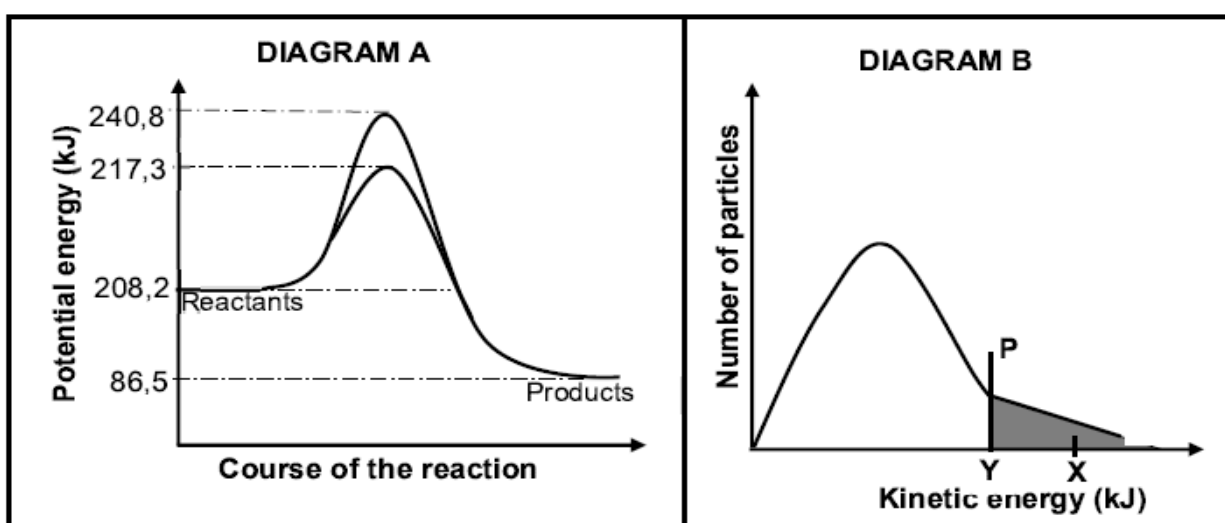


#### 5.1 INVESTIGATION I

The effect of a catalyst on the rate of reaction is determined.

Aluminium powder of mass 5 g reacts with excess  $0,1 \text{ mol} \cdot \text{dm}^{-3} \text{ H}_2\text{SO}_4$  at  $60^\circ \text{C}$ .

Consider the following energy diagrams (not drawn to scale) for this investigation. **X** and **Y** in diagram **B** represent the activation energies.



- 5.1.1 Is the reaction between  $\text{Al(s)}$  and dilute  $\text{H}_2\text{SO}_4(\text{aq})$  ENDOTHERMIC or EXOTHERMIC? Give a reason for the answer by referring to the above diagrams. (2)
- 5.1.2 What does the shaded area to the right of line **P** represent? (1)
- 5.1.3 Determine the numerical value represented by the letter **X** on diagram **B**. (2)



# PHYSICAL SCIENCES

## GRADE 12

### 5.2 INVESTIGATION II

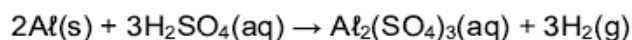
The investigation is now repeated at 30 °C using the same reactants (5g Al powder and excess 0,1 mol·dm<sup>-3</sup> H<sub>2</sub>SO<sub>4</sub>) and catalyst.

How will this affect EACH of the following when compared to INVESTIGATION I? Choose from INCREASES, DECREASES or REMAINS THE SAME.

- 5.2.1 The size of the shaded area (diagram B) (1)
- 5.2.2 The value of Y (1)
- 5.2.3 The TOTAL volume of hydrogen gas produced (1)

### 5.3 INVESTIGATION III

In this investigation, 5 g of the same sample of IMPURE aluminium powder reacts with an EXCESS diluted H<sub>2</sub>SO<sub>4</sub> at 60 °C in each of three runs. The table below summarises the conditions and the results obtained. (Assume that the impurities do not react.)



| RUN | CONCENTRATION<br>H <sub>2</sub> SO <sub>4</sub> (aq) (mol·dm <sup>-3</sup> ) | AVERAGE RATE OF VOLUME<br>H <sub>2</sub> (g) PRODUCED (cm <sup>3</sup> ·s <sup>-1</sup> ) |
|-----|------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------|
| 1   | 0,1                                                                          | 15                                                                                        |
| 2   | 0,2                                                                          | 19                                                                                        |
| 3   | 0,4                                                                          | 40                                                                                        |

- 5.3.1 Write down the independent variable for this investigation. (1)
- 5.3.2 Use the collision theory to explain how the average rate of the reaction is affected in this investigation. (3)
- 5.3.3 The time for the reaction to reach completion in RUN 3 is 2,6 minutes.

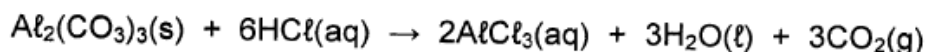
Calculate the percentage purity of the aluminium. Take the molar gas volume at 60 °C to be 27 000 cm<sup>3</sup>·mol<sup>-1</sup>.

(6)  
[18]

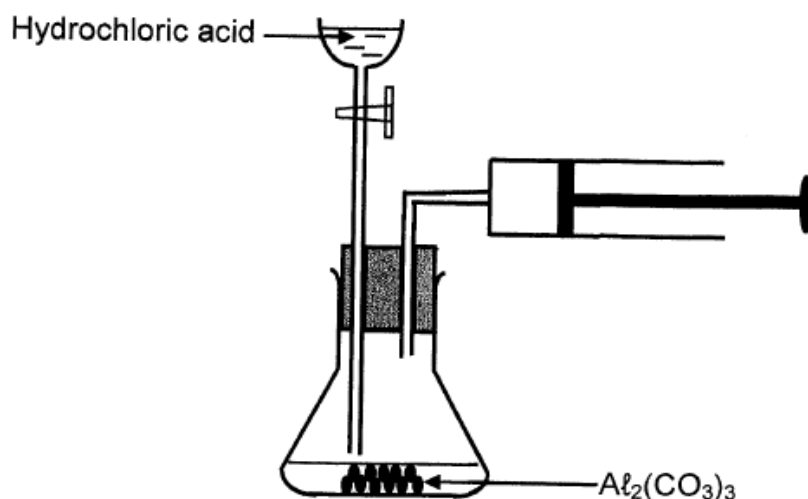


### ACTIVITY 17 M/J21

Two experiments, **I** and **II**, are conducted to investigate one of the factors that affects the rate of the reaction of aluminium carbonate,  $\text{Al}_2(\text{CO}_3)_3$ , with EXCESS hydrochloric acid,  $\text{HCl}$ . The balanced equation for the reaction is:



The apparatus used is shown below.



#### Experiment I:

100 cm<sup>3</sup> of 1,5 mol·dm<sup>-3</sup>  $\text{HCl}(\text{aq})$  reacts with 0,016 mol  $\text{Al}_2(\text{CO}_3)_3$  granules at 25 °C

#### Experiment II:

50 cm<sup>3</sup> of 2 mol·dm<sup>-3</sup>  $\text{HCl}(\text{aq})$  reacts with 0,016 mol  $\text{Al}_2(\text{CO}_3)_3$  granules at 25 °C

- 5.1 Define the term *rate of a reaction*. (2)
- 5.2 Using the experimental setup above, state the measurements that must be made to determine the rate of this reaction. (2)
- 5.3 Use the collision theory to explain how the average reaction rate in **Experiment I** differs from the average reaction rate in **Experiment II**. (3)
- 5.4 The average rate of the reaction in **Experiment II** during the first 2,5 minutes is  $4,4 \times 10^{-3} \text{ mol} \cdot \text{min}^{-1}$ .  
Calculate the number of moles of  $\text{Al}_2(\text{CO}_3)_3$  that remains in the flask after 2,5 minutes. (3)
- 5.5 Calculate the maximum volume of  $\text{CO}_2(\text{g})$  that can be prepared at 25 °C in **Experiment I**. Take molar gas volume at 25 °C as 24 000 cm<sup>3</sup>·mol<sup>-1</sup>. (3)

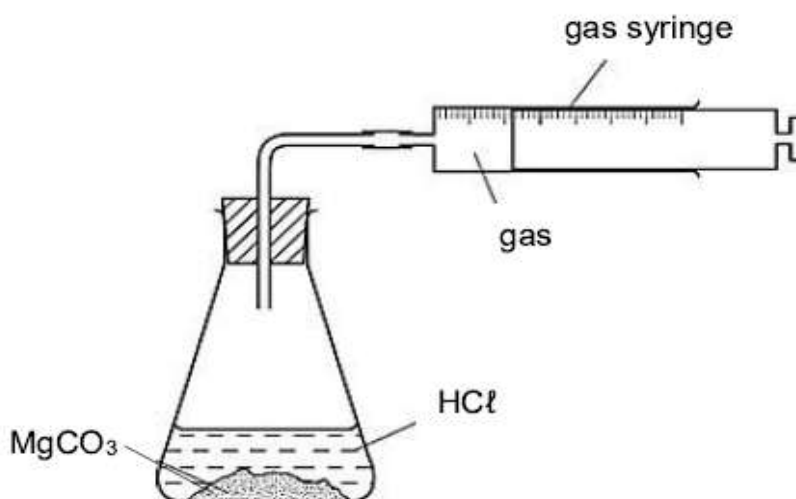
[13]

### ACTIVITY 18 24EJ

A group of learners use the reaction between magnesium carbonate ( $\text{MgCO}_3$ ) and EXCESS hydrochloric acid ( $\text{HCl}$ ) to investigate some of the factors that affect the reaction rate. The balanced equation for the reaction is:



The learners used the apparatus illustrated below.



The table below summarises the reaction conditions:

| EXPERIMENT | REACTION CONDITIONS                                                 |                                      |                                            |
|------------|---------------------------------------------------------------------|--------------------------------------|--------------------------------------------|
|            | CONCENTRATION OF $\text{HCl}$ ( $\text{mol} \cdot \text{dm}^{-3}$ ) | STATE OF DIVISION OF $\text{MgCO}_3$ | INITIAL TEMPERATURE ( $^{\circ}\text{C}$ ) |
| 1          | 0,9                                                                 | Powder                               | 25                                         |
| 2          | 0,9                                                                 | Powder                               | 30                                         |
| 3          | 0,9                                                                 | Lumps                                | 30                                         |

- 5.1 Define *reaction rate*. (2)
- 5.2 Write down the independent variable for the comparison between experiment 1 and 2. (1)
- 5.3 Experiment 2 and 3 is now compared.
  - 5.3.1 Which experiment, 2 or 3, will have the highest reaction rate? (1)
  - 5.3.2 Explain the answer to QUESTION 5.3.1 by referring to the collision theory. (3)



## PHYSICAL SCIENCES

### GRADE 12

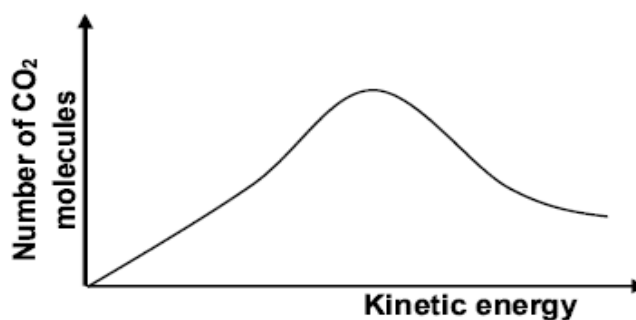
- 5.4 The learners measured the rate at which  $\text{CO}_2$  was produced in experiment 2 and found it to be  $0,25 \text{ g} \cdot \text{min}^{-1}$ . It took 10,44 minutes to measure the time taken for the reaction to reach completion.

Calculate the:

5.4.1 Mass of  $\text{MgCO}_3$  that was used (6)

5.4.2 Molar volume of  $\text{CO}_2$  if  $1,47 \text{ dm}^3$  of  $\text{CO}_2$  was released (3)

- 5.5 The graph below represents Maxwell-Boltzmann distribution curve for  $\text{CO}_2(\text{g})$  produced experiment 1.



Redraw the graph in your ANSWER BOOK. Clearly label the curve as **A**.

On the same set of axes, sketch the curve that will be obtained for  $\text{CO}_2(\text{g})$  if the mass of  $\text{MgCO}_3$  used is increased.

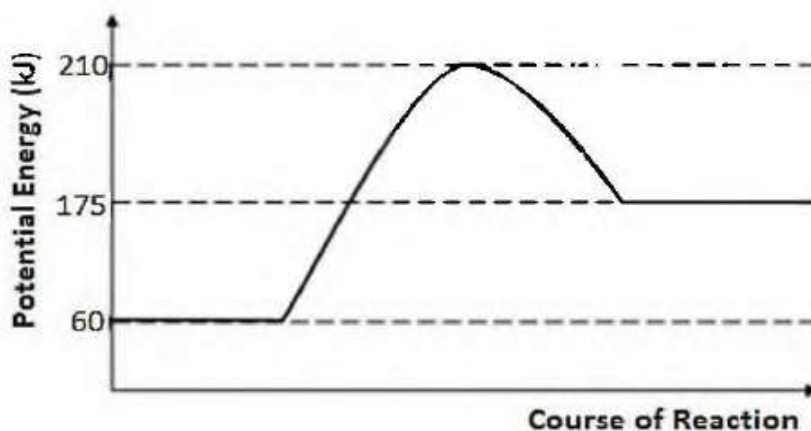
Label this curve as **B**.

(2)  
[18]



### ACTIVITY 19 WCT24

A learner conducts a practical investigation to test whether the dissolution of solid sodium chloride is **exothermic** or **endothermic**. The apparatus used includes a beaker, a salt and a certain measuring instrument. The graph below shows the energy changes that occur when sodium chloride dissolves in water:



5.1 For this reaction, calculate:

5.1.1 The heat of the reaction of the forward reaction (1)

5.1.2 Activation energy of the REVERSE reaction (1)

5.2 In another experiment, a learner adds a suitable catalyst. On addition of the catalyst, state whether the following will INCREASE, DECREASE or REMAIN THE SAME:

5.2.1 Potential energy of the products (1)

5.2.2 Activation energy (1)

5.3 Explain how the addition of a suitable catalyst will affect the rate of a chemical reaction. (2)

[6]



# PHYSICAL SCIENCES

## GRADE 12

### ACTIVITY 20 2FT4

Grade 12 learners use a reaction of  $\text{CaCO}_3$  with EXCESS  $\text{HCl}$  to investigate the relationship between concentration and rate of reaction. The balanced equation for the reaction is:



They conduct the experiment twice, each with a different concentration of  $\text{HCl}$ . A decrease in the mass of the flask and the content is represented in the table below.

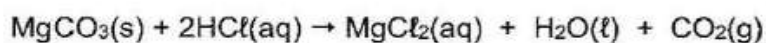
| EXPERIMENT | TIME(s)                        | 0   | 30    | 60    | 90     | 120   | 150 | 180 |
|------------|--------------------------------|-----|-------|-------|--------|-------|-----|-----|
| 1          | Mass of flask and contents (g) | 270 | 268,4 | 267,4 | 266,75 | 266,3 | 266 | 266 |
| 2          | Mass of flask and contents (g) | 270 | 269   | 268,4 | 268,1  | 268   | 268 | 268 |

- 5.1 Write down the name of the apparatus used for measuring the mass. (1)
- 5.2 Write down the NAME of the limiting reagent. (1)
- 5.3 Define the term *rate of reaction*. (2)
- 5.4 For **experiment 1**, calculate the rate of reaction in  $\text{mol}\cdot\text{s}^{-1}$  in the first 30 s. (5)
- 5.5 In which experiment did the learner use a higher concentration of  $\text{HCl}$ ? (1)
- 5.6 Use the collision theory to explain the answer to QUESTION 5.5. (3)
- [13]

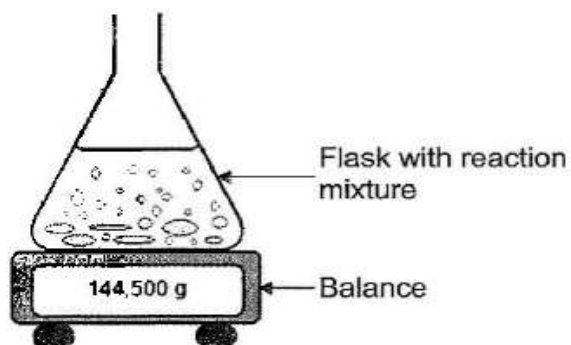


### ACTIVITY 21 M/25J

The reaction between magnesium carbonate pellets,  $\text{MgCO}_3(\text{s})$ , and EXCESS dilute hydrochloric acid,  $\text{HCl}(\text{aq})$ , is used to investigate the effect of concentration on the rate of a reaction.



The apparatus used for this investigation is shown below.

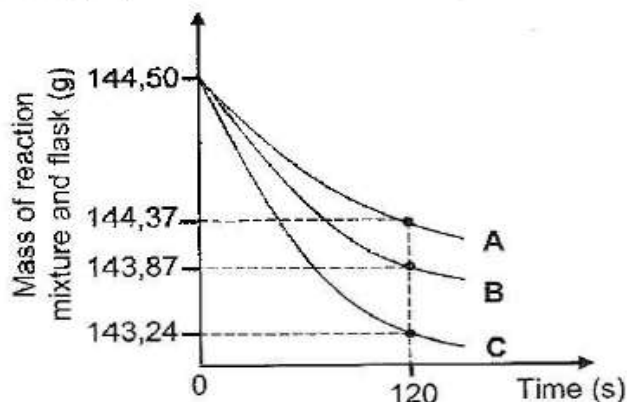


- 5.1 Define the term *rate of reaction*. (2)
- 5.2 Write down ONE controlled variable for this investigation. (1)

Three experiments using different concentrations of  $\text{HCl(aq)}$  are carried out. The concentration of the  $\text{HCl(aq)}$  during each experiment does not change.

| EXPERIMENT | CONCENTRATION OF $\text{HCl(aq)}$<br>( $\text{mol}\cdot\text{dm}^{-3}$ ) |
|------------|--------------------------------------------------------------------------|
| 1          | 0,1                                                                      |
| 2          | 0,5                                                                      |
| 3          | 1,0                                                                      |

The INCOMPLETE graph of the results of the experiments is shown below.

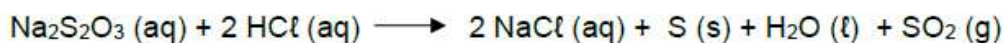


- 5.3 Give a reason why the mass of the reaction mixture and flask decreases. (1)
- 5.4 For curve **B**, calculate the average rate at which  $\text{CO}_2(\text{g})$  is produced for the first 120 s in  $\text{dm}^3\cdot\text{s}^{-1}$ . The molar gas volume is  $24,5 \text{ dm}^3\cdot\text{mol}^{-1}$ . (6)
- 5.5 Which curve represents EXPERIMENT 1? Choose from **A**, **B** or **C**.  
Use the collision theory to explain the answer. (5)
- 5.6 How will the final mass of  $\text{CO}_2(\text{g})$  produced in EXPERIMENT 2 compare to that of EXPERIMENT 3? Choose from MORE THAN, LESS THAN or THE SAME.  
Give a reason for the answer. (2)

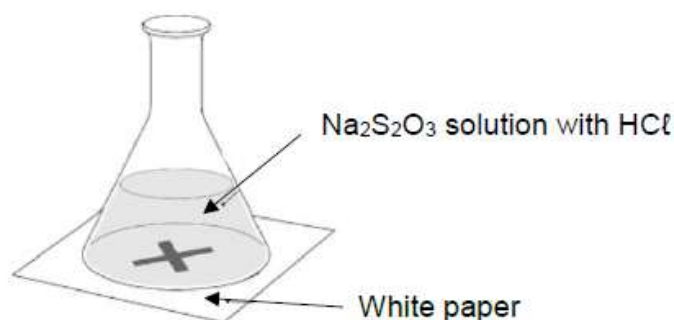
[17]

### ACTIVITY 22 23EJ

A group of learners use the reaction between sodium thiosulphate ( $\text{Na}_2\text{S}_2\text{O}_3$ ) and EXCESS hydrochloric acid ( $\text{HCl}$ ) to investigate one of the factors that affect reaction rate. The balanced equation for the reaction is:

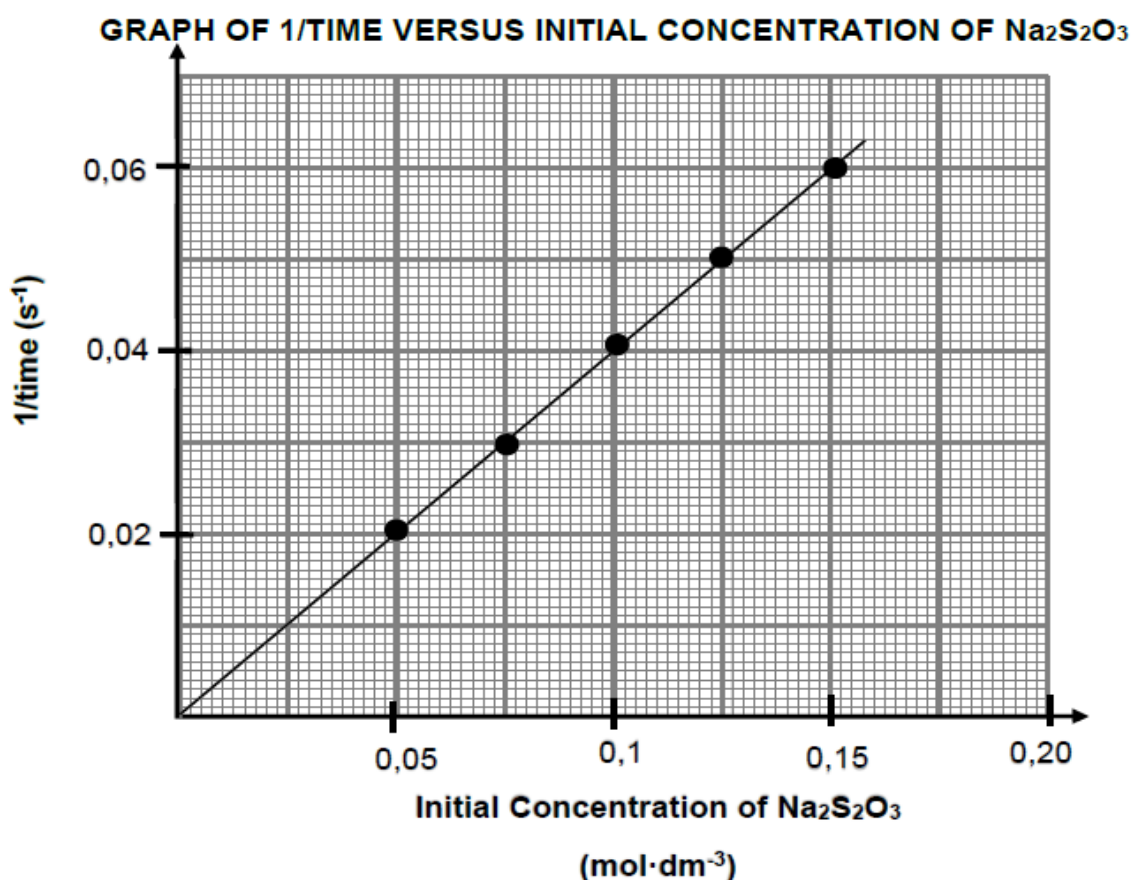


The learners carry out five experiments under the same conditions changing only the factor that is investigated in EACH experiment using the experimental set-up shown below.



They recorded the time taken for the cross to become invisible, when viewed from the top.

The learners' results are shown in the graph below.

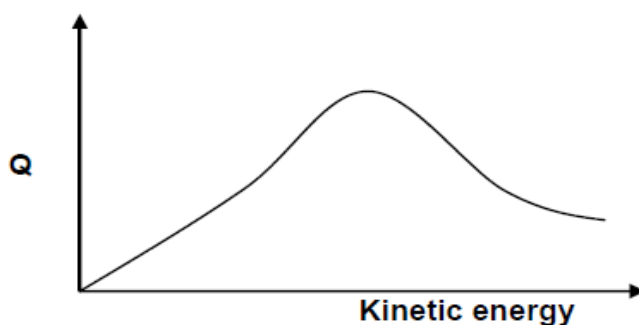




## PHYSICAL SCIENCES

### GRADE 12

- 5.1 Define *reaction rate*. (2)
- 5.2 Write down an investigative question for the above investigation. (2)
- 5.3 Name the substance responsible for the disappearance of the cross. (1)
- 5.4 Give a reason why the same cross must be used in ALL the experiments. (1)
- 5.5 Use the collision theory to explain the effect of concentration on reaction rate. (3)
- 5.6 In one of the experiments  $50 \text{ cm}^3$  of  $\text{Na}_2\text{S}_2\text{O}_3$  is used and it takes 20 seconds for the cross to become invisible.
- Calculate the total mass of sulphur, **S**, formed in this experiment. (6)
- 5.7 The graph below represents Maxwell-Boltzmann distribution curve for  $\text{SO}_2(\text{g})$  at  $30^\circ\text{C}$ .



**Q** is a label on the vertical axis.

- 5.7.1 What does **Q** in the graph represent? (1)

Redraw the graph in the ANSWER BOOK. Clearly label the curve as **A**.

- 5.7.2 On the same set of axes, sketch the curve that will be obtained for  $\text{SO}_2(\text{g})$  at  $40^\circ\text{C}$ .

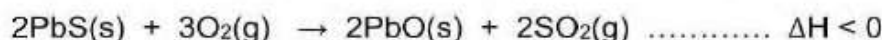
Label this curve as **B**.

(2)  
[18]

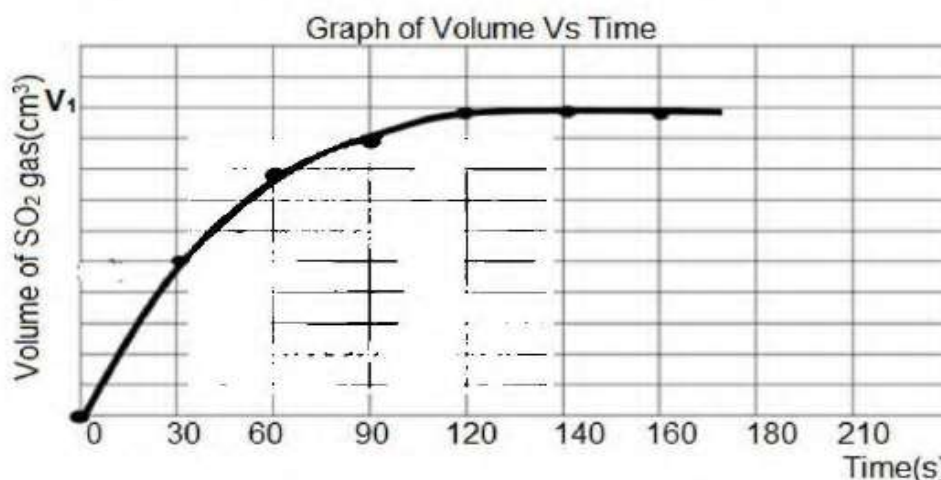


### ACTIVITY 23

One of the reactions in the production of sulphuric acid is the roasting (heating in oxygen) of a metal ore that contains lead (II) sulphide according to the equation below. The  $\text{SO}_2(\text{g})$  produced, is then reacted further to produce sulphuric acid.



- 6.1 When particles collide, state TWO conditions that need to be met for the collisions to be effective collisions. (2)
- 6.2 Define *reaction rate*. (2)
- 6.3 State THREE ways in which the rate of this reaction could be increased. (3)
- 6.4 The reaction is simulated in a laboratory using EXCESS  $\text{O}_2(\text{g})$  and a graph showing the volume of  $\text{SO}_2$  produced versus time is drawn.



- 6.4.1 Suggest a reason, why the graph flattens at  $t = 120 \text{ s}$ . (1)
- 6.4.2 If the average rate of production of  $\text{SO}_2$  is  $600 \text{ cm}^3 \cdot \text{s}^{-1}$ , calculate the value of  $V_1$  (3)
- 6.4.3 If 1,7 kg  $\text{PbS}$  ore is used and the molar volume of gas at this reaction temperature is  $26\,490 \text{ cm}^3 \cdot \text{mol}^{-1}$ , calculate the percentage purity of the ore. (6)

[17]