THEME 2

Exploration of Elements in Nature

Malaysia is the largest producer and exporter of latex gloves in the world. Natural rubber is an organic carbon compound. Is synthetic rubber also an organic carbon compound?

Video

http://buku-teks.com/sc5113

Lithium is used to build electrochemical cells, which are electrolytic cell and chemical cell. Name one electrolytic battery from another type of ion which can potentially replace lithium-ion battery. Is the rate of chemical reaction in electrochemical cells high or low?

CHAPTER

4 RATE OF REACTION

Define rate of reaction.

State five factors that affect rate of reaction.

Give three examples of applications of the concept of rate of reaction in daily life and industries.

Let's study

- Introduction to rate of reaction
- Factors affecting the rate of reaction
- Applications of the concept of rate of reaction

Science Bulletin

The process of making toast involves a chemical reaction known as the Maillard reaction. In the Maillard reaction, carbohydrate reacts with protein to form Amadori compounds that cause bread to become brown and turn into toast. The Maillard reaction is a fast reaction.

Keywords

- Reactant
- Product
- Rate of reaction
- Average rate of reaction
- Rate of reaction at a specific time
- High rate of reaction
- Low rate of reaction
- Temperature
- Concentration
- Size of reactant
- Catalyst
- Pressure
- Haber Process
- Contact Process

4.1 Introduction to Rate of Reaction

Fast Reactions and Slow Reactions in Daily Life

A **chemical reaction** is a process in which one or more **reactants** are converted to one or more **products**.

Reactant $\xrightarrow{\text{Chemical reaction}}$ Product

For example, the **reaction** between the **reactants**, colourless potassium iodide solution and colourless lead(II) nitrate solution will produce yellow-coloured lead(II) iodide precipitate and colourless potassium nitrate solution as the **products**.

$$\underbrace{\text{Lead(II) nitrate} + \text{Potassium iodide}}_{\text{Reactants}} \longrightarrow \underbrace{\text{Lead(II) iodide} + \text{Potassium nitrate}}_{\text{Products}}$$

During a reaction, **reactant** changes into **product**. As such, the quantity of the reactant decreases while the quantity of the product increases in that reaction (Figure 4.1).

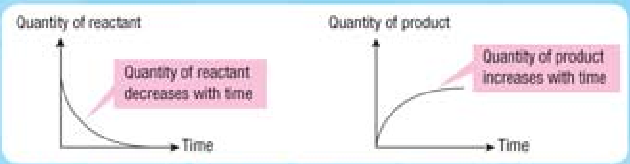
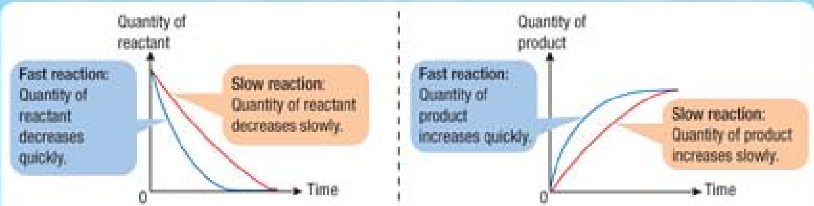


Figure 4.1 Graphs of changes in quantities of reactant and product against time

Observe and understand the similarities and differences between the graphs of changes in the quantity of reactant or product against time in **fast reactions** and **slow reactions** (Figures 4.2(a), (b) and 4.3).



(a) Quantity of reactant against time

(b) Quantity of product against time

Figure 4.2 Graphs of changes in quantities of reactant and product against time

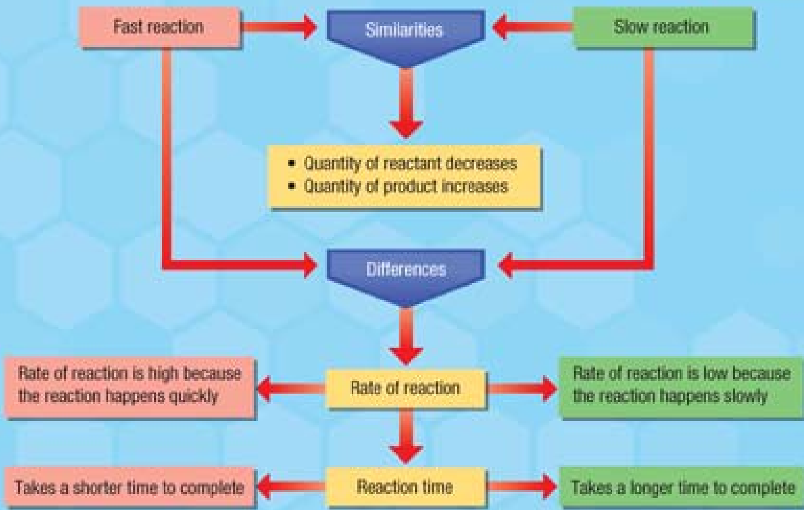


Figure 4.3 Similarities and differences between fast reaction and slow reaction

Photographs 4.1 and 4.2 show examples of reaction in daily life. Which photograph represents a fast reaction and a slow reaction? Explain your answer.

Photograph 4.1
Burning of butane gas

Photograph 4.2
Rusting of iron

Activity 4.1

21st Century Skills
- TPS
- Discussion

To identify examples of fast reactions and slow reactions

Instructions

1. Carry out this activity in groups.
2. Gather information on several examples of reactions usually found in daily life from the Internet, print media and other electronic media.
3. Identify and discuss whether the examples of reactions that you have collected are fast reactions or slow reactions.
4. Present the outcome of your group discussion in the form of a multimedia presentation.

4.1.1

Rate of Reaction

Rate of reaction is the change in the quantity of reactant or product per unit time.

$$\text{Rate of reaction} = \frac{\text{Change in the quantity of reactant or product}}{\text{Time taken for the change to occur}}$$

Among the changes in quantity of reactant or product that can be observed or measured in a specific period of time to determine the rate of reaction include:
- decrease in the mass, volume or concentration of the reactant
- increase in the mass, volume or concentration of the product
- decrease or increase in the pressure, temperature, pH value, electrical conductivity, heat conductivity or intensity of colour of the reacting mixture
- increase in the volume or pressure of the gas released
- increase in the height of the precipitate formed

Entrepreneurship

Why is the price of cheese normally high? How can the price of cheese be reduced?

Determining the Rate of Reaction

Example

0.3 g of magnesium tape reacts completely with excess dilute hydrochloric acid in 30 s (Figure 4.4). Calculate the rate of reaction of this reaction.

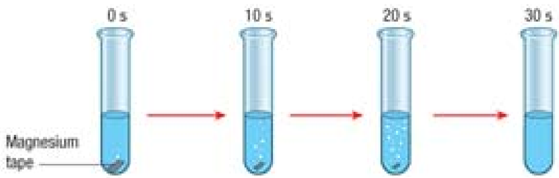


Figure 4.4 Quantity of magnesium tape, a reactant, decreases with time

Solution

$$\text{Rate of reaction} = \frac{\text{Decrease in mass of magnesium}}{\text{Time taken}}$$

$$= \frac{(0.3 - 0.0)\text{ g}}{30\text{ s}}$$

$$= \frac{0.3\text{ g}}{30\text{ s}}$$

$$= 0.01\text{ g s}^{-1}$$

The rate of reaction of a reaction can be measured as:

1. **Average rate of reaction**
   The average value for the rate of reaction that occurs in a specific time interval.

Example

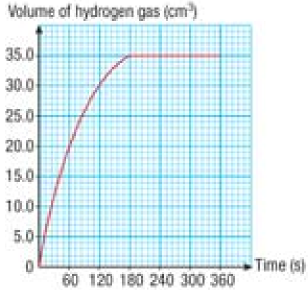
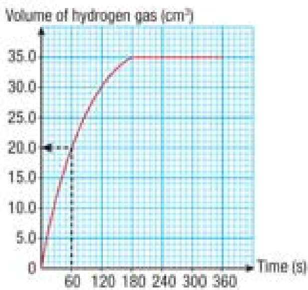


Figure 4.5

Observe Figure 4.5.
Calculate the average rate of reaction:
(a) for the first minute
(b) for the first 2 minutes
(c) in the second minute
(d) in the third minute
(e) for the whole reaction

Solution

(a)



Average rate of reaction for the first minute

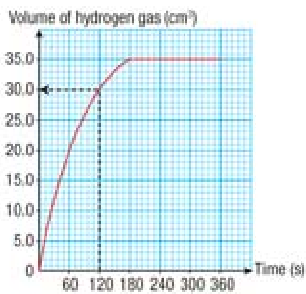
First minute is from 0 s to 60 s

$$= \frac{\text{Total volume of hydrogen gas collected in the first 60 seconds}}{\text{Time of reaction}}$$

$$= \frac{20.00\ \text{cm}^3}{60\ \text{s}}$$

$$= 0.33\ \text{cm}^3\ \text{s}^{-1}$$

(b)



Average rate of reaction for the first 2 minutes

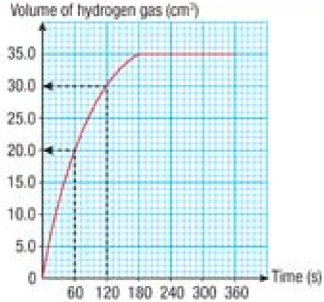
First 2 minutes is from 0 s to 120 s

$$= \frac{\text{Total volume of hydrogen gas collected in the first 120 seconds}}{\text{Time of reaction}}$$

$$= \frac{30.00\ \text{cm}^3}{120\ \text{s}}$$

$$= 0.25\ \text{cm}^3\ \text{s}^{-1}$$

(c)



Average rate of reaction in the second minute

Second minute is from 60 s to 120 s

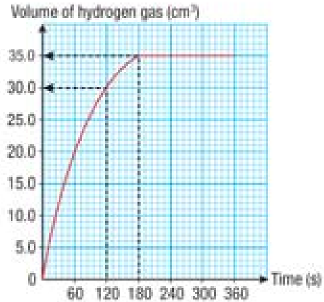
$$= \frac{\text{Total volume of hydrogen gas collected from 60 s to 120 s}}{\text{Time of reaction}}$$

$$= \frac{(30.00 - 20.00)\ \text{cm}^3}{(120 - 60)\ \text{s}}$$

$$= \frac{10.00\ \text{cm}^3}{60\ \text{s}}$$

$$= 0.17\ \text{cm}^3\ \text{s}^{-1}$$

(d)



Average rate of reaction in the third minute

Third minute is from 120 s to 180 s

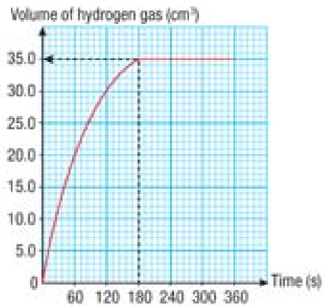
$$= \frac{\text{Total volume of hydrogen gas collected from 120 s to 180 s}}{\text{Time of reaction}}$$

$$= \frac{(35.00 - 30.00)\ \text{cm}^3}{(180 - 120)\ \text{s}}$$

$$= \frac{5.00\ \text{cm}^3}{60\ \text{s}}$$

$$= 0.08\ \text{cm}^3\ \text{s}^{-1}$$

(e)



Average rate of reaction for the whole reaction

$$= \frac{\text{Total volume of hydrogen gas collected}}{\text{Time taken for the reaction to complete}}$$

$$= \frac{35.00\ \text{cm}^3}{180\ \text{s}}$$

$$= 0.19\ \text{cm}^3\ \text{s}^{-1}$$

Reaction ends at 180 s and not 360 s

2. **Rate of reaction at a particular point of time** or **instantaneous rate of reaction**
The rate of reaction at any particular point of time or specific instance.

Example 1

Rate of reaction at time t = Gradient of the tangent to the curve at time t

Observe Figure 4.6.

Rate of reaction at the 20^{th} second = Gradient of the tangent to the curve at the 20^{th} second

$$= \frac{PQ}{RQ}$$

$$= \frac{(49.0 - 21.0)\ cm^3}{(29 - 9)\ s}$$

$$= \frac{28.0\ cm^3}{20\ s}$$

$$= 1.40\ cm^3\ s^{-1}$$

Figure 4.6

Science Info

How to draw a tangent
http://buku-teks.com/sc5121

Example 2

In an experiment, excess zinc granules reacted with dilute hydrochloric acid (Figure 4.7).

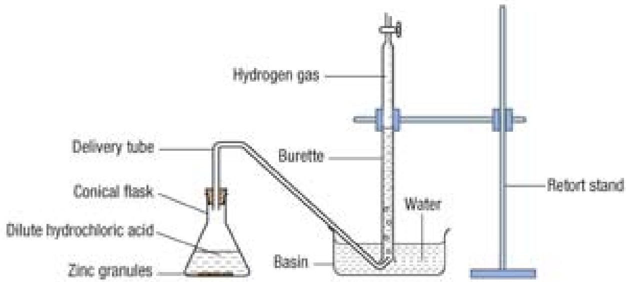


Figure 4.7

The volume of hydrogen gas released is recorded at intervals of 40 seconds. The graph of volume of hydrogen gas against time is shown in Figure 4.8.

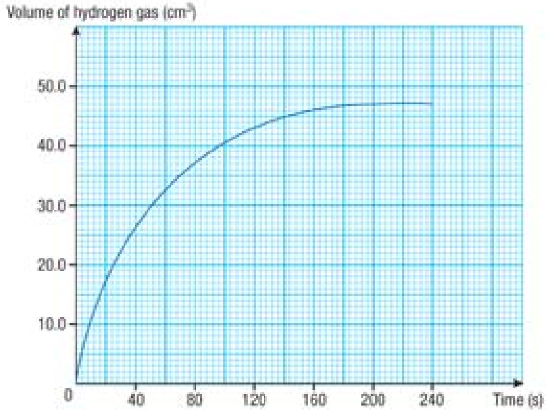
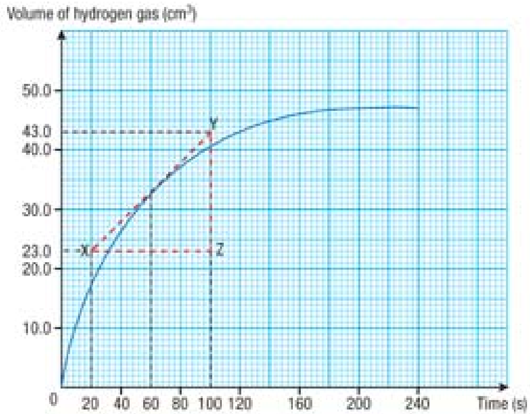


Figure 4.8

For this reaction,
(a) calculate the rate of reaction at the 60th second
(b) calculate the rate of reaction at the 120th second

Solution

(a)



Rate of reaction at the 60th second
= Gradient of tangent of curve at the 60th second

$= \frac{YZ}{XZ}$

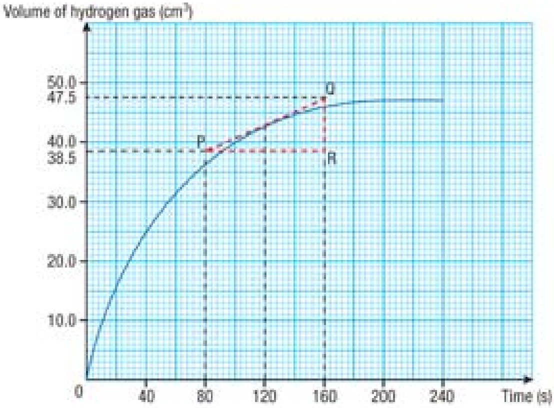
Rate of reaction at time t = Gradient of tangent of curve at time t $= \frac{YZ}{XZ}$

$= \frac{(43.00 - 23.00)\ cm^3}{(100 - 20)\ s}$

$= \frac{20.00\ cm^3}{80\ s}$

$= 0.25\ cm^3\ s^{-1}$

(b)



Rate of reaction at the 120th second
= Gradient of tangent of curve at the 120th second

$= \frac{QR}{PR}$

Rate of reaction at time t = Gradient of tangent of curve at time t $= \frac{QR}{PR}$

$= \frac{(47.50 - 38.50)\ cm^3}{(160 - 80)\ s}$

$= \frac{9.00\ cm^3}{80\ s}$

$= 0.11\ cm^3\ s^{-1}$

Activity 4.2

To solve numerical problems involving data analysis

21st Century Skills
- TPS
- Discussion

Instructions

1. Carry out this activity individually.
2. Solve the following numerical problems involving data analysis:
   (a) 1.3 g of zinc powder is mixed with excess dilute nitric acid. 480 cm^3 of hydrogen gas is collected in 10 s. Calculate the average rate of reaction for the whole reaction in $cm^3\ s^{-1}$.
   (b) The volume of oxygen gas released from a mixture of hydrogen peroxide solution and manganese(IV) oxide powder is recorded at intervals of 30 seconds for 270 seconds in Table 4.1.
      (i) Based on Table 4.1, draw a graph of volume of oxygen gas against time.
      (ii) Calculate the average rate of reaction:
         - for the first 2 minutes
         - in the second minute
         - for the whole reaction
      (iii) Calculate the rate of reaction:
         - at the 60th second
         - at the 150th second
         - at the 240th second

Table 4.1

Time (s)	Volume of oxygen gas (cm^3)
0	0.00
30	14.50
60	23.00
90	28.50
120	33.00
150	36.50
180	39.00
210	40.00
240	40.00
270	40.00

Formative Practice 4.1

1. Give **one** example of a fast reaction and **one** example of a slow reaction in daily life.
2. Define rate of reaction.
3. Figure 1 shows the graph of volume of hydrogen gas released against time.
   Calculate the average rate of reaction:
   (a) for the first 2 minutes
   (b) in the second minute
   (c) for the whole reaction

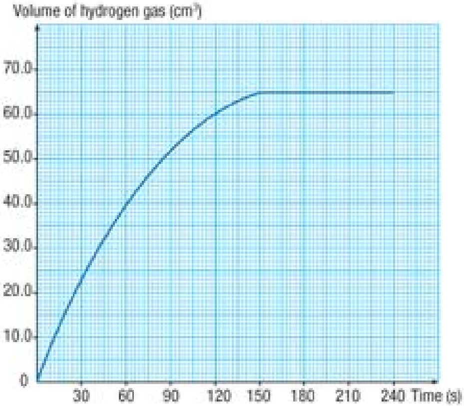


Figure 1

4.1.3

4.2 Factors Affecting Rate of Reaction

There are **five** factors affecting the rate of reaction (Figure 4.9).

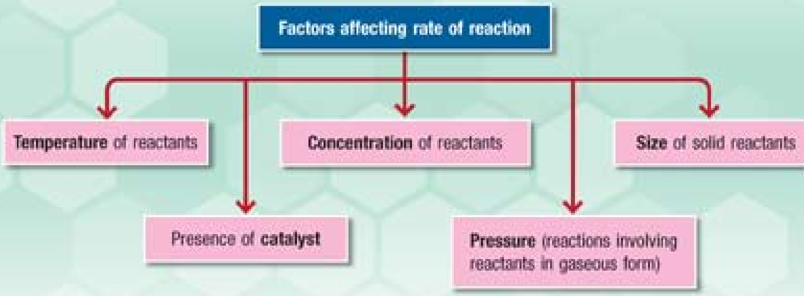


Figure 4.9 Factors affecting the rate of reaction

1. When the temperature of reactants increases, the rate of reaction increases.
2. When catalyst is used in a reaction, the rate of reaction increases.
3. When the concentration of reactants increases, the rate of reaction increases.
4. When pressure increases, the rate of reaction involving gaseous reactants increases.
5. When the size of solid reactants decreases, the rate of reaction increases.

Let us carry out Experiments 4.1 – 4.4 to study how factors such as the temperature of reactants, concentration of reactants, size of reactants and presence of catalyst affect the rate of reaction.

Experiment 4.1

Aim: To study the effect of temperature of reactants on rate of reaction

Problem statement: How does temperature of reactants affect the rate of reaction?

Hypothesis: The higher the temperature of reactants, the higher the rate of reaction.

Variables:
(a) manipulated : Temperature of sodium thiosulphate solution
(b) responding : Time taken until 'X' is no longer visible
(c) constant : Concentration and volume of sodium thiosulphate solution, concentration and volume of sulphuric acid and size of conical flask

4.2.1

Materials: 0.2 mol dm^{-3} sodium thiosulphate solution, 1 mol dm^{-3} sulphuric acid and a piece of white paper with an 'X' at the centre

Apparatus: 250 cm^3 conical flask, 50 cm^3 measuring cylinder, 10 cm^3 measuring cylinder, stopwatch, thermometer, Bunsen burner, tripod stand and wire gauze

Procedure:

1. Using a measuring cylinder, measure and pour 50 cm^3 of 0.2 mol dm^{-3} sodium thiosulphate solution into a clean and dry conical flask.
2. Leave the solution for 5 minutes.
3. Measure and record in the table the temperature of the sodium thiosulphate solution.
4. Place the conical flask on the 'X' on the white paper (Figure 4.10).

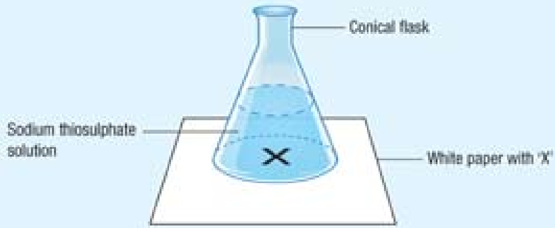


Figure 4.10

5. Measure and quickly pour 5 cm^3 of 1 mol dm^{-3} sulphuric acid into the sodium thiosulphate solution and start the stopwatch simultaneously.
6. Observe the 'X' from the mouth of the conical flask (Figure 4.11).

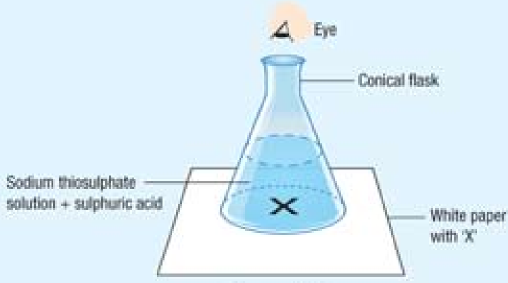


Figure 4.11

7. Stop the stopwatch once the 'X' on the white paper is no longer visible.
8. Record the time taken in the table. Calculate the value of $\frac{1}{\text{time}}$.

9. Repeat steps 1 to 8 by replacing the sodium thiosulphate solution at room temperature with sodium thiosulphate solution heated to 35°C, 40°C, 45°C and 50°C (Figure 4.12).

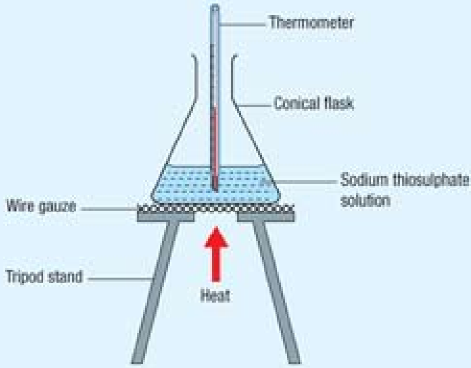


Figure 4.12

Result:

Temperature of sodium thiosulphate solution (°C)	Room temperature	35	40	45	50
Time taken until 'X' is no longer visible (s)					
$\frac{1}{\text{time}}$ (s^{-1})					

Data analysis:

Draw the following graphs:
(a) graph of temperature against time
(b) graph of temperature against $\frac{1}{\text{time}}$

Conclusion:

Is the hypothesis accepted? What is the conclusion for this experiment?

Questions:

1. State the factor that affects the rate of reaction in this experiment.
2. How does the factor concerned affect the rate of reaction?
3. State the operational definition of rate of reaction based on this experiment.

Experiment 4.2

Aim: To study the effect of concentration of reactants on the rate of reaction

Problem statement: How does concentration of reactants affect the rate of reaction?

Hypothesis: The higher the concentration of reactants, the higher the rate of reaction.

Variables:
(a) manipulated : Concentration of sodium thiosulphate solution
(b) responding : Time taken until 'X' is no longer visible
(c) constant : Volume of sodium thiosulphate solution, concentration and volume of sulphuric acid and size of conical flask

Materials: 0.20, 0.16, 0.12, 0.08, 0.04 mol dm^{-3} sodium thiosulphate solutions, 1 mol dm^{-3} sulphuric acid, distilled water and a piece of white paper with an 'X' at the centre

Apparatus: 250 cm^3 conical flask, 50 cm^3 measuring cylinder, 10 cm^3 measuring cylinder and stopwatch

Procedure:

1. Using a measuring cylinder, measure and pour 50 cm^3 of 0.20 mol dm^{-3} sodium thiosulphate solution into a clean and dry conical flask.
2. Place the conical flask on the 'X' on the white paper (Figure 4.13).
3. Measure and quickly pour 5 cm^3 of 1 mol dm^{-3} sulphuric acid into the sodium thiosulphate solution and start the stopwatch simultaneously.
4. Observe the 'X' from the mouth of the conical flask (Figure 4.14).

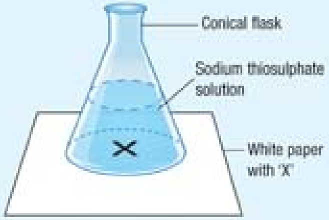


Figure 4.13

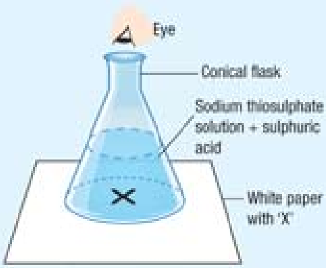


Figure 4.14

5. Stop the stopwatch once the 'X' on the white paper is no longer visible.
6. Record the time taken in the table. Calculate the value of $\frac{1}{\text{time}}$.
7. Repeat steps 1 to 6 by replacing the 0.20 mol dm^{-3} sodium thiosulphate solution with sodium thiosulphate solution of different concentrations as given in the table.

Result:

Concentration of sodium thiosulphate solution ($mol\ dm^{-3}$)	0.20	0.16	0.12	0.08	0.04
Time taken until 'X' is no longer visible (s)					
$\frac{1}{time}$ (s^{-1})					

Data analysis:

Draw the following graphs:

(a) graph of concentration of sodium thiosulphate solution against time

(b) graph of concentration of sodium thiosulphate solution against $\frac{1}{time}$

Conclusion:

Is the hypothesis accepted? What is the conclusion for this experiment?

Questions:

1. State the factor which affects the rate of reaction in this experiment.
2. How does the factor affect the rate of reaction?

Experiment 4.3

Aim: To study the effect of size of solid reactants on rate of reaction

Problem statement: How does the size of reactants affect the rate of reaction?

Hypothesis: The smaller the size of solid reactants, the higher the rate of reaction.

Variables:
(a) manipulated : Size of marble
(b) responding : Time taken to collect 30.00 cm^3 of gas
(c) constant : Temperature, mass of marble, concentration and volume of hydrochloric acid

Materials: Small pieces of marble chips, large pieces of marble chips and 0.1 $mol\ dm^{-3}$ dilute hydrochloric acid

Apparatus: 250 cm^3 conical flask, 50 cm^3 measuring cylinder, rubber stopper with delivery tube, burette, basin, electronic balance, retort stand with clamp and stopwatch

Procedure:

1. Fill the burette and basin with water. Then, invert the burette into the basin filled with water and clamp the burette vertically using a retort stand (Figure 4.15).

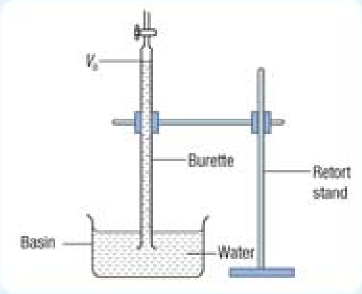


Figure 4.15

2. Adjust the water level in the burette. Observe and record the initial burette reading, V_0.
3. Measure 40 cm^3 of 0.1 mol dm^{-3} dilute hydrochloric acid using a measuring cylinder. Pour the measured acid into a clean and dry conical flask.
4. Weigh 2 g of large pieces of marble chips using an electronic balance. Then, put the 2 g of marble pieces into the conical flask.
5. Immediately close the conical flask with the rubber stopper which is connected to a delivery tube. The other end of the delivery tube is placed under the burette (Figure 4.16). Start the stopwatch.
6. Observe the burette reading. When 30.00 cm^3 of gas is collected, stop the stopwatch. Observe and record the reading on the stopwatch.

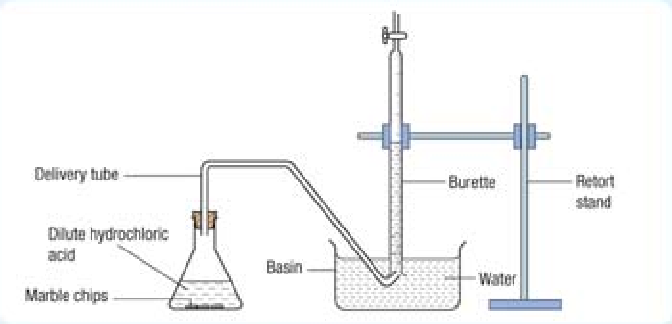


Figure 4.16

7. Repeat steps 1 to 6 by replacing the large pieces of marble chips with small pieces of marble chips of the same mass.

Result:

Size of marble	Time taken to collect 30.00 cm^3 of gas (s)
Large pieces of marble chips	
Small pieces of marble chips	

Data analysis:

1. Compare the time taken to collect 30.00 cm^3 of carbon dioxide released from the reaction using large pieces of marble chips to the reaction using small pieces of marble chips.
2. Compare the rate of reaction of a reaction using large pieces of marble chips to the rate of reaction of a reaction using small pieces of marble chips.

Conclusion:

Is the hypothesis accepted? What is the conclusion for this experiment?

Question:

How does the size of marble chips affect the rate of reaction between marble and hydrochloric acid?

Experiment 4.4

Aim: To study the effect of presence of catalyst on rate of reaction

Problem statement: How does the presence of a catalyst affect the rate of reaction?

Hypothesis: Presence of catalyst increases the rate of reaction.

Variables:

(a) manipulated : Presence of catalyst
(b) responding : Time taken to collect 30.00 cm^3 of gas
(c) constant : Temperature, volume and concentration of hydrochloric acid

Materials: Small pieces of zinc, 0.1 mol dm^{-3} dilute hydrochloric acid and 0.5 mol dm^{-3} copper(II) sulphate solution

Apparatus: 250 cm^3 conical flask, 50 cm^3 measuring cylinder, rubber stopper with delivery tube, burette, basin, electronic balance, retort stand with clamp, spatula and stopwatch

4.2.1

Procedure:

1. Fill the burette and basin with water. Then, invert the burette into the basin filled with water and clamp the burette vertically using a retort stand (Figure 4.17).

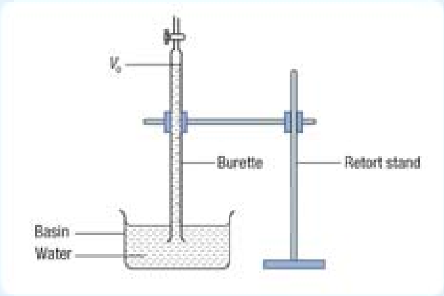


Figure 4.17

CAUTION!

The mixture of hydrogen and air in the burette can explode when ignited. Do not ignite the gas in the burette.

2. Adjust the water level in the burette. Observe and record the initial burette reading, V_0.
3. Measure 40 cm^3 of 0.1 mol dm^{-3} dilute hydrochloric acid using a measuring cylinder. Pour the measured acid into a clean and dry conical flask.
4. Weigh 2 g of zinc pieces using an electronic balance. Then, put the 2 g of zinc pieces into the conical flask.
5. Immediately close the conical flask with the rubber stopper which is connected to a delivery tube. The other end of the delivery tube is placed under the burette (Figure 4.18). Start the stopwatch.

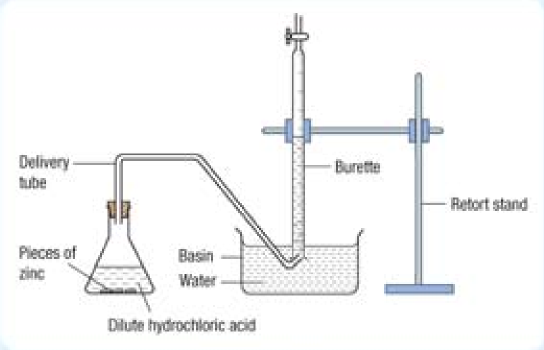


Figure 4.18

6. Observe the burette reading. When 30.00 cm^3 of gas is collected, stop the stopwatch. Record the reading on the stopwatch.

7. Repeat steps 1 to 6 by replacing the 40 cm^3 of 0.1 mol dm^{-3} dilute hydrochloric acid with a mixture of 40 cm^3 of 0.1 mol dm^{-3} dilute hydrochloric acid and 5 cm^3 of 0.5 mol dm^{-3} copper(II) sulphate solution (Figure 4.19).

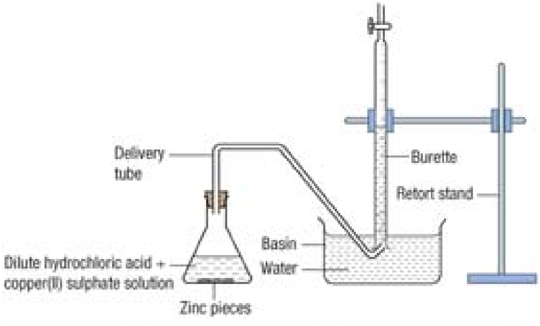


Figure 4.19

Result:

Mixture in the conical flask	Time taken to collect 30.00 cm^3 of gas (s)
Zinc pieces and dilute hydrochloric acid	
Zinc pieces, dilute hydrochloric acid and copper(II) sulphate solution	

Data analysis:

1. Compare the time taken to collect 30.00 cm^3 of hydrogen gas released from the reaction using a mixture of zinc and dilute hydrochloric acid to the reaction using a mixture of zinc, dilute hydrochloric acid and copper(II) sulphate solution as a catalyst.
2. Compare the rate of reaction of a reaction using a mixture of zinc and dilute hydrochloric acid to a reaction using a mixture of zinc, dilute hydrochloric acid and copper(II) sulphate solution as a catalyst.

Conclusion:

Is the hypothesis accepted? What is the conclusion for this experiment?

Questions:

1. State the factor which affects the rate of reaction in this experiment.
2. How does the factor affect the rate of reaction?

Besides the factors studied in Experiments 4.1 – 4.4, one other factor which affects the rate of reaction is **pressure**. Pressure affects the rate of reaction of a reaction that involves gaseous reactants. For reactions involving gaseous reactants, the rate of reaction usually increases when pressure increases. Name two examples of industrial processes which use high pressure to increase their rate of reaction.

BRAIN TEASER

Why is the rate of reaction for solid or liquid reactant normally not affected by pressure?

Formative Practice 4.2

1. State **five** factors which affect the rate of reaction.
2. Complete the following statements:
   (a) The ______ the temperature of reactants, the higher the rate of reaction.
   (b) The ______ the concentration of reactants, the higher the rate of reaction.
   (c) The ______ the size of reactants, the higher the rate of reaction.
3. State **one** factor that only affects the rate of reaction involving reactants in the form of gas.

4.3 Applications of the Concept of Rate of Reaction

In daily life and industries, factors that affect the rate of reaction are normally adjusted to change **the rate of reaction** of a reaction. For example, a refrigerator lowers the temperature of food or drinks kept in it. This lowering of temperature slows down food spoilage.

Photograph 4.3 Example of an appliance which applies the concept of rate of reaction

4.2.1 4.3.1

Haber Process

In the Haber Process, a mixture of nitrogen gas, N_2 and hydrogen gas, H_2 in the ratio of 1:3 at a temperature of 450°C – 550°C and a pressure of 200 atm is passed over iron filings, Fe which functions as a catalyst to produce ammonia, NH_3 (Figure 4.20).

$$\underset{\text{Nitrogen}}{N_2} + \underset{\text{Hydrogen}}{3H_2} \rightleftharpoons \underset{\text{Ammonia}}{2NH_3}$$

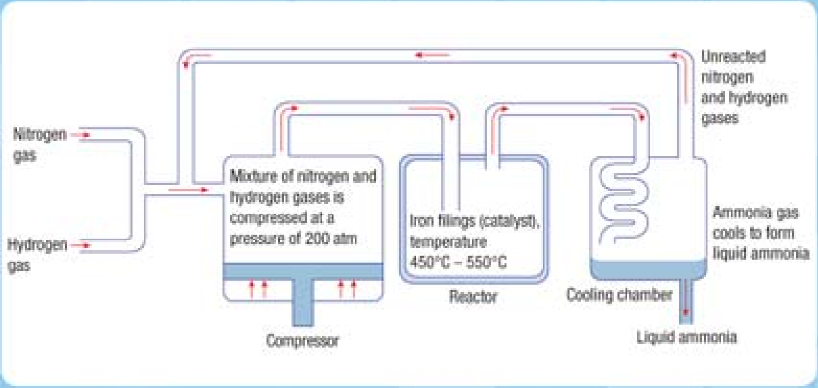


Figure 4.20 Production of ammonia using Haber Process

Contact Process

In the Contact Process, sulphur is burnt in an excess of air to produce sulphur dioxide gas, SO_2.

$$\underset{\text{Sulphur}}{S} + \underset{\text{Oxygen}}{O_2} \longrightarrow \underset{\text{Sulphur dioxide}}{SO_2}$$

Sulphur dioxide gas mixed with an excess of air at a temperature of 450°C and a pressure of 1 atm is passed over vanadium(V) oxide, which functions as a catalyst, to produce sulphur trioxide gas, SO_3.

$$\underset{\text{Sulphur dioxide}}{2SO_2} + \underset{\text{Oxygen}}{O_2} \rightleftharpoons \underset{\text{Sulphur trioxide}}{2SO_3}$$

4.3.1

Sulphur trioxide gas is dissolved in concentrated sulphuric acid to produce oleum, $H_2S_2O_7$.

SO_3 Sulphur trioxide	+	H_2SO_4 Sulphuric acid	$\longrightarrow$	$H_2S_2O_7$ Oleum

Oleum is diluted with water to produce concentrated sulphuric acid (Figure 4.21).

$H_2S_2O_7$ Oleum	+	H_2O Water	$\longrightarrow$	$2H_2SO_4$ Sulphuric acid

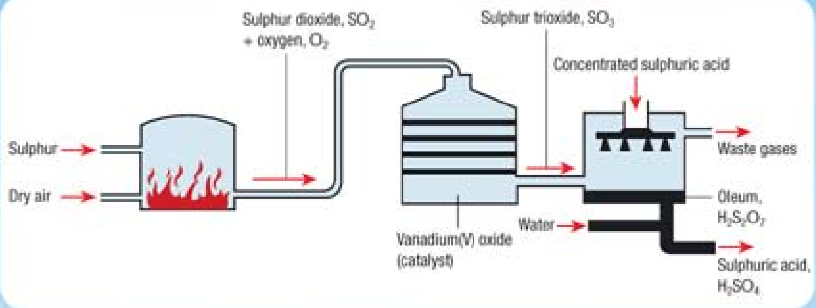


Figure 4.21 Production of sulphuric acid using Contact Process

Factors which increase the rate of reaction in Haber Process and Contact Process are as follows:

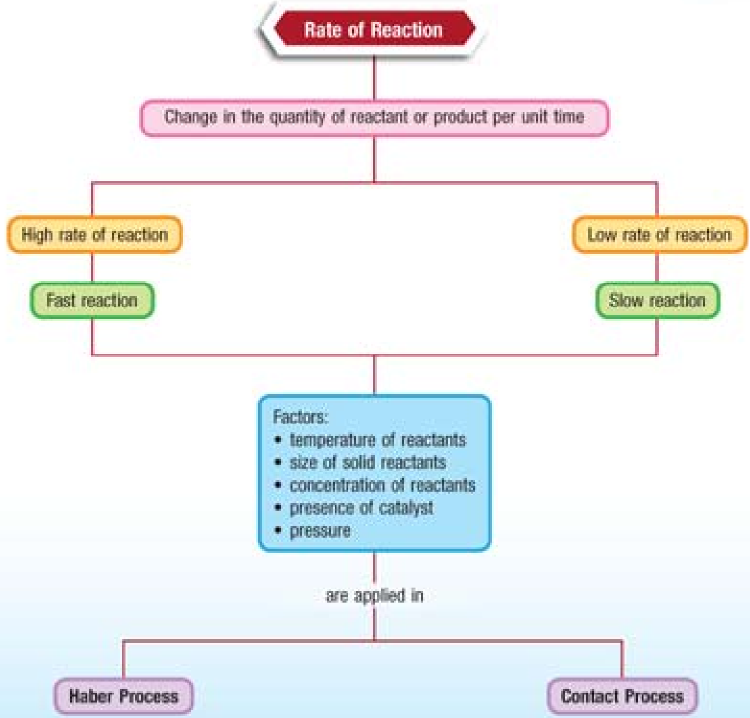
(a) **Haber Process**
Temperature : 450°C – 550°C
Pressure : 200 atm
Catalyst : Iron filings

(b) **Contact Process**
Temperature : 450°C
Pressure : 1 atm
Catalyst : Vanadium(V) oxide

Formative Practice 4.3

1. (a) Name **one** life process in the human body which involves the concept of rate of reaction.
   (b) How does the application of rate of reaction influence the life process in question 1(a)?
2. State the factors which influence the rate of reaction in the following processes:
   (a) Haber Process
   (b) Contact Process

Summary


Rate of Reaction
Change in the quantity of reactant or product per unit time
High rate of reaction
Fast reaction
Low rate of reaction
Slow reaction
Factors:
• temperature of reactants
• size of solid reactants
• concentration of reactants
• presence of catalyst
• pressure
are applied in
Haber Process
Contact Process

Self-Reflection

After studying this chapter, you are able to:

4.1 Introduction to Rate of Reaction

- [ ] Explain with examples fast reactions and slow reactions in daily life.
- [ ] Define the rate of reaction.
- [ ] Determine the rate of reaction.

4.2 Factors Affecting Rate of Reaction

- [ ] Carry out experiments to study factors affecting rate of reaction.

4.3 Application of the Concept of Rate of Reaction

- [ ] Communicate about the application of the concept of rate of reaction in daily life and industries.

Summative Practice 4

Quiz
http://buku-teks.com/sc5138

Answer the following questions:

1. (a) What is meant by chemical reaction?
   (b) Is the rate of reaction affected by pressure? Explain your answer.

2. A student carried out an experiment to study a factor which affects the rate of reaction between marble (calcium carbonate) and dilute hydrochloric acid. Figure 1 shows the apparatus set-up for the experiment.

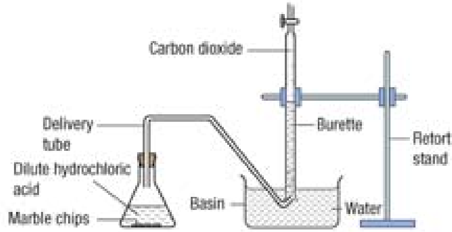


Figure 1

The student carried out the experiment using marble chips (Set I) and repeated the experiment by replacing the marble chips with marble powder (Set II). Table 1 shows the results of the experiment for Set I and Set II.

Table 1

Time (s)	0	30	60	90	120	150	180	210
Volume of gas collected in Set I (cm^3)	0.00	12.50	23.00	31.00	37.50	42.00	45.00	45.00
Volume of gas collected in Set II (cm^3)	0.00	20.00	32.00	39.00	43.00	45.00	45.00	45.00

(a) In this experiment, state the:
   (i) manipulated variable
   (ii) responding variable
   (iii) constant variable
(b) State **one** hypothesis for this experiment.
(c) Based on Table 1, draw **two** graphs of volume of gas collected against time for Set I and Set II experiments on the same set of axis on a graph paper.
(d) Based on Set II, calculate:
   (i) average rate of reaction for the first minute
   (ii) average rate of reaction for the first two minutes
   (iii) average rate of reaction in the second minute
   (iv) rate of reaction at the 60^{th} second
   (v) average rate of reaction for the whole reaction
(e) Based on the results of Set I, calculate the average rate of reaction for the whole reaction.

Enrichment Practice

3. Digestive enzymes function as biological catalysts to change the rate of decomposition of complex food molecules into simpler molecules in the digestive system. What is the use of digestive enzymes other than aiding in the digestion of food? Figure 2 shows one application of biological catalysts in daily life.

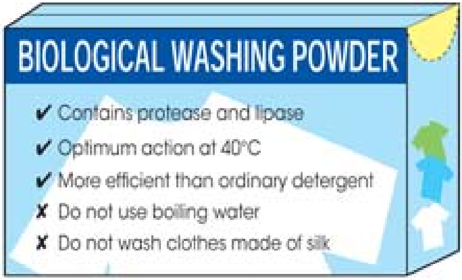


Figure 2

(a) Give **two** examples of biological catalyst in the washing powder.
(b) What is the effect of the biological catalyst towards food stains on clothes?
(c) State **one** factor that influences the effectiveness of the biological catalyst in the reaction.
(d) How does this factor influence the action of the biological catalyst?