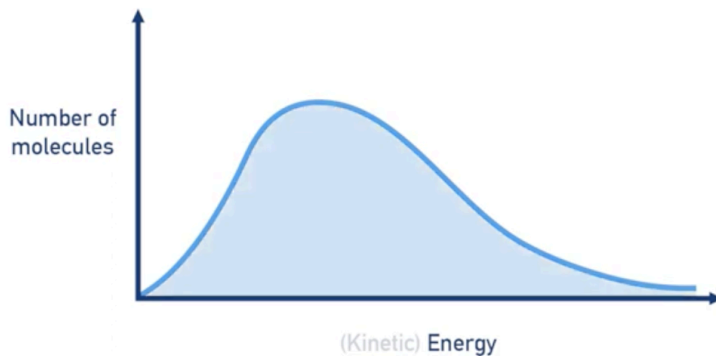
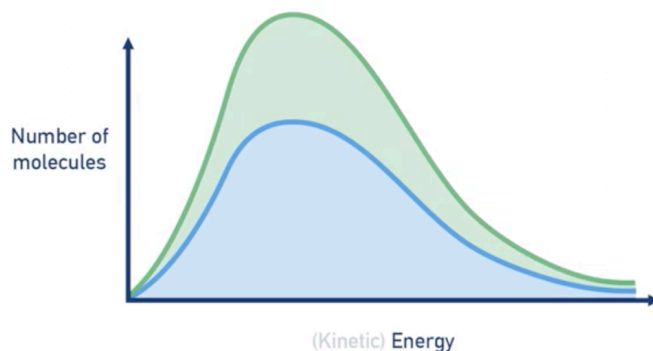


NOTE: Maxwell-Boltzmann curve

Basic shape



- y-axis = number of molecules
 - x-axis = (kinetic) energy
 - Area under curve = proportional to total number of molecules in the system
 - Highest point = energy that most molecules are likely to have (at any one moment of time)
 - The curves are never symmetrical
 - Curve will always start at 0, and stay above 0 at this point, because all gas molecules have some energy.
-
- When number of molecules is doubled, area under curve doubles.
 - When number of molecules is halved, area under curve is halved.



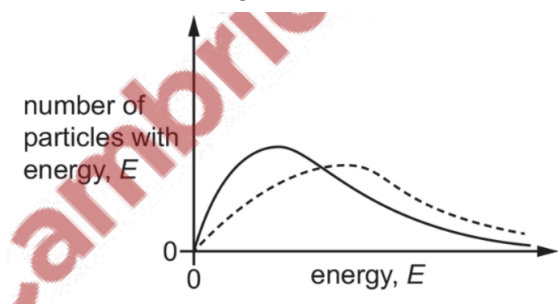
When concentration of molecules is increased

- Total number of molecules increases = area under curve increases
- If concentration doubles, area under doubles.
- Average energy of molecules in the system remains same, so distribution of energy remains the same; same shape, but higher peak.
- Total number of molecules with energy $> E_a$ increases, but proportion of molecules with energy $> E_a$ remains the same.

When temperature is increased

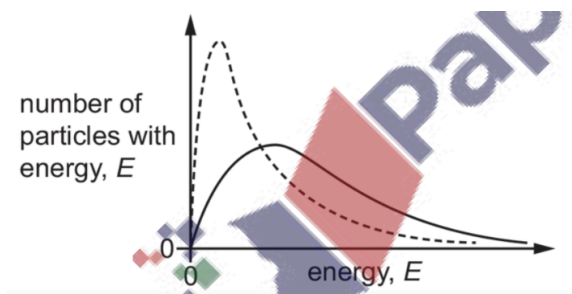
- More energy is available, shared among the same number of molecules.

- Temperature doesn't impact total number of molecules: total area under curve stays the same.
- Graph shifts to the right, and highest point is slightly lower than before as more molecules have higher energy.
- proportion of particles with energy more than E_a increases; area under curve after E_a is higher.



When temperature is decreased

- Less energy is available, shared among the same number of molecules.
- Temperature doesn't impact total number of molecules: total area under curve stays the same.
- Graph shifts to the left, and highest point is higher than before as more molecules have less energy.
- proportion of particles with energy more than E_a decreases; area under curve after E_a is lower.



When catalyst is added

- E_a lower, so greater proportion of molecules have energy $> E_a$.
- Shape of the curve remains same.

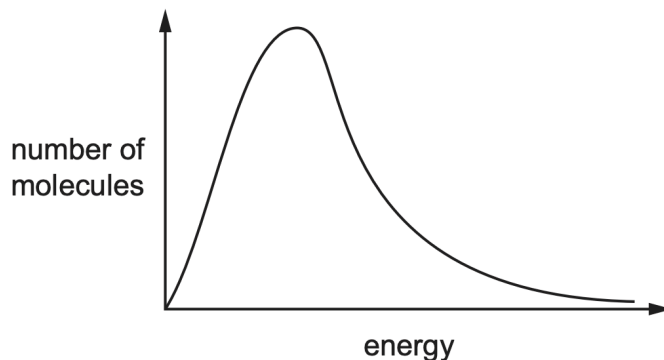
1. State and explain the effect of using a catalyst on a reaction

- increases the rate of reaction
- by providing an alternative reaction pathway of lower E_a

2.

Al_2O_3 is used as a catalyst in the dehydration of alcohols.

State the effect of using Al_2O_3 as a catalyst in the dehydration of alcohols. Use the Boltzmann distribution in Fig. 2.1 to help explain your answer.

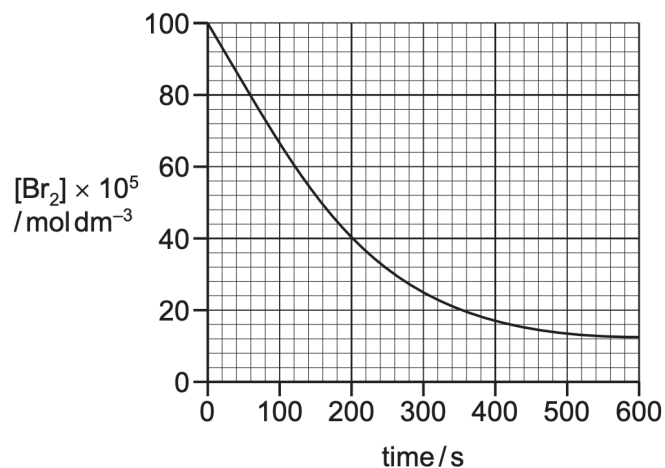


- 2 lines on the diagram = E_A and $E_{A,cat}$
- Greater proportion of molecules with $E \geq E_A$
- Frequency of effective collisions increases

3.

This reaction can be followed by measuring the concentration of bromine present in the mixture at regular time intervals.

The graph shows the change in concentration of bromine against time in a reaction carried out at $20^\circ C$.



- (i) Use the graph to calculate the average rate of reaction at $20^\circ C$ during the first 600 s. State the units of this rate of reaction.

rate = total change in concentration of Br₂ divided by time taken

calculation dependent on graph

$$(100 \times 10^{-5} - 12 \times 10^{-5}) / 600$$

M1 average rate of reaction 1.47×10^{-6}

M2 units mol dm⁻³ s⁻¹

4. The rate of reaction increases when the frequency of successful collisions between reactant particles increases. Explain why an increase in temperature produces this effect.
- at increased temp, the average kinetic energy of particles / species / molecules increases.
 - (many) more/ greater proportion of particles with energy $\geq E_a$.
5. State and explain the effect of using a catalyst on a reaction
- Increases the rate of reaction
 - By providing an alternate reaction pathway of lower E_a
6. State and explain the effect, if any, on the rate of the Haber process as the pressure is lowered.
- rate is lowered
 - lower frequency of successful collisions / number of successful collisions per unit time
- 7.

N₂(g) reacts with H₂(g) in the Haber process, as shown in reaction 1.

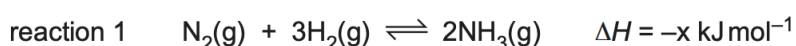


Table 2.1 shows the different conditions used to produce three equilibrium mixtures, **A**, **B** and **C**.

Table 2.1

	A	B	C
initial molar ratio of N ₂ : H ₂ added	1 : 3	1 : 3	1 : 3
temperature / °C	500	500	1000
pressure / atm	1000	1000	1000
iron present in mixture	no	yes	no
percentage yield of NH ₃ (g) at equilibrium	58	x	y

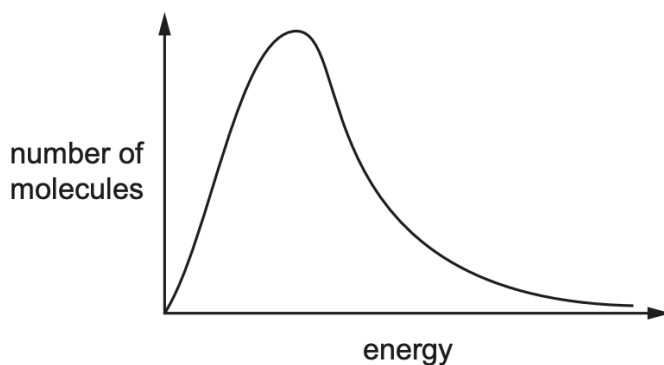
Describe and explain the change to the rate of the forward reaction that occurs to establish the equilibrium in C compared to A. You do not need to refer to the Boltzmann distribution in your answer.

- increase in temperature / energy from A to C so more collisions with particles that have $E > E_a$ AND increase frequency of effective collisions
- (initial) rate (of the forward reaction) increases

8.

Al_2O_3 is used as a catalyst in the dehydration of alcohols.

State the effect of using Al_2O_3 as a catalyst in the dehydration of alcohols. Use the Boltzmann distribution in Fig. 2.1 to help explain your answer.



- two lines shown on diagram, e.g. E_A and $E_{A,cat}$
 - greater proportion of molecules with $E \geq E_A$
 - frequency of effective collisions increases
9. Explain what is meant by the term rate of reaction.
- change in amount of substance with time