Catalysts

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

What catalysts do, how they speed up reactions by providing a pathway with a lower activation energy, and how to show this on a reaction profile. Questions ask you to identify a catalyst from data, explain catalytic action and draw or use reaction profiles.

Key facts

- Catalyst: speeds up a reaction, is not used up, same mass at the end
- Enzymes = catalysts in biological systems
- A catalyst provides a different pathway with a lower activation energy
- Reaction profile: activation energy = from the reactants' level up to the peak
- Catalysts are not included in the chemical equation
- Different reactions need different catalysts
- A catalyst does not change the energy change or the amount of product

Notes

What a catalyst is

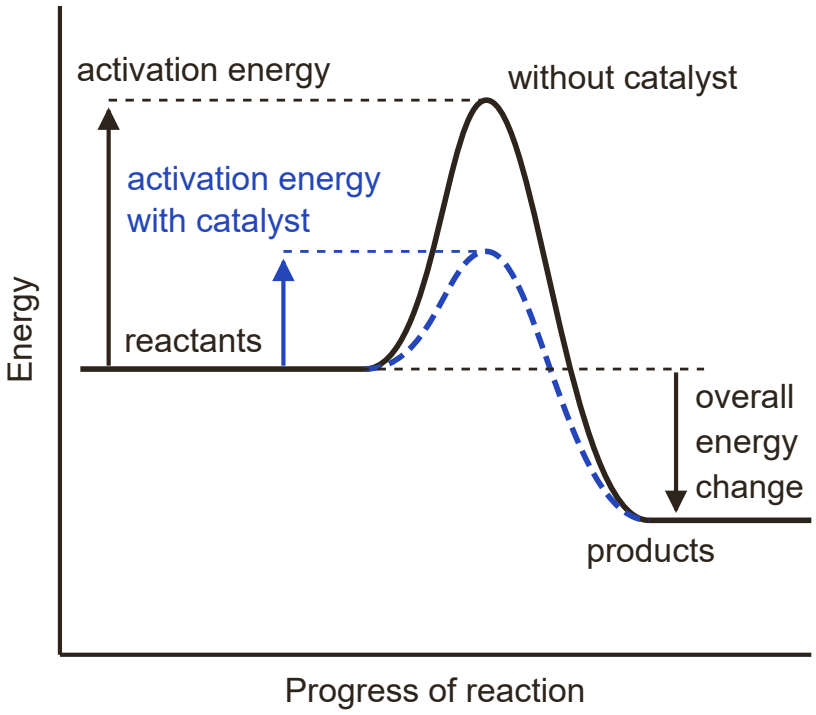
- A **catalyst** changes the rate of a chemical reaction but is **not used up** during the reaction.
- At the end of the reaction the catalyst is chemically unchanged and has the same mass, so it can be used again.
- Catalysts are not included in the chemical equation for the reaction (sometimes the name is written above the arrow).
- Different reactions need different catalysts.
- **Enzymes** act as catalysts in biological systems.
- You can identify a catalyst from data: it makes the reaction faster, its mass is the same at the end, and it is not a reactant or product in the equation.
- Comparing catalysts on a graph of gas volume against time: the best catalyst gives the steepest curve and the most gas in a given time.

How a catalyst works

- A catalyst provides a **different pathway** for the reaction that has a **lower activation energy**.
- So a greater proportion of particles have energy equal to or greater than the activation energy, and successful collisions are more frequent.
- A catalyst does not change the overall energy change of the reaction or the amount of product made.
- With a catalyst, a reaction can be fast enough at a lower temperature, which saves energy.

Reaction profiles

- A reaction profile shows energy (y-axis) against the progress of the reaction (x-axis).
- Activation energy is the energy difference from the reactants' level up to the peak of the curve.
- With a catalyst, the reactants and products are at the same energy levels, but the peak is lower.



Catalysed path (blue, dashed): lower peak, same reactants, products and overall energy change.

- Draw the catalysed curve starting at the reactants and finishing at the products, with a lower hump. Label its activation energy with an arrow from the reactant level up to the new peak.

How to answer each type of question

Explain how a catalyst increases the rate

2 to 3 marks | **Grade 5**

1. Say it provides a different pathway (route) for the reaction.
2. Say this pathway has a lower activation energy.
3. For a third mark: so more collisions have enough energy to react, and successful collisions are more frequent.

Example. Manganese(IV) oxide is a catalyst for the decomposition of hydrogen peroxide. Explain how manganese(IV) oxide increases the rate of this reaction.

Model answer. It provides a different pathway for the reaction (1) that has a lower activation energy (1). So a greater proportion of collisions have energy equal to or greater than the activation energy, and successful collisions are more frequent (1).

Identify the catalyst from experimental results

2 to 3 marks | Grade 5

1. Find the substance that makes the reaction faster than with nothing added.
2. Check its mass at the end: a catalyst has the same mass as at the start.
3. Check the equation: a catalyst is not a reactant or a product.

Example. A student added 0.50 g of each of three powders, A, B and C, to separate samples of the same hydrogen peroxide solution.

Powder added	Time to collect 50 cm^3 of oxygen in s	Mass of powder at the end in g
none	400	–
A	400	0.50
B	35	0.50
C	90	0.32

Which powder is a catalyst for this reaction? Give two reasons for your answer.

Model answer. B (1). It made the reaction faster than with no powder (1). Its mass did not change, so it was not used up (1).

Use a reaction profile for a catalysed reaction

2 to 3 marks | Grade 6

1. Keep the reactant and product levels the same as for the uncatalysed reaction.
2. The catalysed peak is lower, so the activation energy is smaller.
3. Activation energy = peak energy − reactant energy (never measure it from the products).

Example. In a reaction profile for an exothermic reaction, the reactants are at 120 kJ/mol and the products are at 40 kJ/mol. Without a catalyst the peak is at 250 kJ/mol. With a catalyst the peak is at 180 kJ/mol.
(a) Calculate the activation energy without the catalyst.
(b) Calculate the activation energy with the catalyst.
(c) How much energy is released overall by the catalysed reaction?

Model answer.

(a) 250 − 120 = 130 kJ/mol (1)
(b) 180 − 120 = 60 kJ/mol (1)
(c) 120 − 40 = 80 kJ/mol, the same as without the catalyst (1)

Don’t lose marks

- Writing only 'it lowers the activation energy'. The full answer is that it provides a different pathway with a lower activation energy.
- Saying a catalyst gives the particles more energy or makes them move faster. It does neither.

- ✗ Saying a catalyst is used up in the reaction.
- ✗ Moving the product level on a catalysed profile, or measuring activation energy from the products.
- ✗ Saying a catalyst increases the amount of product. It only makes the product form faster.

More tips

Memory tricks

- A catalyst is like a tunnel through a hill: same start and finish, but a lower climb.
- Catalyst check: faster? same mass at the end? not in the equation? Then it is a catalyst.
- On a reaction profile, a catalyst only lowers the hump. The start and end levels never move.
- Enzyme = biological catalyst: the same idea you meet in Biology.

Exam technique

- Learn the key phrase: 'provides a different pathway with a lower activation energy'.
- If asked how you know a substance is a catalyst, use evidence from the data: the rate increased and its mass stayed the same.
- On reaction profiles, draw activation energy arrows from the reactant line up to the peak, with the arrowhead at the peak.
- You do not need to learn the names of particular catalysts for this topic: the question will tell you which one is used.

What each grade needs

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

Grade 3 — **State what a catalyst does**
It increases the rate of a reaction but is not used up.

Grade 4 — **Know that enzymes are biological catalysts**
Enzymes are the catalysts that speed up reactions in living things.

Grade 5 — **Identify a catalyst from experimental data**
It speeds up the reaction, has the same mass at the end and is not in the equation.

Grade 5 — **Explain how a catalyst increases the rate**
It provides a different pathway for the reaction that has a lower activation energy.

Grade 5 — **Draw a reaction profile with a catalyst**
Show a lower peak between the same reactant and product energy levels.

Grade 7 — **Link catalysis to successful collisions**
With a lower activation energy, more collisions have enough energy to react, so successful collisions are more frequent.

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