

Rate of Reaction

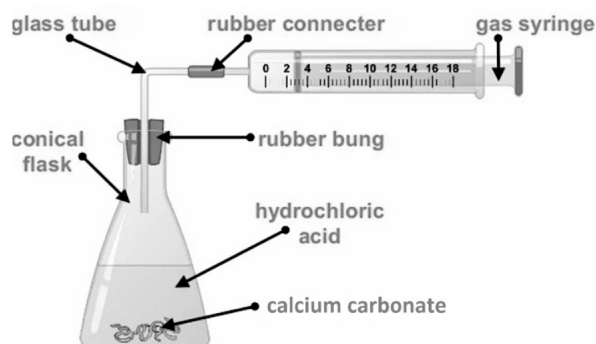
Definition: Rate of Reaction

- The **rate (or speed)** of a chemical reaction tells us **how quickly or slowly** a reaction takes place.
- It is defined as the **change in amount of product formed or reactant used per unit time**.

Methods to Determine Rate of Reaction

Method 1: Measuring Volume of Gas Produced Per Unit Time

When 0.50 g of CaCO_3 solid is added to excess hydrochloric acid, carbon dioxide is formed. The carbon dioxide gas can be collected in the gas syringe using the following apparatus. To determine the rate of the reaction, the volume of gas collected in the gas syringe can be measured over a period of time. A graph of volume of gas collected against time is plotted.



**note: you need to know how to diagram the experimental set-up.*

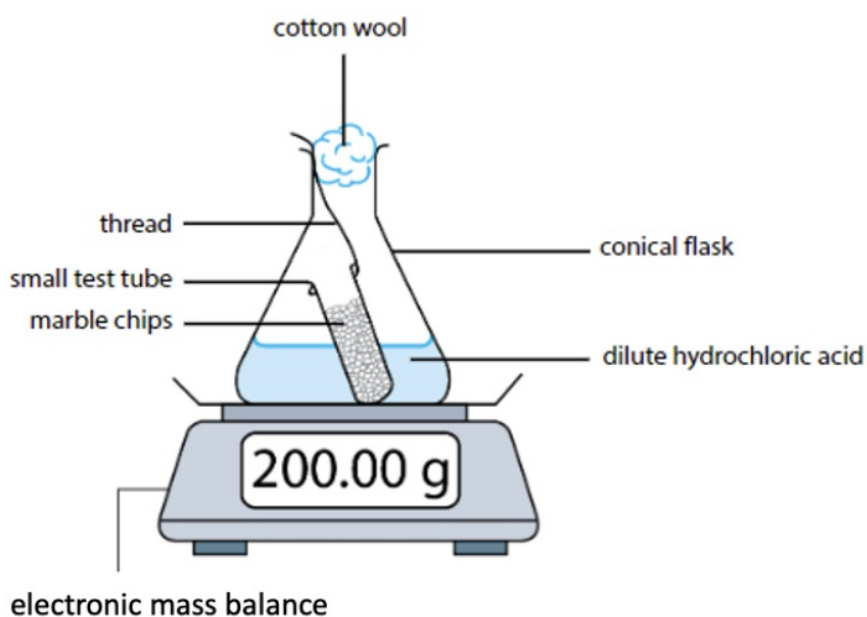
Method 2: Measuring loss in mass of reaction per unit time

To determine the rate of reaction between 0.50 g of CaCO_3 solid and excess hydrochloric acid.

Apparatus

- Conical flask
- Electronic mass balance
- Stopwatch

Experimental Setup

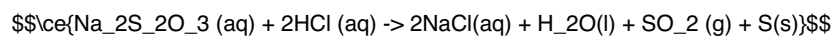


Procedure

1. Set up the apparatus as shown above.
2. Use a cotton wool plug to cover the mouth of the conical flask to prevent acid from splashing out during the reaction (resulting in a loss in reactants).
3. Record the mass of the conical flask and its contents.
4. Release the thread and ensure that the calcium carbonate are added into the acid. Start the stopwatch immediately.
5. Record the mass of the conical flask and its contents at regular time intervals (e.g. every 1 minute) until mass remains constant.
6. Use the data collected to plot a graph of mass of conical flask and contents against time.
7. The rate of reaction can be determined from the gradient of the graph of mass against time.

Method 3: Measuring a changing quantity

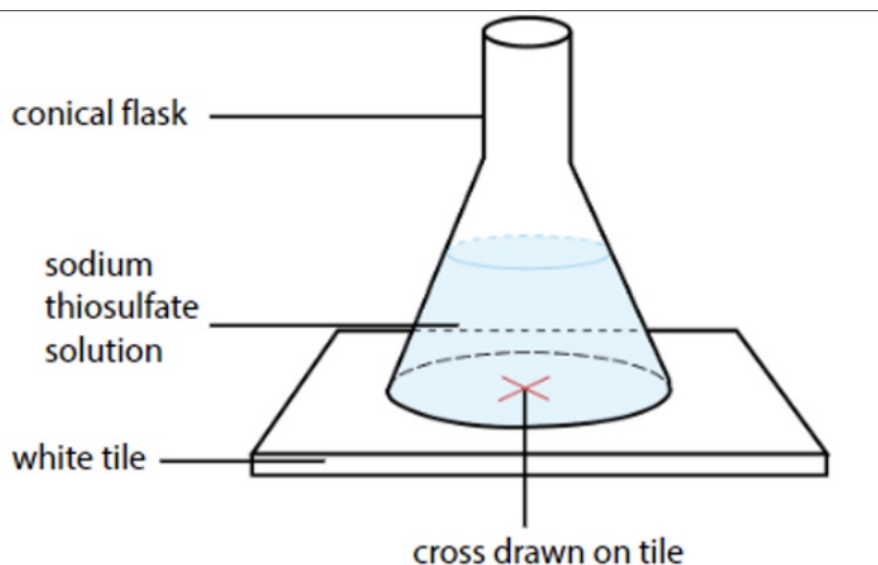
To determine the rate of the reaction between 50 cm³ of 0.200 mol/dm³ sodium thiosulfate solution and hydrochloric acid.



Apparatus

- Conical flask/beaker
- Stopwatch
- White tile with cross or colourimeter

Experimental Setup



Procedure

1. Set up the apparatus as shown above.
2. Using a measuring cylinder, measure 50 cm^3 of 0.2 mol/dm^3 of sodium thiosulfate solution into the conical flask
3. Using a measuring cylinder, add 100 cm^3 of 0.2 mol/dm^3 dilute hydrochloric acid into the conical flask and start the stopwatch immediately.
4. Look at the cross through the mouth of the flask. Stop the stopwatch when the cross is no longer visible. (yellow solid sulfur produced is opaque and blocks the cross from view as more of it is formed.)
5. Repeat the experiment with a changed variable (e.g. temperature, concentration of solution).
6. The change in rate of reaction can be determined by comparing the change in time taken for the cross to be covered.

Alternative Method

1. Use the colourimeter to measure the colour intensity of the reaction mixture in the conical flask at regular time intervals (e.g. every 1 minute).
2. Use the data collected to plot a graph of colour intensity against time.
3. The rate of reaction can hence be determined through the gradient of the graph of colour intensity against time.

Collision Theory

- For a reaction to occur and products to form, **the reactant particles must collide with each other.**
- However, only **effective collisions will result in a reaction.** An effective collision must fulfil the following conditions:
 - The reactant particles must **collide with sufficient energy, equal to or greater than the reaction's activation energy.**
 - The reactant particles must also collide with the **correct orientation**, i.e., "the

right way round".

Factors Affecting Rate of Reaction

There are five factors affecting the rate of reaction. They are:

1. **Concentration:** applicable for reactants in **aqueous** state
2. **Pressure:** applicable for reactants in **gaseous** state
3. **Particle Size:** applicable for reactants in **solid** state.
4. **Temperature**
5. **Presence of Catalyst**

Factor 1: Concentration

Lower Concentration	Higher Concentration
Fewer reactant particles per unit volume	More reactant particles per unit volume
Reactant particles are further from each other.	Reactant particles are closer to each other
Fewer collisions per unit time between particles	More collisions per unit time between particles
Frequency of effective collisions is lower	Frequency of effective collisions is higher
Slower rate of reaction	Faster rate of reaction

Factor 2: Pressure

Lower Pressure	Higher Pressure
Fewer reactant particles per unit volume	More reactant particles per unit volume
Reactant particles are further from each other	Reactant particles are closer to each other
Fewer collisions per unit time between particles	More collisions per unit time between particles
Frequency of effective collisions is lower	Frequency of effective collisions is higher
Slower rate of reaction	Faster rate of reaction

Factor 3: Particle Size

Large Particle Size (Granulated Solid)	Small Particle Size (Powdered Solid)
Bigger pieces of solid reactants	Smaller pieces of solid reactants

Large Particle Size (Granulated Solid)	Small Particle Size (Powdered Solid)
Smaller surface area of solid reactants (given same mass, less number of particles)	Bigger surface area of solid reactants (given same mass, more number of particles)
Fewer collisions per unit time between particles	More collisions per unit time between particles
Frequency of effective collisions is lower	Frequency of effective collisions is higher
Slower rate of reaction	Faster rate of reaction

Factor 4: Temperature

Lower Temperature	Higher Temperature
Particles have less kinetic energy and move slower	Particles have more kinetic energy and move faster
Less frequent collisions between particles	More frequent collisions between particles
Less particles collide with energy greater or equal to activation energy, E_a	More particles collide with energy greater or equal to activation energy, E_a
Frequency of effective collisions is lower	Frequency of effective collisions is higher
Slower rate of reaction	Faster rate of reaction

Catalysts

A catalyst increases the rate of chemical reactions without being chemically changed at the end of the reaction.

Characteristics of Catalysts

- Increased rate of reaction but not the yield
- Not used up in the reaction as it can be regenerated at the end of the reaction
- Selective in action (i.e. each catalyst only catalyses certain reactions)
- Can be poisoned by impurities
- Physical appearance may change but remain chemically the same
- Provide an alternative pathway with a lower activation energy, E_a , for the reaction

Factor 5: Presence of Catalyst

Uncatalysed reaction	Catalysed reaction
----------------------	--------------------

Uncatalysed reaction	Catalysed reaction
No catalysts to provide alternative pathway of lower activation energy for the reaction to proceed.	Catalysts increase the speed of reaction by providing an alternative pathway of lower activation energy for the reaction to succeed.
Less particles collide with energy greater or equal to activation energy, E_a	More particles collide with energy greater or equal to activation energy, E_a
Frequency of effective collisions is lower	Frequency of effective collision is higher
Slower speed of reaction	Faster rate of reaction

Industrial Catalyst

- Industrial catalysts are usually transition metals and their compounds due to the ability to have variable oxidation states
- By using catalysts, less extreme physical conditions (heat and pressure) are required, saving energy.

Catalyst	Use
Iron	Manufacture of ammonia in the Haber process
Aluminium or Silicon Dioxide	Cracking of hydrocarbons
Nickel	Manufacture of margarine from vegetable oils
Platinum, Palladium, and rhodium	Catalytic converters

Biological Catalysts (Enzymes)

- Enzymes are biological catalysts, which catalyse biological processes such as digestion, energy production, detoxification etc.
- Enzymes are made of proteins
- Sensitive to temperature - most enzymes operate best at body temperature (between 35 degrees Celsius and 40 degrees Celsius). Enzymes are dormant/inactive at low temperatures and **denatured** at high temperatures. Denaturation is when the specific active site changes and enzyme cannot catalyse the specific reaction anymore.
- Sensitive to pH - operates best at optimal pH range. Different enzymes have different optimal pH range.

Specific Catalytic Action

- The active site of each enzyme is specific, and can only fit certain reactant molecules in a specific orientation.
- Applications - Manufacture of food such as cheese, yoghurt and bread, in laundry detergent.

Graphical Analysis

- Graphs are often used to describe information about a chemical reaction.
- Gradient of graph indicates the speed of the reaction. The steeper the gradient, the faster the speed of reaction. The gradient can change as reaction proceeds as reactants are used up.
- The final volume of gas / mass of the reaction indicates the yield of the reaction. The yield of the products depends on the amount of limiting reagents.