Chapter 8: Rates and equilibrium 1

Knowledge organiser

Rates of reaction

The **rate of a reaction** is how quickly the reactants turn into the products.

To calculate the rate of a reaction, you can measure:

- how quickly a reactant is used up

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

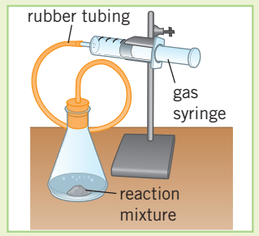
- how quickly a product is produced.

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

For reactions that involve a gas, this can be done by measuring how the mass of the reaction changes or the volume of gas given off by the reaction.

Volume of gas produced

The reaction mixture is connected to a gas syringe or an upside down measuring cylinder. As the reaction proceeds the gas is collected.



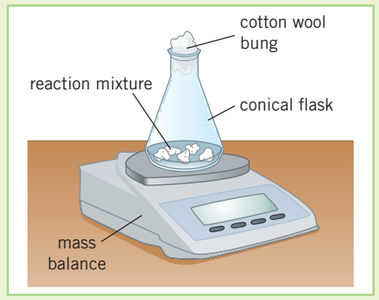
The rate for the reaction is then:

$$\text{rate} = \frac{\text{volume of gas produced}}{\text{time taken}}$$

Volume is measured in cm^3 and time in seconds, so the unit for rate is cm^3/s.

Change in mass

The reaction mixture is placed on a mass balance. As the reaction proceeds and the gaseous product is given off, the mass of the flask will decrease.



The rate for the reaction is then:

$$\text{rate} = \frac{\text{change in the mass}}{\text{time taken}}$$

The mass is measured in grams and time is measured in seconds. Therefore, the unit of rate is g/s.

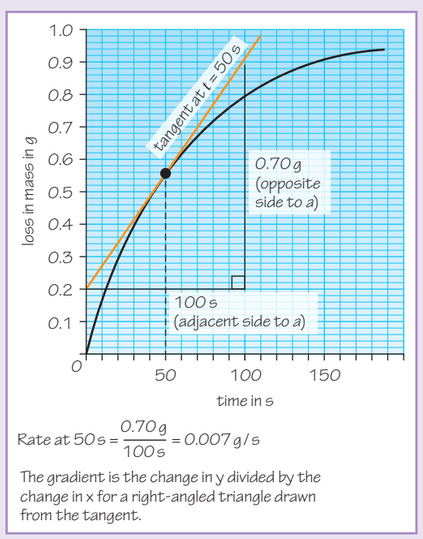
Calculating rate from graphs (HT only)

The results from an experiment can be plotted on a graph.

- A steep gradient means a high rate of reaction – the reaction happens quickly.
- A shallow gradient means a low rate of reaction – the reaction happens slowly.

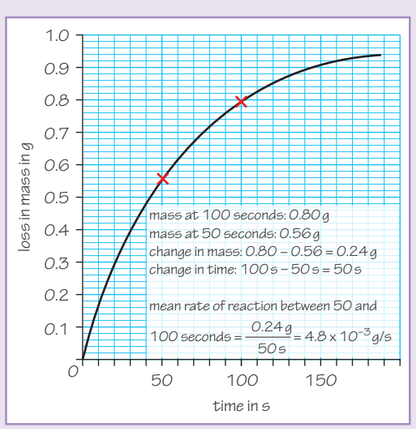
Mean rate at specific time

To obtain the rate at a specific time draw a **tangent** to the graph and calculate its **gradient**.



Mean rate between two points in time

To get the mean rate of reaction between two points in time:



Collision theory

For a reaction to occur, the reactant particles need to collide. When the particles collide, they need to have enough energy to react or they will just bounce apart. This amount of energy is called the **activation energy**.

You can increase the rate of a reaction by:

- increasing the **frequency of collisions**
- increasing the energy of the particles when they collide.

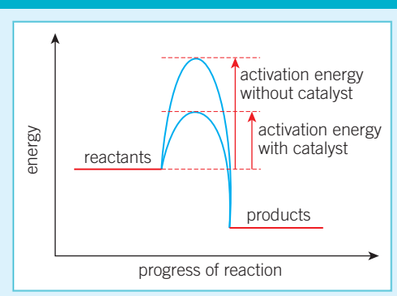
Factors affecting rate of reaction

Condition that increases rate	How is this condition caused?	Why it has that effect
increasing the temperature	Heat the container in which the reaction is taking place.	1 particles move faster, leading to more frequent collisions 2 particles have more energy, so more collisions result in a reaction note that these are two *separate* effects
increasing the concentration of solutions	Use a solution with more solute in the same volume of solvent.	there are more reactant particles in the reaction mixture, so collisions become more frequent
increasing the pressure of gases	Increase the number of gas particles you have in the container or make the container smaller.	less space between particles means more frequent collisions
increasing the surface area of solids	Cut the solid into smaller pieces, or grind it to create a powder, increasing the surface area. Larger pieces decrease the surface area.	only reactant particles on the surface of a solid are able to collide and react; the greater the surface area the more reactant particles are exposed, leading to more frequent collisions

Catalysts

Some reactions have specific substances called **catalysts** that can be added to increase the rate. These substances are not used up in the reaction.

A catalyst provides a different reaction pathway that has a lower activation energy. As such, more particles will collide with enough energy to react, so more collisions result in a reaction.



Chapter 8: Rates and equilibrium 2

Knowledge organiser

Reaction conditions

The conditions of a reaction refer to the external environment of the reaction. When the reaction occurs in a closed system, you can change the conditions by:

- changing the concentration of one of the substances
- changing the temperature of the entire reaction vessel
- changing the pressure inside the vessel.

Le Châtelier's principle (HT only)

At equilibrium, the amount of reactants and products is constant. In order to change the amounts of reactant and product at equilibrium the *conditions* of the reaction must be changed. The closed system will then counteract the change by favouring either the forward reaction or the reverse reaction. This is known as **Le Châtelier's principle**.

For example, lowering the concentration of the product in the system causes the forward reaction to be **favoured** to increase the concentration of the product.

Changing concentrations (HT only)

Change	Effect	Explanation
decrease concentration of product	favours the forward reaction	opposes the change by making *less* reactant and *more* product
increase concentration of product	favours the reverse reaction	opposes the change by making *more* reactant and *less* product
decrease concentration of reactant	favours the reverse reaction	opposes the change by making *more* reactant and *less* product
increase concentration of reactant	favours the forward reaction	opposes the change by making *less* reactant and *more* product

Changing temperature (HT only)

Change	Effect	Explanation
increase temperature of surroundings	favours the endothermic reaction	opposes the change by decreasing the temperature of the surroundings
decrease temperature of surroundings	favours the exothermic reaction	opposes the change by increasing the temperature of the surroundings

Changing pressure (HT only)

Change	Effect	Explanation
increase the pressure	favours the reaction that results in fewer molecules	decreasing the number of molecules within the vessel opposes the change because it decrease pressure
decrease the pressure	favours the direction that results in more molecules	increasing the number of molecules within the vessel opposes the change because it increase pressure

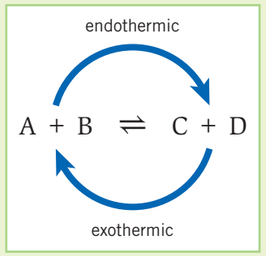
Key terms

Make sure you can write a definition for these key terms.

activation energy *catalyst* *collision* *collision theory* *closed system* *conditions* *dynamic equilibrium* *frequency of collision* *gradient* *Le Châtelier's principle* *rate of reaction* *reversible reaction* *tangent*

Reversible reactions

In some reactions, the products can react to produce the original reactants. This is called a **reversible reaction**. When writing chemical equations for reversible reactions, use the ⇌ symbol.



In this reaction:

- A and B can react to form C and D – the forward reaction
- C and D can react to form A and B – the reverse reaction.

The different directions of the reaction have opposite energy changes.

If the forward reaction is *endothermic*, the reverse reaction will be *exothermic*.

The same amount of energy is transferred in each direction.

Equilibrium

In a **closed system** no reactants or products can escape. If a reversible reaction is carried out in a closed system, it will eventually reach **dynamic equilibrium** – a point in time when the forward and reverse reactions have the same rate.

At dynamic equilibrium:

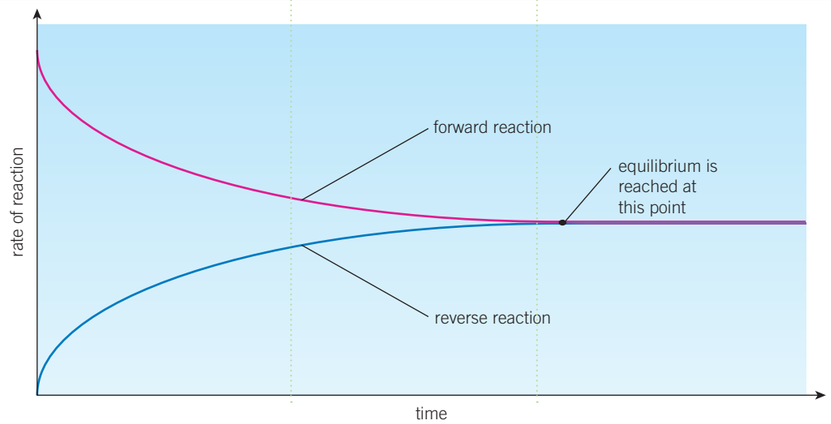
- the reactants are still turning into the products
- the products are still turning back into the reactants
- *the rates of* these two processes are *equal*, so overall the amount of reactants and products are constant.

Dynamic equilibrium

At dynamic equilibrium the amount of reactant and product are constant, but not necessarily equal.

You could have a mixture of reactants and products in a 50:50 ratio, in a 75:25 ratio, or in any ratio at all. The **conditions** of the reaction are what change that ratio.

How dynamic equilibrium is reached

Progress of reaction	start of reaction	middle of reaction	at dynamic equilibrium
Amount of A + B	high	decreasing	constant
Frequency of collisions A + B	high	decreasing	constant
Rate of forward reaction	high	decreasing	same as rate of reverse reaction
			
Amount of C + D	zero	increasing	constant
Frequency of collisions C + D	no collisions	increasing	constant
Rate of reverse reaction	zero	increasing	same as rate of forward reaction

Chapter 8: Rates and equilibrium

Retrieval questions

Learn the answers to the questions below then cover the answers column with a piece of paper and write as many as you can. Check and repeat.

C8 questions		Answers
1	What is the rate of a reaction?	how quickly reactants are used up or products are produced
2	What is the equation for calculating the mean rate of reaction?	mean rate = $\frac{\text{change in quantity of product or reactant}}{\text{time taken}}$
3	What is the unit for rate of reaction in a reaction involving a change in mass?	g/s
4	What is the unit for rate of reaction in a reaction involving a change in volume?	cm^3/s
5	What is the activation energy?	the minimum amount of energy colliding particles have to have before a reaction will take place
6	What effect does increasing concentration have on the rate of reaction?	increases
7	Why does increasing concentration have this effect?	more reactant particles in the same volume lead to more frequent collisions
8	What effect does increasing pressure have on the rate of reaction?	increases
9	Why does increasing pressure have this effect?	less space between particles means more frequent collisions
10	What effect does increasing surface area have on the rate of reaction?	increases
11	Why does increasing surface area have this effect?	more reactant particles are exposed and able to collide, leading to more frequent collisions
12	What effect does increasing temperature have on the rate of reaction?	increases
13	Why does increasing temperature have this effect?	particles move faster, leading to more frequent collisions – particles have the same activation energy, so more collisions result in a reaction
14	What is a catalyst?	a substance that increases the rate of a reaction but is not used up in the reaction
15	How do catalysts increase the rate of a reaction?	lower the activation energy of the reaction, so more collisions result in a reaction
16	What is a reversible reaction?	the reactants turn into products and the products turn into reactants
17	Which symbol shows a reversible reaction?	⇌
18	What is dynamic equilibrium?	the point in a reversible reaction when the rate of the forward and reverse reactions are the same
19	What are the three reaction conditions that can be changed?	concentration, temperature, pressure
20	What is Le Châtelier's principle?	the position of equilibrium will shift to oppose external changes
21	What is the effect of increasing the concentration of reactants on a reaction at dynamic equilibrium?	favours the forward reaction
22	What is the effect of increasing the concentration of reactants on a reaction at dynamic equilibrium?	favours the forward reaction
23	What is the effect of decreasing the concentration of products on a reaction at dynamic equilibrium?	favours the forward reaction
24	What is the effect of increasing pressure on a reaction at dynamic equilibrium?	favours the reaction that leads to the fewest molecules
25	What is the effect of decreasing pressure on a reaction at dynamic equilibrium?	favours the reaction that leads to the most molecules
26	What is the effect of increasing temperature on a reaction at dynamic equilibrium?	favours the endothermic reaction
27	What is the effect of decreasing temperature on a reaction at dynamic equilibrium?	favours the exothermic reaction

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