Equilibrium

4.6.2.3 · The rate and extent of chemical change · revision notes

In a closed system, a reversible reaction reaches equilibrium when the forward and reverse reactions happen at exactly the same rate. You need to explain what 'dynamic' means, interpret graphs and data showing when equilibrium is reached, and avoid the classic trap of saying the amounts are equal.

Key facts

- Closed system: reactants and products cannot escape
- Dynamic: both reactions keep going, at the same rate
- Before equilibrium: forward rate falls, reverse rate rises
- Equilibrium: rate of forward reaction = rate of reverse reaction
- At equilibrium, concentrations are constant (not necessarily equal)
- Horizontal lines on a concentration–time graph = equilibrium

Notes

Reaching equilibrium

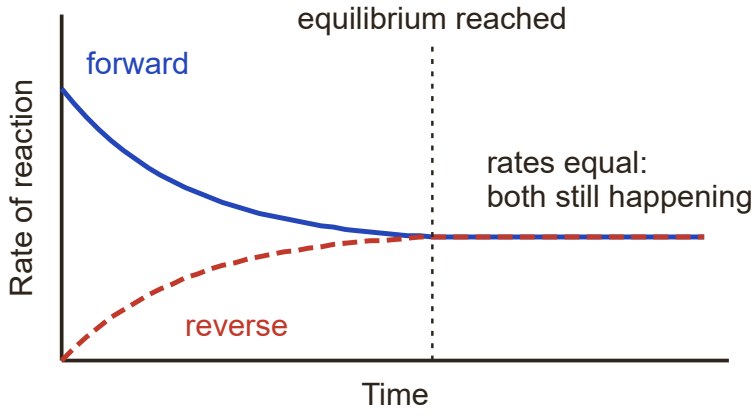
- Equilibrium can only be reached in a **closed system**: apparatus that prevents the reactants and products from escaping, such as a sealed container.
- At the start there are only reactants, so only the forward reaction happens, at its fastest rate.
- As the reactants are used up, the forward reaction slows down. As the products build up, the reverse reaction speeds up.
- **Equilibrium** is reached when the forward and reverse reactions happen at **exactly the same rate**.

What equilibrium means

- The equilibrium is **dynamic**: both reactions are still happening, but at the same rate.
- So the amounts (and concentrations) of the reactants and products stay **constant**.
- Constant does not mean equal. At equilibrium there may be much more product than reactant, or much less.
- If a product escapes (an open system), it cannot react to re-form the reactants, so equilibrium is not reached.

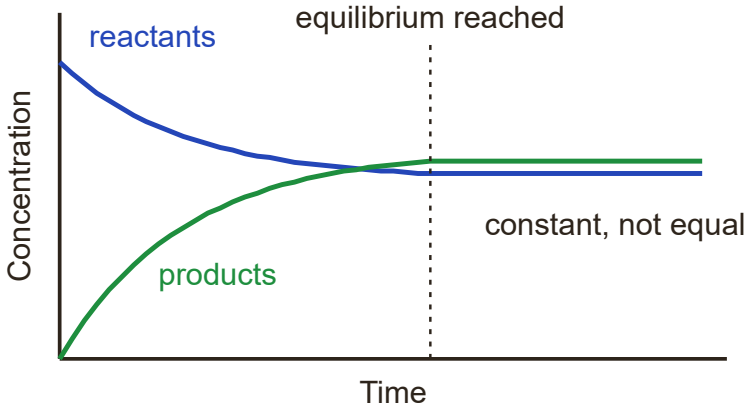
Graphs and data

- Rate against time: the forward rate falls and the reverse rate rises (from zero) until they meet. After that, both lines are horizontal at the same value.



Rates: the forward rate falls, the reverse rate rises, and they meet at equilibrium.

- Concentration against time: reactant concentrations fall and product concentrations rise, then all the lines become horizontal. Equilibrium is reached when they first level off.
- Horizontal lines on a concentration graph do not mean the reaction has stopped. Both reactions are still going on.



Concentrations: the lines go flat at equilibrium, but they are not equal.

How to answer each type of question

Recall: what is meant by dynamic equilibrium

2 marks | Grade 5

1. Say both the forward and reverse reactions are still happening.
2. Say they happen at the same rate.

Example. Hydrogen and iodine react in a sealed flask to form hydrogen iodide.
$H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$
What is meant by saying that this reaction is at dynamic equilibrium?

Model answer. The forward and reverse reactions are both still happening (1) at the same rate (1).

Use data to find when equilibrium is reached

2 marks | Grade 6

1. Look for the first time the amount or concentration stops changing.
2. Give that time, and say the amount stays constant after it.

Example. Two gases were sealed in a flask and reacted in a reversible reaction. The mass of product in the flask was measured.

Time in min	0	2	4	6	8	10	12
Mass of product in g	0	1.8	2.9	3.4	3.5	3.5	3.5

By what time had equilibrium been reached? Explain how you know.

Model answer. 8 minutes (1). After this the mass of product stays constant (1).

Explain why a statement about equilibrium is wrong

2 marks | Grade 5

1. Deal with each wrong idea separately.
2. Correct it using 'rate' for the reactions and 'amount' or 'concentration' for the substances.

Example. A student says:
'At equilibrium the reaction has stopped and the amounts of reactants and products are equal.'
Give **two** reasons why the student is wrong.

Model answer. The reaction has not stopped: the forward and reverse reactions are still happening at the same rate (1). The amounts of reactants and products are constant, but they are not necessarily equal (1).

Explain how the rates change until equilibrium 3 marks **Grade 7**

1. Forward: reactant concentrations fall, so there are fewer collisions per second and the rate falls.
2. Reverse: zero at the start (no products), then rises as the product concentration increases.
3. Equilibrium is reached when the two rates become equal.

Example. Substances P and Q are sealed in a container, where they react to form R.
$P + Q \rightleftharpoons R$
At the start there is no R.
Explain how the rates of the forward and reverse reactions change from the start until equilibrium is reached.

Model answer. At the start the forward rate is at its highest and the reverse rate is zero, because there is no R (1). As P and Q are used up their concentrations fall, so the forward reaction slows down (1). As R builds up the reverse reaction speeds up, until the two rates are equal and equilibrium is reached (1).

Don't lose marks

- Saying the concentrations of reactants and products are equal at equilibrium.
- Saying the reaction has stopped at equilibrium.
- Forgetting that equilibrium can only be reached in a closed system.
- Writing that the reactions happen 'at the same time' instead of 'at the same rate'.

More tips

Memory tricks

- Picture walking down an up escalator at the same speed it moves: you stay in one place, but both movements carry on.
- Equilibrium = equal RATES, not equal AMOUNTS.
- Closed system = nothing escapes.

Exam technique

- Two marks for 'dynamic equilibrium' usually need both ideas: both reactions continue AND they happen at the same rate.
- Use 'rate' when writing about the reactions, and 'amount' or 'concentration' when writing about the substances.
- On graphs and tables, give the time when the values first stop changing as the time equilibrium was reached.

What each grade needs

What you need to be able to do, from the first marks up to the top grade.

Grade 4 **Define a closed system**
Apparatus that prevents the reactants and products from escaping.

Grade 5 **State when equilibrium is reached**

When the forward and reverse reactions happen at exactly the same rate.

Grade 5

Know that amounts stay constant at equilibrium

The concentrations of reactants and products stop changing, but they are not necessarily equal.

Grade 5

Explain why the equilibrium is dynamic

Both the forward and reverse reactions are still happening, at the same rate.

Grade 6

Find when equilibrium is reached from data

Equilibrium starts when the amounts or concentrations stop changing (the lines become horizontal).

Grade 7

Explain how the rates change before equilibrium

The forward rate falls as reactants are used up and the reverse rate rises as products build up, until they are equal.

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