

Exercise walk-through

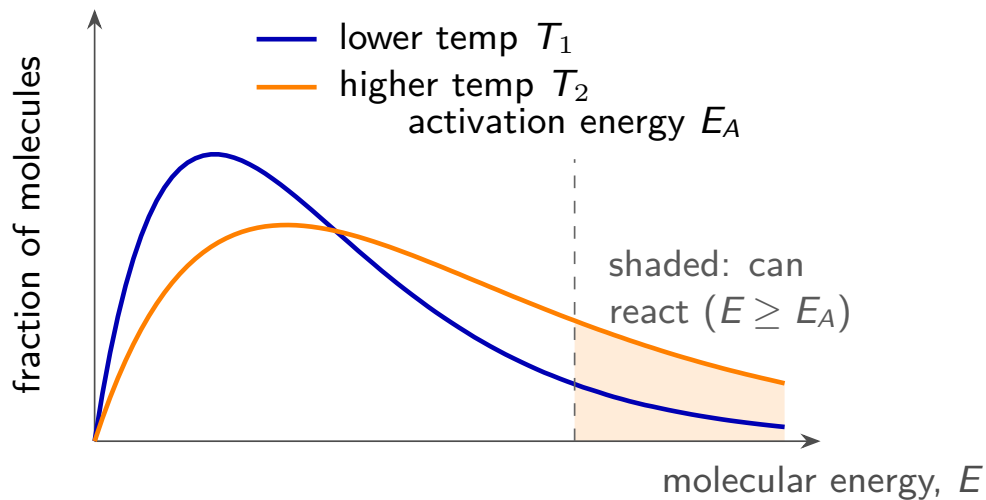
# 8.2

## Effect of temperature on reaction rates and the concept of activation energy

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A-Level Chemistry

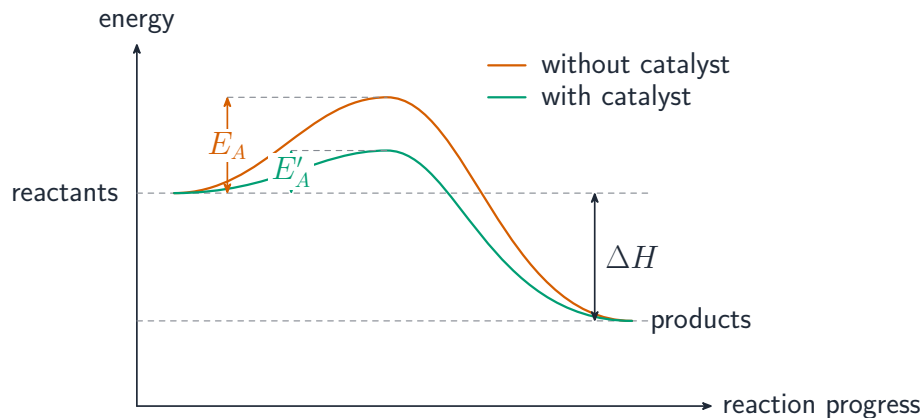
# The Boltzmann distribution



Only molecules past the **activation energy**  $E_A$  can react.

Raising the temperature spreads the **Boltzmann distribution** to the right, so a **much larger fraction** exceed  $E_A$  – a small rise gives a big rate increase.

# Catalysts



A **catalyst** speeds a reaction without being used up: it offers a different **reaction mechanism** – a new route with a **lower**  $E_A$ . On a **reaction pathway diagram** the catalysed route has a lower hill.

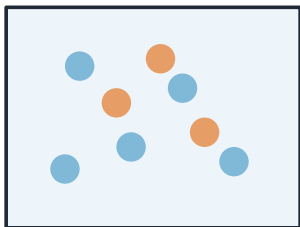
More molecules now exceed  $E_A$ , so the rate rises – but the **enthalpy change**  $\Delta H$  is **unchanged**.

# Types of catalyst

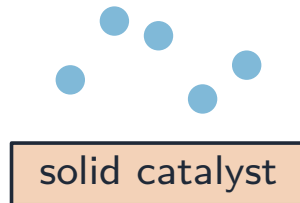
- a **homogeneous catalyst**
- a **heterogeneous catalyst**  
(a catalytic converter)

is in the **same** state as the reactants

is in a **different** state (a solid surface, like



homogeneous  
(same state,  
mixed in)

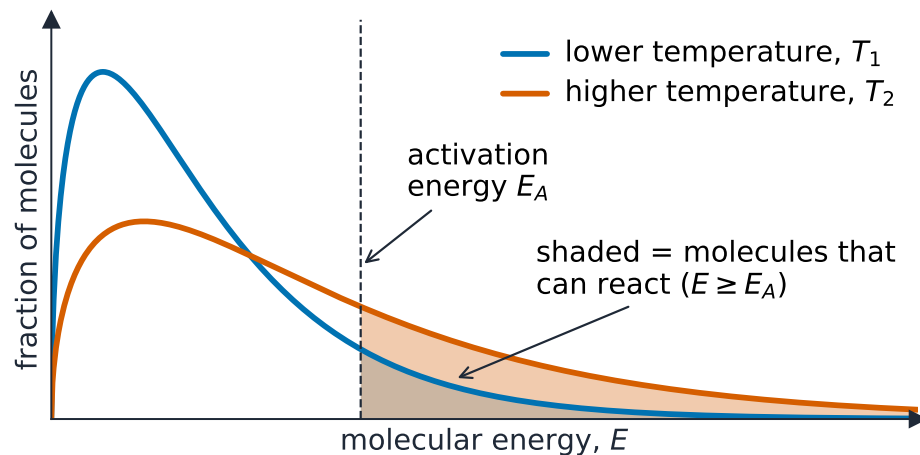


heterogeneous  
(different state,  
a surface)

## Exam tips

- Explain rate changes with **collision theory** – more frequent and/or more energetic **effective collisions**.
- On a **Boltzmann distribution** mark  $E_A$ , shade to its right, and show the curve **flatten and shift right** at higher temperature; it starts at the origin and never touches the axis.
- A **catalyst** gives an alternative route with **lower  $E_A$  and does not** change  $\Delta H$ .
- Say why a small temperature rise gives a large rate rise: a **much greater proportion** of molecules now exceed  $E_A$  (the main effect).

# At higher temperature the curve spreads to the right



higher  $T \Rightarrow$  more molecules with  $E \geq E_A$

At higher temperature the curve spreads to the right, so a larger fraction of molecules can react

## Exercises 2.1·3.1

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2.1 Define **activation energy**.

[1]

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2.2 On a Boltzmann distribution, state which molecules are able to react.

[1]

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3.1 When the temperature is increased, the main reason the rate rises is:

[1]

☐

**A** the activation energy falls

**B** a much larger fraction of molecules have energy  $\geq E_A$

**C** the molecules get bigger

**D** the enthalpy change increases

## Exercises 2.1·3.1

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2.1 Define **activation energy**.

[1]

2.1

- the minimum energy a collision needs to be effective (to react)

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2.2 On a Boltzmann distribution, state which molecules are able to react.

[1]

2.2

- those with energy greater than (to the right of) the activation energy

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3.1 When the temperature is increased, the main reason the rate rises is:

[1]

☐

**A** the activation energy falls

**B** a much larger fraction of molecules have energy  $\geq E_A$

**C** the molecules get bigger

**D** the enthalpy change increases

3.1 B

- A higher temperature gives a larger fraction of molecules with energy  $\geq E_A$

## Exercises 3.2-3.3

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**3.2** The total area under a Boltzmann distribution curve represents: [1]

☐

- A** the activation energy
- B** the total number of molecules
- C** the rate of reaction
- D** the temperature

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**3.3** Sketch a Boltzmann distribution curve. Mark the activation energy  $E_A$  and shade the molecules that can react. [3]

## Exercises 3.2-3.3

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**3.2** The total area under a Boltzmann distribution curve represents: [1]

☐

- A the activation energy
- B the total number of molecules
- C the rate of reaction
- D the temperature

**3.2 B**

- The area under the curve is the total number of molecules

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**3.3** Sketch a Boltzmann distribution curve. Mark the activation energy  $E_A$  and shade the molecules that can react. [3]

**3.3**

- curve from the origin rising to a peak then tailing off, not touching the x-axis;  $E_A$  marked on the energy axis to the right of the peak; area to the right of  $E_A$  shaded

## Exercise 3.4

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**3.4** Explain, using the Boltzmann distribution, why a 10 °C rise in temperature can roughly double the rate of a reaction. [3]

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**3.4** Explain, using the Boltzmann distribution, why a 10 °C rise in temperature can roughly double the rate of a reaction. [3]

### 3.4

- at higher temperature the curve spreads to the right; the fraction of molecules with energy  $\geq E_A$  increases greatly; so many more collisions are effective each second, roughly doubling the rate