What is the rate of the reaction?

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What is the rate of the reaction?

- **Rate of reaction** measures the speed at which the reactants are converted to the products in a chemical reaction.

$$\text{Reactants} \xrightarrow{\text{speed}} \text{Products}$$

- For a reaction that occurs **rapidly,** the rate of reaction is **high.** Conversely, for a reaction that occurs **slowly,** the rate of reaction is low.
- The **time taken** for a **fast** reaction is **short,** whereas the time taken for a slow reaction is **long.**
- Hence, the **rate** of a particular reaction is **inversely proportional** to the **time taken** for the reaction.

$$\text{Rate of reaction} \propto \frac{1}{\text{time taken}}$$

- Different chemical reactions occur at different rates. Some examples are illustrated in Table.

Type of reaction	Fast reaction	Slow reaction
Reaction involving liberation of a gas	Bubbles of carbon dioxide gas liberate rapidly when sodium carbonate powder reacts with dilute hydrochloric acid. $Na_2CO_3(s) + 2HCl(aq) \rightarrow 2NaCl(aq) + CO_2(g) + H_2O(l)$	In photosynthesis, carbon dioxide reacts with water very slowly in the presence of sunlight and chlorophyll to produce glucose and oxygen gas. $6CO_2(g) + 6H_2O(l) \rightarrow C_6H_{12}O_6(s) + 6O_2(g)$
Precipitation reaction	When silver nitrate solution is added to sodium chloride solution, a white precipitate of silver chloride is formed immediately. $AgNO_3(aq) + NaCl(aq) \rightarrow AgCl(s) + NaNO_3(aq)$	When dilute hydrochloric acid is added to sodium thiosulphate solution, a yellow precipitate of sulphur appears only after a few seconds. $Na_2S_2O_3(aq) + 2HCl(aq) \rightarrow 2NaCl(aq) + S(s) + SO_2(g) + H_2O(l)$
Heating a metal in air	When a small piece of potassium is heated in air, it burns rapidly to form a white solid of potassium oxide. $4K(s) + O_2(g) \rightarrow 2K_2O(s)$	When a small piece of copper is heated in air, it reacts slowly with oxygen in the air to form a black solid of copper(II) oxide. $2Cu(s) + O_2(g) \rightarrow 2CuO(s)$

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What does the rate of reaction measure?

Observable changes for measuring the rate of reaction:

1. When a reaction occurs, **two obvious changes** that occur are:

- the **quantity of a reactant decreases** with **time**
- the **quantity of a product increases** with **time**

2. The **quantity** of a reactant/product can be the

- **number of moles** of a substance
- **mass** of a solid
- **volume** of a gas
- **concentration** of a solution

3. If the **changes** of any of these quantities are **visible** and **measurable** during a reaction, then it can be used to **measure** the **rate** of that reaction.

4. Suitable measurable visible changes in a chemical reaction are:

- **volume** of a gas liberated
- **formation** of a precipitate
- changes in the **mass** during a reaction
- **colour** changes
- changes in the **electrical conductivity** of the solution
- **temperature** changes
- **pressure** changes
- changes in **concentration** of the solution of a reactant
- **pH** changes

5. One of these measurable visible changes can be selected as a **suitable quantity** to determine the rate of a particular reaction.
The **changes** in this **selected quantity** can be measured by carrying out **an experiment** and the results are then **analysed** to determine the rate of that reaction.

6. Definition: Rate of reaction is defined as the **change** in a **selected quantity** during a reaction **per unit time** whereby the selected quantity can be any of the measurable visible changes in the reaction.

7. Two examples to illustrate the meaning of rate of reaction.
Reaction between magnesium and dilute sulphuric acid
$Mg(s) + H_2SO_4(aq) \rightarrow MgSO_4(aq) + H_2(g)$

- In the reaction between dilute sulphuric acid and a magnesium ribbon, the following **two changes** are observed:
  - The **mass of magnesium** (the reactant) **decreases** with **time.**
  - The **volume of hydrogen gas** (the product) **increases** with **time.**
- Hence, the **rate of reaction** between dilute sulphuric acid and magnesium can be **determined** by measuring the **change in the mass** of magnesium or the **volume** of hydrogen gas per **unit time.**
  Quantitatively,

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- When excess aqueous ethanedioic acid is added to acidified potassium manganate(VII) solution, the **purple** colour of the solution **slowly decolourises** at room temperature.
- By **measuring the time taken** for the purple colour to decolourise, the rate of reaction can be determined.
- Rate of reaction is **inversely proportional** to the time taken for the purple colour to decolourise.

- Rate of reaction is reflected by the value of 1/time taken. The **larger** the value time taken of **1/time taken**, the **higher** the **rate** of reaction.

- Table shows the units for the rate of reaction measured in different ways.

Change in a selected quantity per unit time	Units for the rate of reaction
Change in mass per unit time	$g\ s^{-1}$ or $g\ min^{-1}$
Change in volume of a gas liberated per unit time	$cm^3\ s^{-1}$ or $cm^3\ min^{-1}$
Change in concentration of a reactant per unit time	$mol\ dm^{-3}\ s^{-1}$ or $mol\ dm^{-3}\ min^{-1}$
Change in number of moles of a reactant per unit time	$mol\ s^{-1}$ or $mol\ min^{-1}$

Rate of Reaction Experiment

Aim: To compare the rates of a few reactions.
Materials: Marble chips, 2 mol dm^{-3} hydrochloric acid, 0.1 mol dm^{-3} sodium thiosulphate solution, 1 mol dm^{-3} lead(II) nitrate solution.
Apparatus: 50 cm^3 beakers, test tubes.

Procedure:

1. 5 cm^3 of 2 mol dm^{-3} hydrochloric acid is poured into each of the three test tubes on a rack.
2. The test tubes are labelled I to III respectively.
3. One piece of marble chip is added into test tube I.
4. About 2 cm^3 of 0.1 mol dm^{-3} sodium thiosulphate solution is poured into test tube II and the mixture is shaken well.
5. About 2 cm^3 of 1 mol dm^{-3} lead(II) nitrate solution is poured into test tube III and the mixture is shaken well.
6. The changes are observed carefully. The rates of reactions in the three test tubes are compared.

Observations:

Test tube	Reactants	Observation
I	Marble chip and hydrochloric acid	Bubbles of a colourless gas are liberated rapidly, that is, effervescence occurs rapidly.
II	Sodium thiosulphate solution and hydrochloric acid	A yellow precipitate appears only after about 12 seconds.
III	Lead(II) nitrate solution and	A white precipitate is formed immediately.

1. The reaction between lead(II) nitrate solution and hydrochloric acid is very fast.
2. The reaction between the marble chip and hydrochloric acid is moderately fast.

3. The reaction between sodium thiosulphate solution and hydrochloric acid is slow.

Discussion:

1. The chemical equation for the reaction in
2. The rate of reaction in ascending order is: rate in test tube II < rate in test tube I < rate in test tube III
3. The observable change that can be used to compare the rate of reaction in
   (a) test tube I is the time taken for the effervescence to stop completely.
   (b) test tube II is the time taken for the appearance of a yellow precipitate.
   (c) test tube III is the time taken for the appearance of a white precipitate.

Conclusion:

1. The rate of reaction between sodium thiosulphate solution and hydrochloric acid is the lowest.
2. The rate of reaction between the marble chip and hydrochloric acid is moderately high.
3. The rate of reaction between lead(II) nitrate solution and hydrochloric acid is the highest.

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