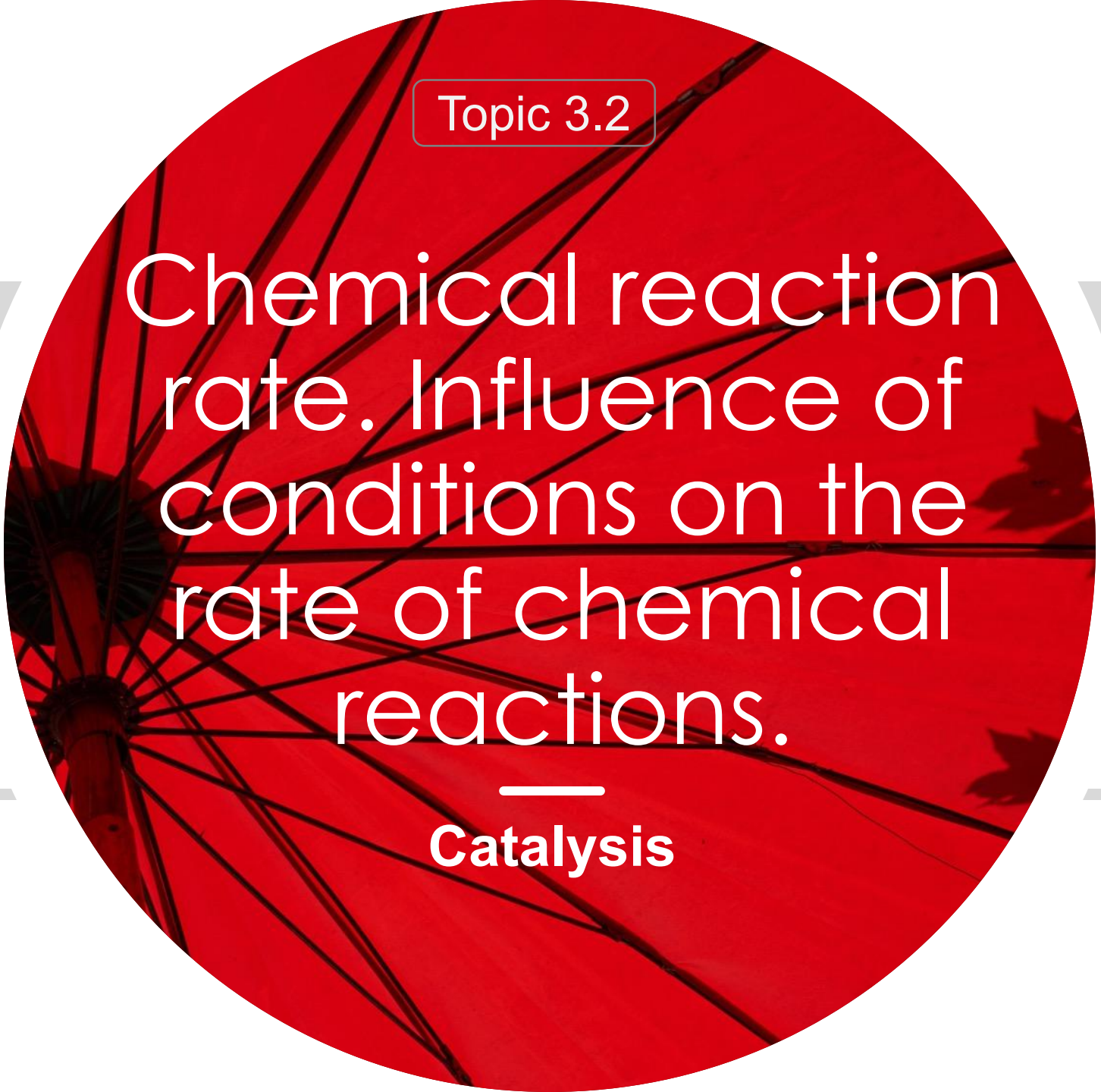


Topic 3.2

Chemical reaction rate. Influence of conditions on the rate of chemical reactions.

Catalysis

OUTLINE:

1. Chemical reaction rate
2. Collision theory
3. Influencing factors
4. Catalysis
5. Inhibitors

Definition

The Reaction Rate for a given chemical reaction is the measure of the change in concentration of the reactants or the change in concentration of the products per unit time. The speed of a chemical reaction may be defined as the change in concentration of a substance divided by the time interval during which this change is observed:

$$\text{rate} = \frac{\Delta\text{concentration}}{\Delta\text{time}}$$

Rate of reactions – Calculating rates of reactions

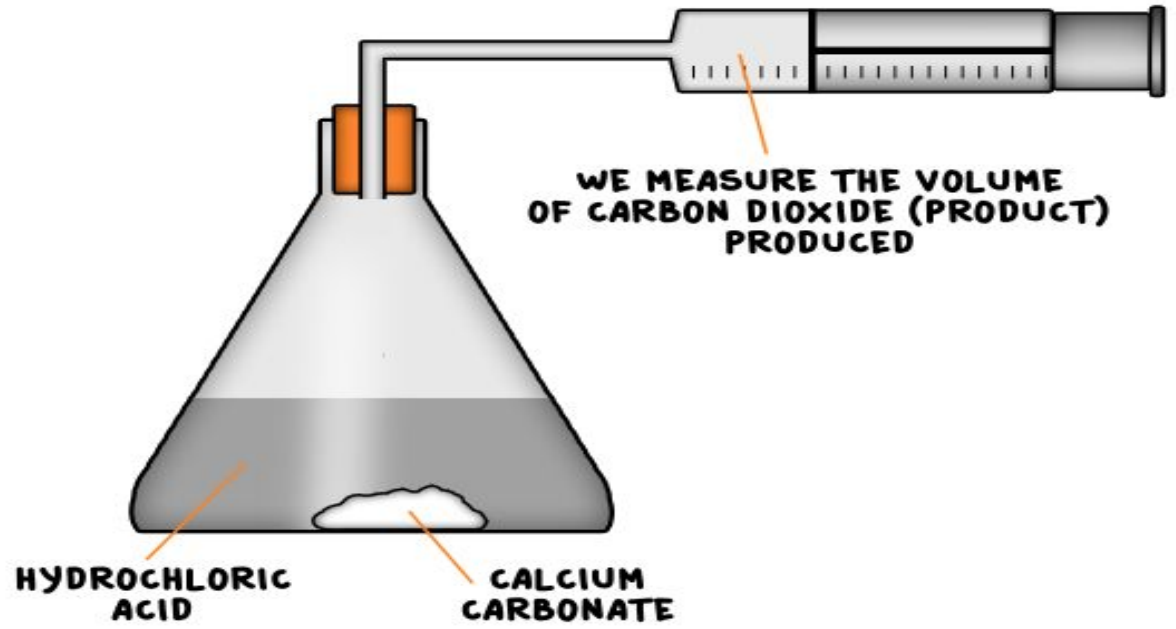
The rate of a chemical reaction can be found by measuring the quantity of a reactant used or the quantity of product formed over time.

$$\text{mean rate of reaction} = \frac{\text{quantity of reactant used}}{\text{time taken}}$$

$$\text{mean rate of reaction} = \frac{\text{quantity of product formed}}{\text{time taken}}$$

The quantity of reactant or product can be measured by the mass in grams or by a volume in cm^3.

The units of rate of reaction may be given as g/s or cm^3/s.



Rate of reactions part 1 – Calculating rates of reactions

Worked example 1

25cm^3 of carbon dioxide was given off in the first 2 seconds of a reaction. Calculate the mean rate of reaction and give the units.

Mean rate of reaction = $\frac{\text{quantity of product formed}}{\text{time taken}}$

Mean rate of reaction = $\frac{25\text{cm}^3}{2\text{ s}}$

Mean rate of reaction = 12.5 cm^3/s

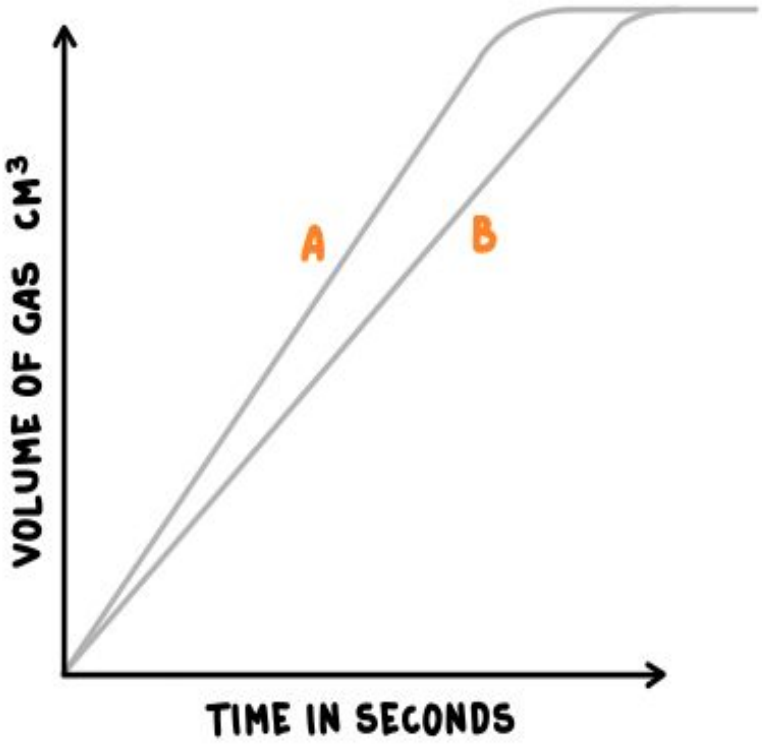
Worked example 2 (Higher Tier)

The above reaction was carried out again. The new results showed that 2 dm^3 of carbon dioxide was released in 200 seconds. Calculate the mean rate of reaction in mol/dm^3

(1 mole of any gas occupies 24 dm^3 at STP)

Moles of carbon dioxide = $\frac{2\text{ dm}^3}{24\text{ dm}^3}$ = 0.83 moles

Mean rate of reaction = $\frac{0.83\text{ moles}}{200\text{ s}}$ = 0.0042 mol/s



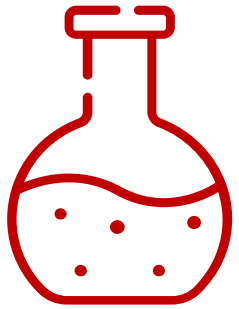
Slope A will have a greater rate of rea
as it is steeper.

For a reaction of the form A+B→C , the rate can be expressed in terms of the change in concentration of any of its components

$$\text{rate} = -\frac{\Delta[A]}{\Delta t}$$

$$\text{rate} = -\frac{\Delta[B]}{\Delta t}$$

$$\text{rate} = \frac{\Delta[C]}{\Delta t}$$



in which Δ[A] is the difference between the concentration of A over the time interval t2–t1 :

$$\Delta[A] = [A]_2 - [A]_1$$

1. State two ways of finding the rate of reaction.

2. State two units of rate of reaction. (HT: state 3)

3. State two ways of measuring the quantity of reactant or product.
4. A student carries out an experiment reacting hydrochloric acid (HCl) with calcium carbonate (CaCO3) to give calcium chloride (CaCl2) carbon dioxide and water. Write the balanced symbol equation for this reaction.

5. The student collects 50 cm3 of carbon dioxide gas in 10 seconds. What is the rate of reaction? Include the units.
6. (HT only) The student repeats the experiment again, this time they find the mass of the carbon dioxide collected. They collect 11 g of carbon dioxide in 10 seconds. Calculate the rate of reaction in mol/s.

7. (HT only) What mass of carbon dioxide are they collecting per second if the rate of reaction is 0.075 mol/s?

ANSWERS

1. State two ways of finding the rate of reaction.
   Measuring the quantity of reactant used or product formed.
2. State two units of rate of reaction. (HT: state 3)
   g/s; cm^3/s; (mol/s)
3. State two ways of measuring the quantity of reactant or product.
   Mass in grams or volume cm^3

4. A student carries out an experiment reacting hydrochloric acid (HCl) with calcium carbonate ($CaCO_3$) to give calcium chloride ($CaCl_2$) carbon dioxide and water. Write the balanced symbol equation for this reaction.

$$CaCO_3\,(s) + 2HCl\,(aq) \rightarrow CaCl_2\,(aq) + CO_2\,(g) + H_2O\,(l)$$

5. The student collects 50 cm^3 of carbon dioxide gas in 10 seconds. What is the rate of reaction? Include the units.

rate of reaction = $\frac{\text{volume of gas collected}}{\text{time taken}} = \frac{50}{10} = 5\ cm^3/s$

6. (HT only) The student repeats the experiment again, this time they find the mass of the carbon dioxide collected. They collect 11 g of carbon dioxide in 10 seconds. Calculate the rate of reaction in mol/s.

11g/44g = 0.25 moles of carbon dioxide

so 0.25 moles/10 seconds

= 0.025 mol/s

7. (HT only) What mass of carbon dioxide are they collecting per second if the rate of reaction is 0.075 mol/s

0.075 moles of CO_2 is 44 x 0.075 so 3.3 g/s

Rates of reactions – Factors which affect rates of reactions

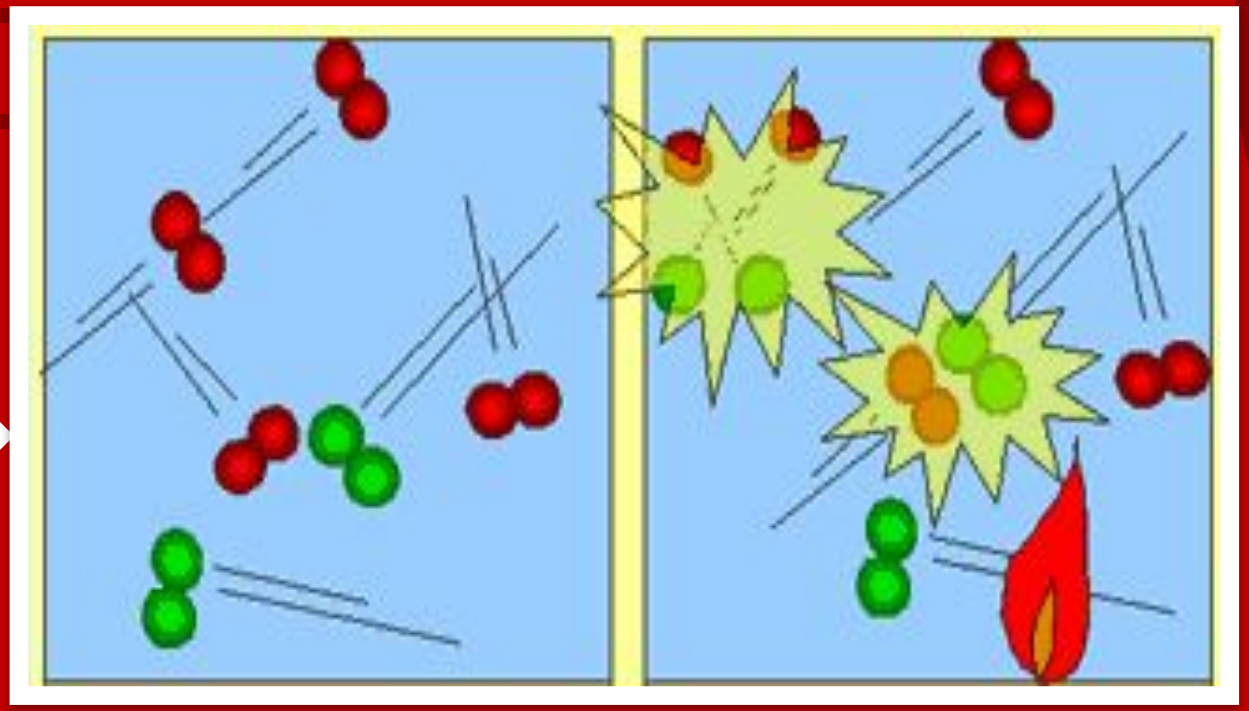
Factors which affect the rates of chemical reactions include:

- **The concentrations of reactants in solution**
- **The pressure of reacting gases**
- **The surface area of solid reactants**
- **The temperature**
- **The presence of a catalyst**

Collision theory explains how these factors affect rates of reactions. According to this theory, chemical reactions can occur only when reacting particles collide with each other and with sufficient energy. The minimum amount of energy that particles must have to react is called the activation energy.

The explanations on the next slide are very important and you will need to use them accurately in the exams to gain credit.

Collision theory

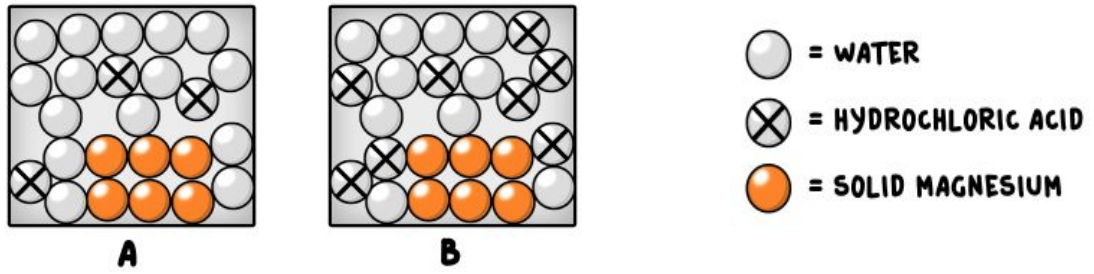


Collision theory explains why some reactions like the formation of water or carbon dioxide from their elements are very slow – they have high activation energies, often with multiple steps.

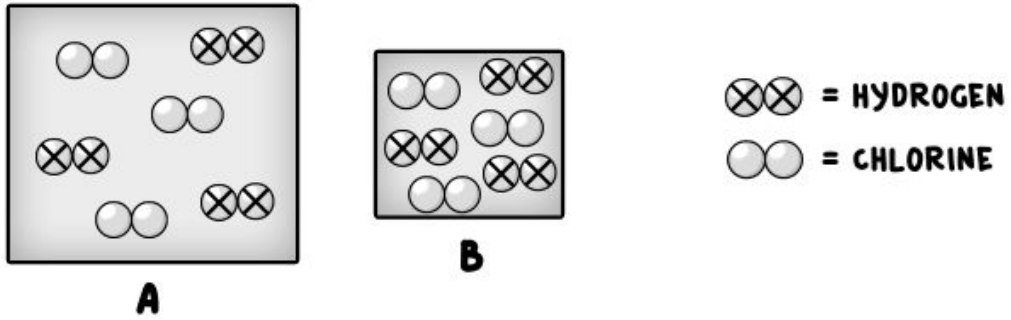
At room temperature, molecular collisions are not energetic enough to overcome the activation energy barrier, so the reaction rate is close to zero.

Rates of reactions part 2 – Factors which affect rates of reactions

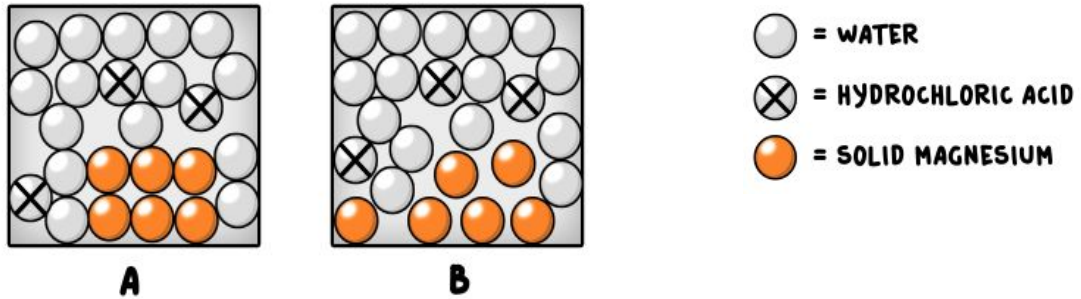
Increasing the concentration of reactants in solution increases the frequency of collisions, and so increases the rate of reaction.



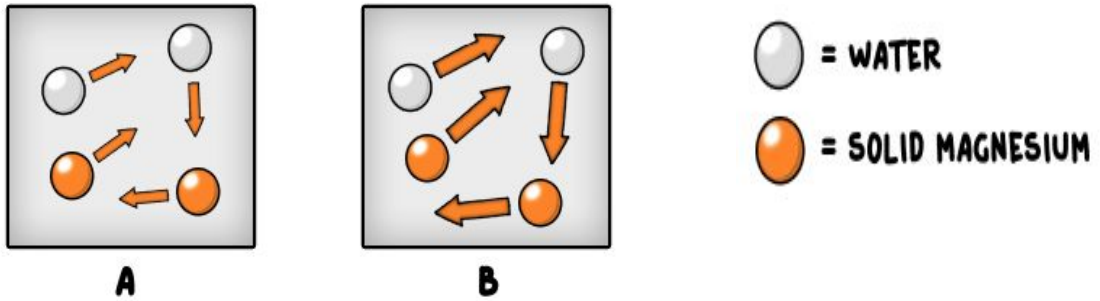
Increasing the pressure of reacting gases increases the frequency of collisions, and so increases the rate of reaction.



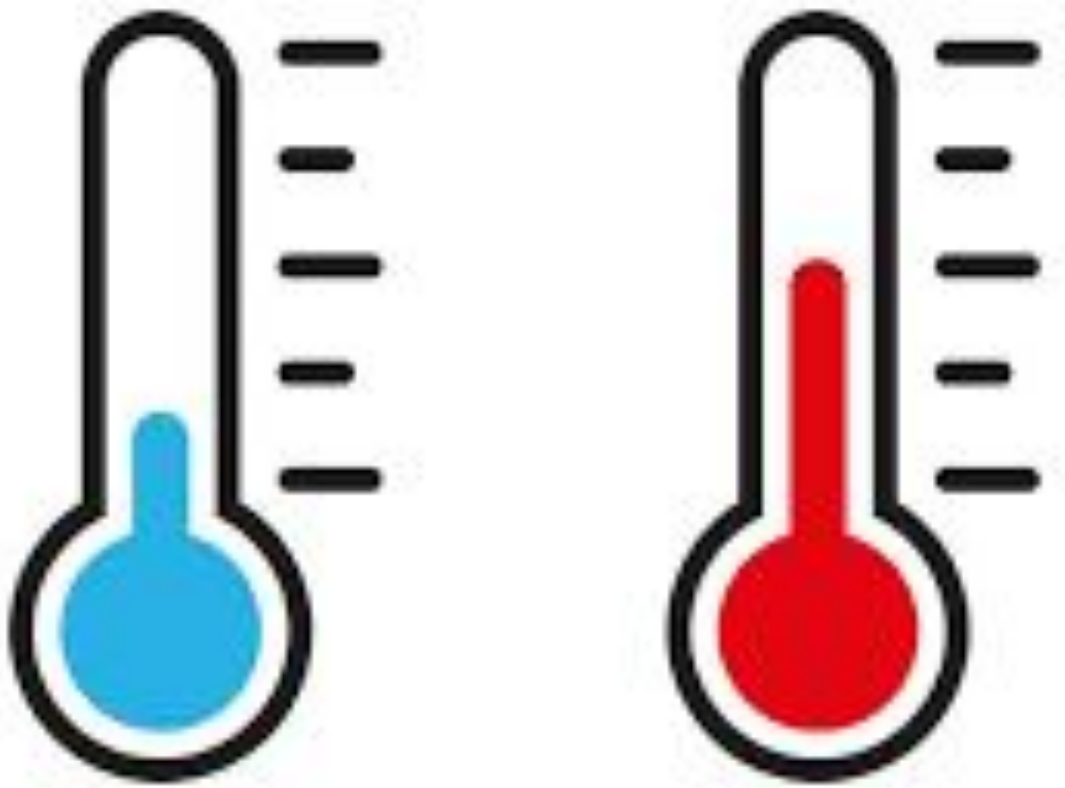
Increasing the surface area of solid reactants increases the frequency of collisions, and so increases the rate of reaction.



Increasing the temperature increases the frequency of collisions and makes the collisions more energetic, and so increases the rate of reaction.

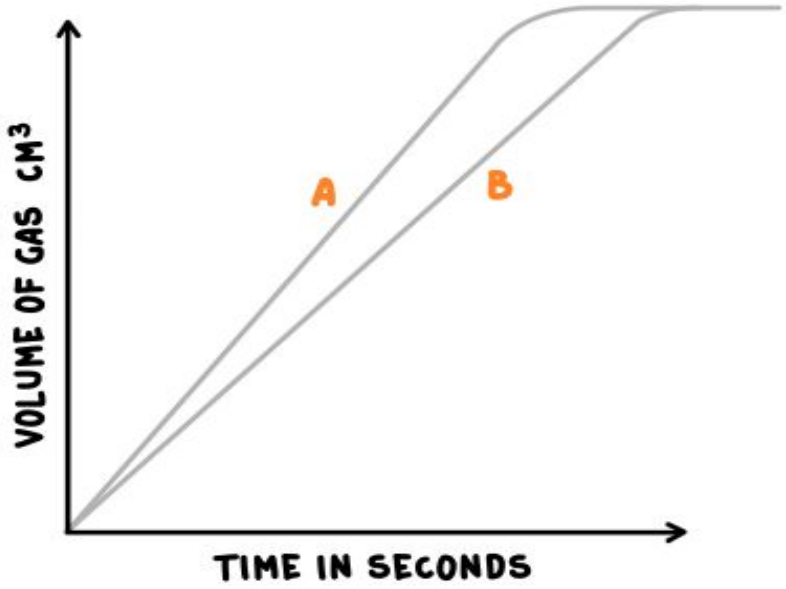


- ✔ temperature usually speeds up chemical reactions
- ✔ at high temperature, reactant particles are more chaotic and more energetic than at low temperatures
- ✔ high temperatures increase the likelihood that the kinetic energy barrier (activation energy) will be breeched.
- ✔ Frequency of collisions also increases



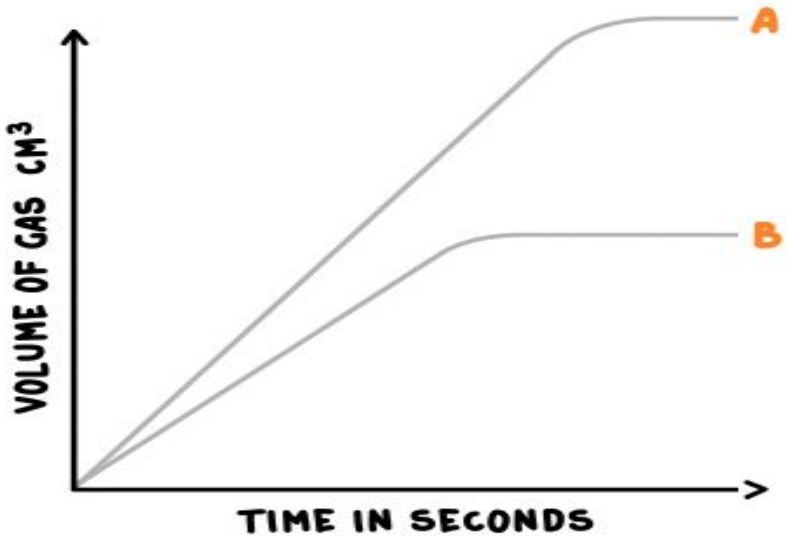
Temperature

Rates of reactions part 2 – Factors which affect rates of reactions



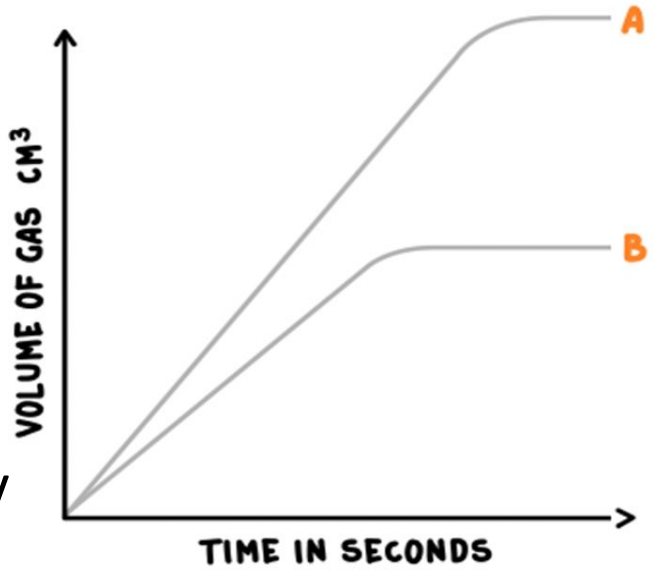
Increasing the **surface area, temperature** or using a **catalyst** will increase the rate of reaction so the **gradient of the line increases** from B to A. Finishing at the **same final volume of gas**.

Increasing the **concentration** provides more reacting particles therefore more product. So the **gradient of the line increases** and the **final volume of gas increases**.



Questio

1. What is meant by the term ‘collision theory’?
2. What happens to the gradient of a line if the rate of reaction is increased?
3. According to collision theory, chemical reactions can only occur when…
4. Other than concentration, give three factors that affect the rate of reaction.
5. Draw a labelled graph to show how changing any one of these factors may affect the rate of reaction. Include the line before and after the change.
6. The graph below shows how the reaction is affected when the concentration of hydrochloric acid is doubled when reacting with excess magnesium. Explain why the amount of hydrogen gas doubles and why the rate of reaction doubles. Use collision theory in your response.



Answers

1. What is meant by the term ‘collision theory’?

   Explains how reactions occur when particles collide, and how rates of reaction are increased when the frequency and/ or energy of collisions is increased.

2. What happens to the gradient of a line if the rate of reaction is increased?

   Becomes steeper.

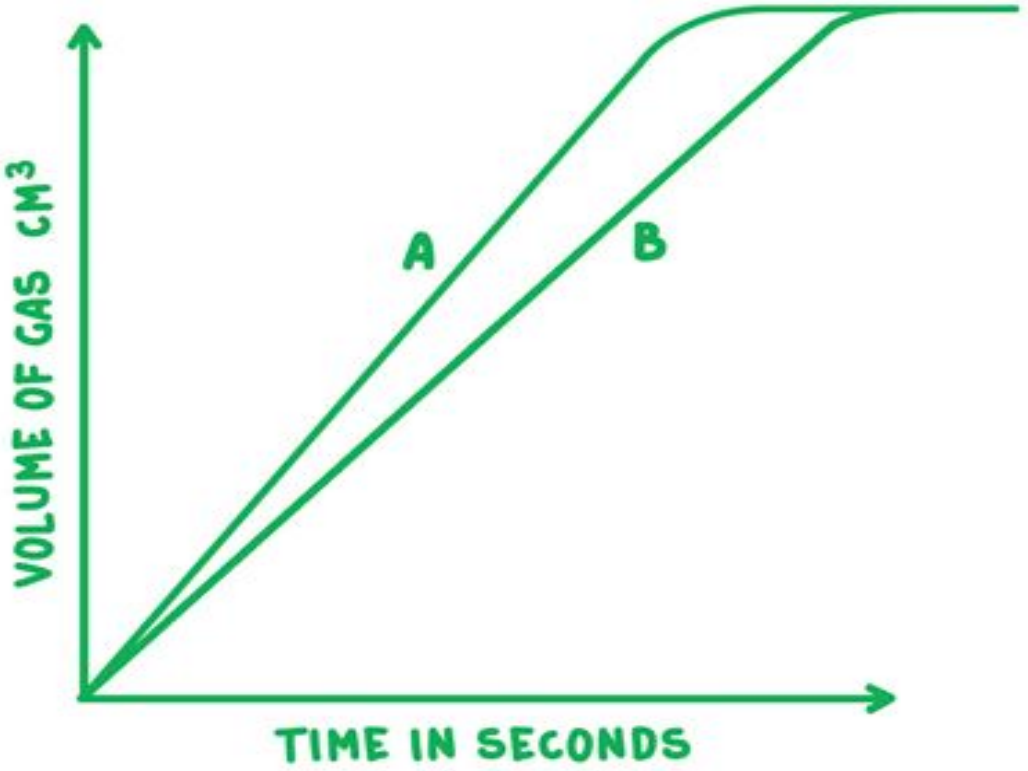
3. According to collision theory, chemical reactions can only occur when…

reacting particles collide with each other with sufficient energy.

4. Other than concentration, give three factors that affect the rate of reaction.

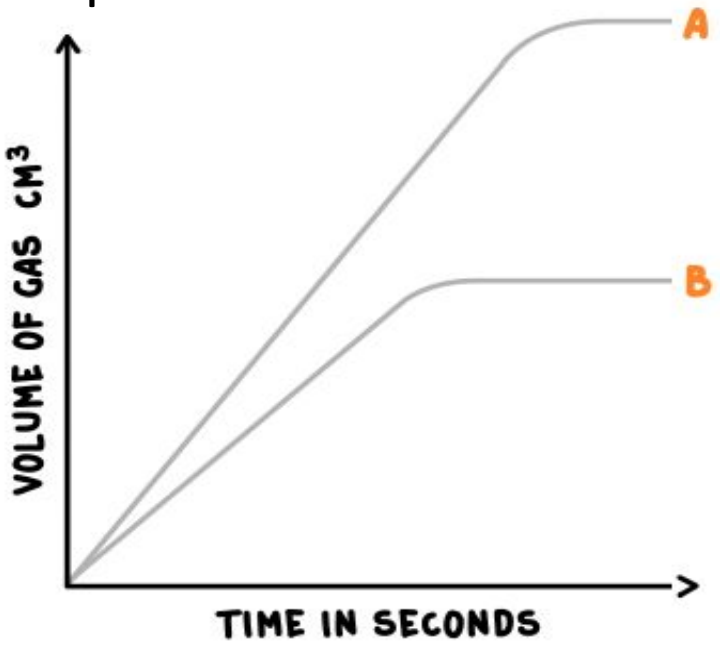
   Any from: temperature, surface area, pressure and a catalyst

5. Draw a labelled graph to show how changing any one of these factors may affect the rate of reaction. Include the line before and after the change.



Factors which affect the rates of reactions – AnswerIT

6. The graph below shows how the reaction is affected when the concentration of hydrochloric acid is doubled when reacting with excess magnesium. Explain why the amount of hydrogen gas doubles and why the rate of reaction doubles. Use collision theory in your response.



If concentration of acid is doubled then there are twice the number of collisions with magnesium atoms.
There will be twice the number of successful collisions so rate of reaction doubles.
As there are twice as many acid particles (and the magnesium is in excess) there will be twice the volume of (hydrogen) gas released

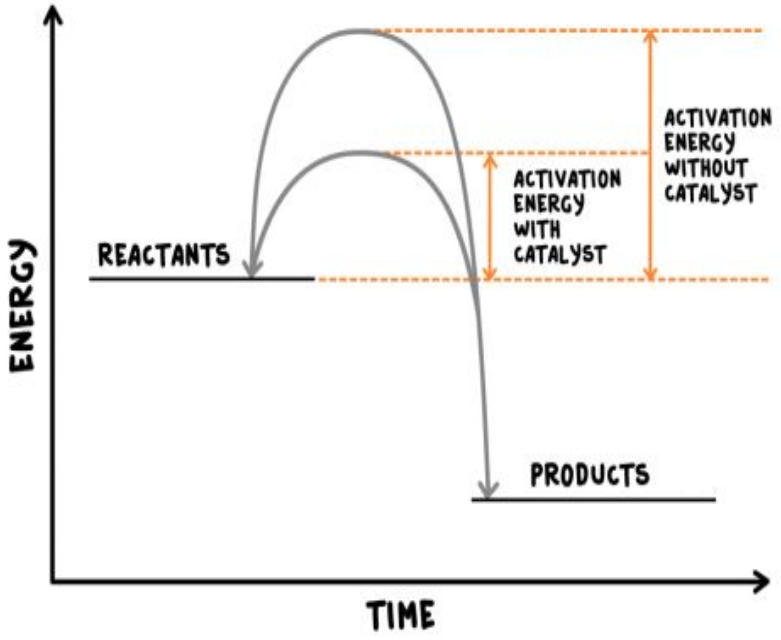
Rates of reactions part 3 – Factors which affect rates of reactions - catalysts

Catalysts **speed up the rate** of chemical reactions **without altering the products** of the reaction, being itself **unchanged chemically and in mass** at the end of the reaction.

This means that the catalyst is still there, unchanged, at the end of the reaction.

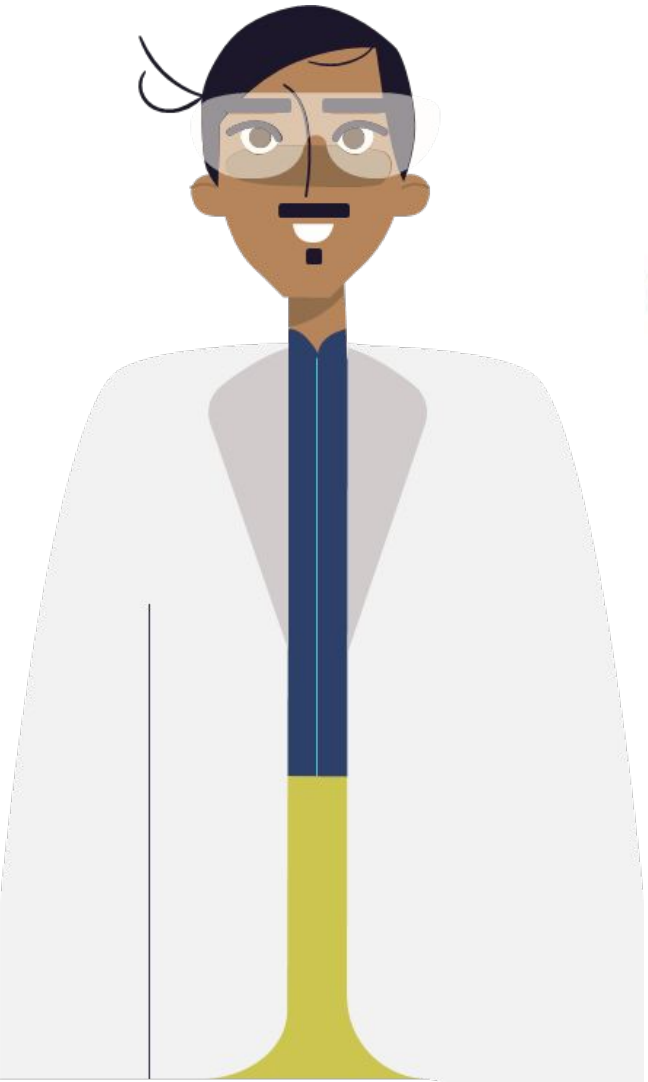
Enzymes are biological catalysts. Enzymes are used in the production of alcoholic drinks by fermentation.

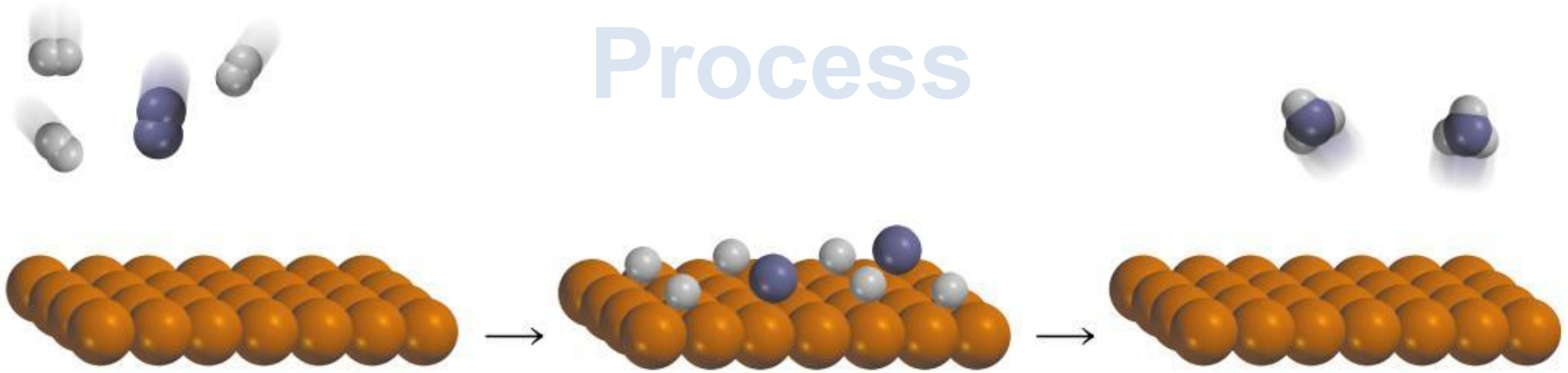
Catalysts increase the rate of reaction by providing a different pathway for the reaction that has a lower activation energy. A reaction profile for a catalysed reaction can be drawn as shown on the right.



You should be able to explain catalytic action in terms of activation energy. For example, "from the reaction profile I can see that the catalyst **lowers** the activation energy".

Haber Process

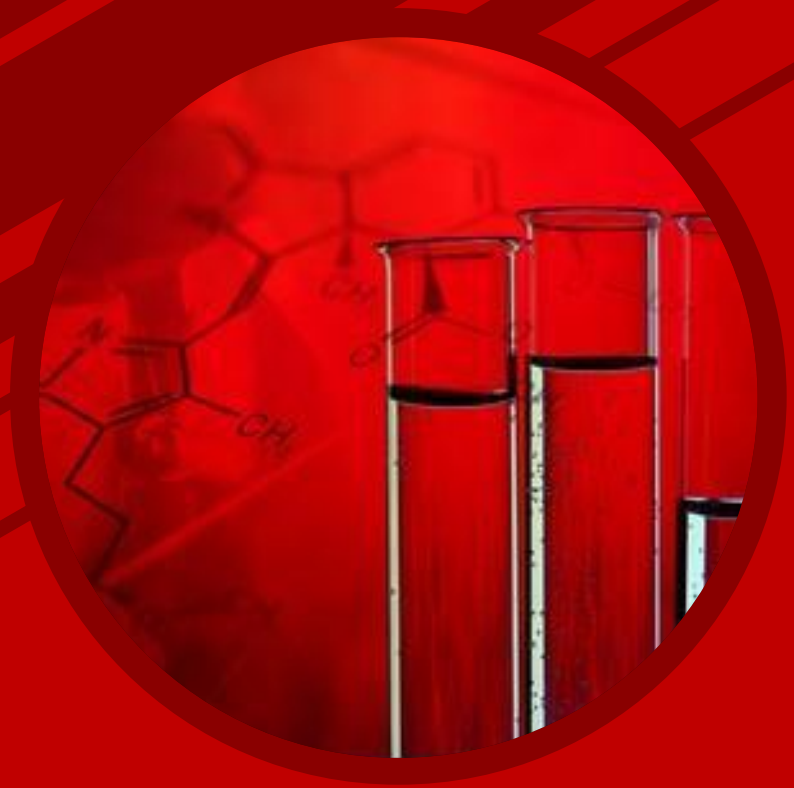




$$N_2\,(g) + 3H_2\,(g) \xrightarrow[\text{catalyst}]{Fe/Al_2O_3/K_2O} 2NH_3\,(g)$$

A catalyst works by

- increasing the potential energy of the reactants
- increasing the energy released during a reaction
- decreasing the potential energy of the products
- decreasing the activation energy required for a reaction



Inhibitors are an agent that slows or interferes with a chemical action, a substance that reduces or suppresses the activity of another substance (such as an enzyme)

Inhibitors

1. What is the formula for rate of reaction
A) Quantity of product X Time
B) Quantity of reactant X Time
C) Quantity of product / Time
D) Quantity of product + Time
2. Catalyst is a substance, which _____ chemical reaction.
A) Increases the speed of a
B) Decreases the speed of a
C) Can either increase or decrease the speed of a
D) Alters the value of equilibrium constant in a reversible
3. The rate of a chemical reaction tells us about
A) the reactants taking part in the reaction
B) how slow or fast the reaction is taking place
C) the products formed in the reaction
D) none of the above
4. What happens to the rate of a reaction when temperature increases?
A) The rate of reaction slows down
B) The rate of the reaction speeds up
C) The rate of reaction stays the same

5. Increasing the pressure of a reacting vessel only affects:
A) Gaseous reactants
B) Solid reactants
C) Liquid reactants
D) None of the above
6. Increasing the concentration of a reacting vessel only affects:
A) Gaseous reactants
B) Solid reactants
C) Liquid reactants
D) None of the above
7. A substance that decreases speed of chemical reaction without being being changed is called:
A) Catalyst
B) Inhibitor
C) Base
D) pressure
8. Increasing the surface area of a reacting vessel only affects:
A) Gaseous reactants
B) Solid reactants
C) Liquid reactants
D) None of the above

9. True or False: Increasing the concentration of the reactants will slow down the reaction.
A) True
B) False
10. Reactants or Products: These are jocated on the left side of the chemical equation
A) reactants
B) products
11. What is the name given to a catalyst in the human body?
A) Reactant
B) Product
C) Enzyme
D) Collide
12. True or False: Collision theory explains how these factors affect rates of reactions.
A) True
B) False