8. Reaction kinetics

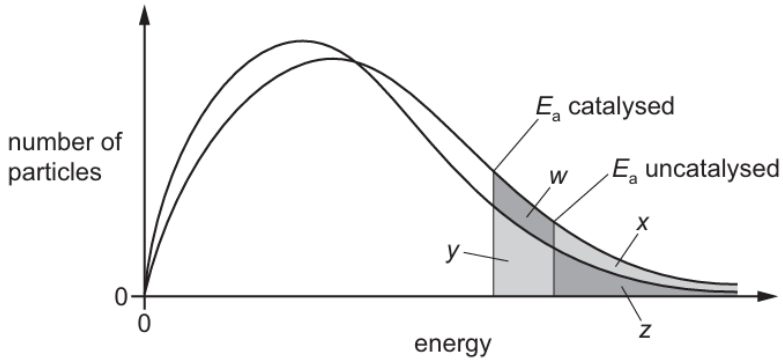
8.2 Activation energy

Paper 1

Question Paper

1 The Boltzmann distribution for a mixture of gases capable of reaction is shown.

The two curves represent the mixture of gases at 25 °C and at 35 °C. The activation energies for the catalysed and uncatalysed reactions are shown.

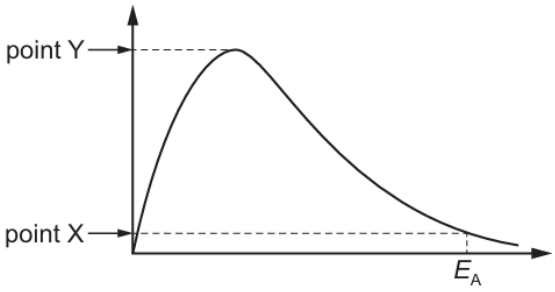


Which row is correct?

	number of particles with enough energy to react at 25 °C in the catalysed reaction	number of particles with enough energy to react at 35 °C in the uncatalysed reaction
A	$w + x + y + z$	z
B	$w + x + y + z$	$x + z$
C	$y + z$	z
D	$y + z$	$x + z$

2 The diagram shows a Boltzmann distribution curve.

The axes are not labelled.

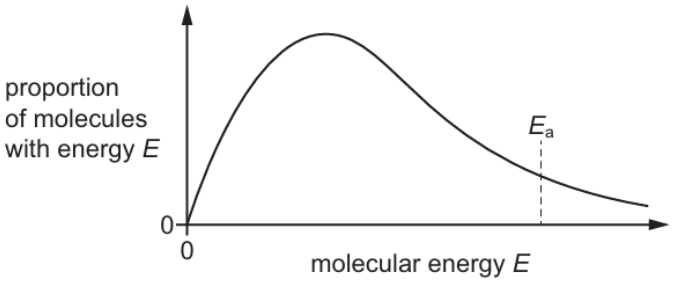


Points X and Y are points on the vertical axis.

What is represented by both points X and Y?

	point X	point Y
A	number of molecules with energy equal to E_A	largest number of molecules with the same energy
B	number of molecules with energy equal to or greater than E_A	largest number of molecules with the same energy
C	number of molecules with energy equal to E_A	the amount of energy of the greatest number of molecules
D	number of molecules with energy equal to or greater than E_A	the amount of energy of the greatest number of molecules

3 The Boltzmann distribution for the hydrogenation of an alkene at a particular temperature in the absence of a catalyst is shown.



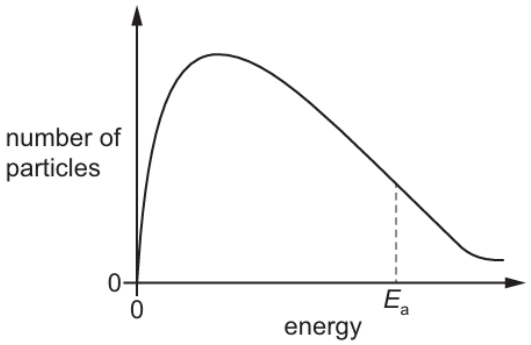
Which row correctly describes the effects of adding a nickel catalyst to the reaction vessel?

	the shape of the Boltzmann distribution	activation energy, E_a
A	changes	decreases
B	changes	increases
C	does **not** change	decreases
D	does **not** change	increases

4 Gas Q decomposes slowly at room temperature.

$$Q(g) \rightarrow X(g) + Z(g)$$

The Boltzmann distribution curve for gas Q at room temperature is shown.



Which change occurs when a catalyst is added to gas Q?

A The peak of the curve moves to the right on the diagram.

B The number of particles with enough energy to decompose increases.

C The kinetic energy of the unreacted particles increases.

D The value of E_a decreases, moving the vertical dotted line to the right on the diagram.

5 The forward reaction of a reversible reaction is exothermic and has an activation energy of $+30\,kJ\,mol^{-1}$.

The reverse reaction proceeds by a mechanism that is the exact reverse of the mechanism of the forward reaction.

Which statement about the activation energy of the reverse reaction is correct?

A The activation energy for the reverse reaction is equal to $-30\,kJ\,mol^{-1}$.

B The activation energy for the reverse reaction is greater than $0\,kJ\,mol^{-1}$ but less than $+30\,kJ\,mol^{-1}$.

C The activation energy for the reverse reaction is equal to $+30\,kJ\,mol^{-1}$.

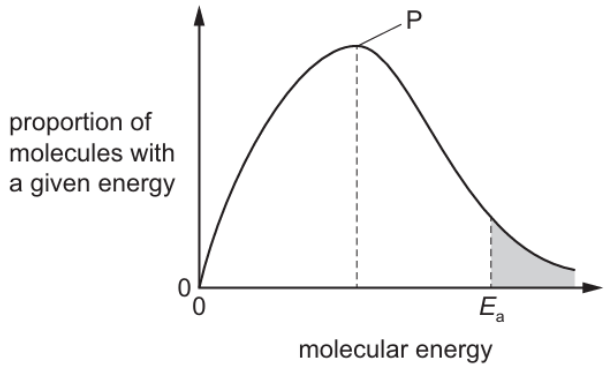
D The activation energy for the reverse reaction is greater than $+30\,kJ\,mol^{-1}$.

6 The temperature of a sample of an inert gas is increased.

What effect does this have on the number of molecules with the most probable energy and on the number of molecules with higher energy?

	number of molecules with the most probable energy	number of molecules with higher energy
A	decreases	decreases
B	decreases	increases
C	increases	decreases
D	increases	increases

7 The diagram shows the Boltzmann distribution of energies in a gas. The gas can take part in a reaction with an activation energy, E_a. The gas is maintained at a constant temperature.



Which statement is correct?

A If a catalyst is added, peak P will be lower and E_a will move to the left.

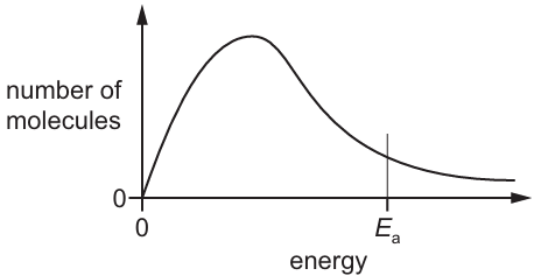
B If a catalyst is added, peak P will be lower and E_a will move to the right.

C If a catalyst is added, peak P will be the same and E_a will move to the left.

D If a catalyst is added, peak P will be the same and E_a will move to the right.

8 Measurements are made to determine the activation energy, E_a, of a reaction.

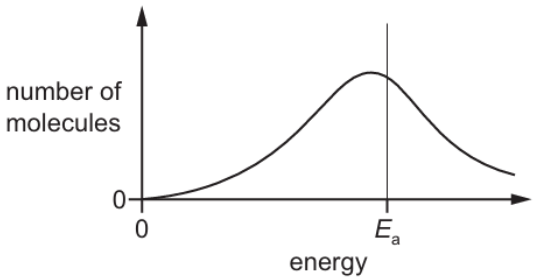
The diagram shows E_a on the Boltzmann distribution at temperature T_1.



Measurements are then made at a higher temperature, T_2.

Which diagram correctly shows the Boltzmann distribution and E_a at T_2?

A



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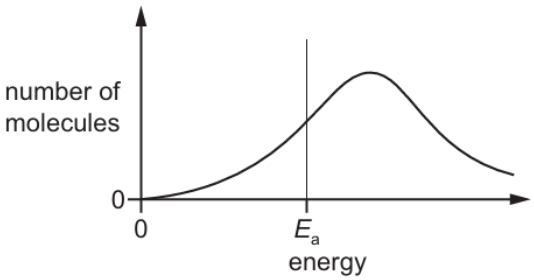

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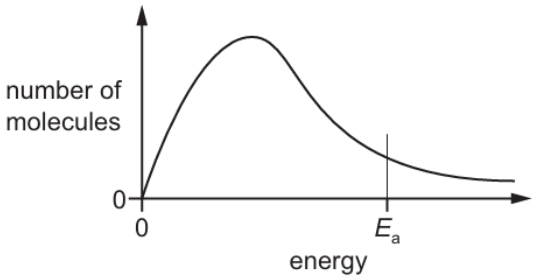

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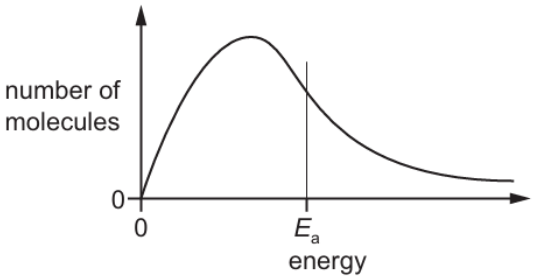


9 Hydrogen peroxide decomposes slowly at 20 °C to form water and oxygen.

$$2H_2O_2 \rightleftharpoons 2H_2O + O_2 \qquad \text{equilibrium constant} = K_c$$

The reaction is faster when a catalyst is present.

Which statement is correct?

A The catalyst alters the Boltzmann distribution so that the reactant molecules have more energy.

B The catalyst has no effect on the value of K_c.

C The catalyst increases the value of K_c.

D The catalyst provides a different reaction mechanism with a higher activation energy.

10 The enthalpy changes for the possible reactions W, X, Y and Z are given.

W $NaOH(aq) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l)$ $\Delta H^{\ominus} = -56\,kJ\,mol^{-1}$

X $NaCl(aq) + H_2O(l) \rightarrow NaOH(aq) + HCl(aq)$ $\Delta H^{\ominus} = +56\,kJ\,mol^{-1}$

Y $2HI(g) \rightarrow H_2(g) + I_2(g)$ $\Delta H^{\ominus} = +11\,kJ\,mol^{-1}$

Z $H_2(g) + I_2(g) \rightarrow 2HI(g)$ $\Delta H^{\ominus} = -11\,kJ\,mol^{-1}$

Which statement about the activation energies of these reactions is correct?

A X is greater than W; Z is greater than Y.

B X is greater than W; Y is greater than Z.

C W is greater than X; Z is greater than Y.

D W is greater than X; Y is greater than Z.

11 The Haber process is carried out with a nitrogen partial pressure of 50 kPa, a hydrogen partial pressure of 150 kPa, a temperature of 400 °C and an iron catalyst.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

If all other conditions are kept the same, which change will result in a raised activation energy?

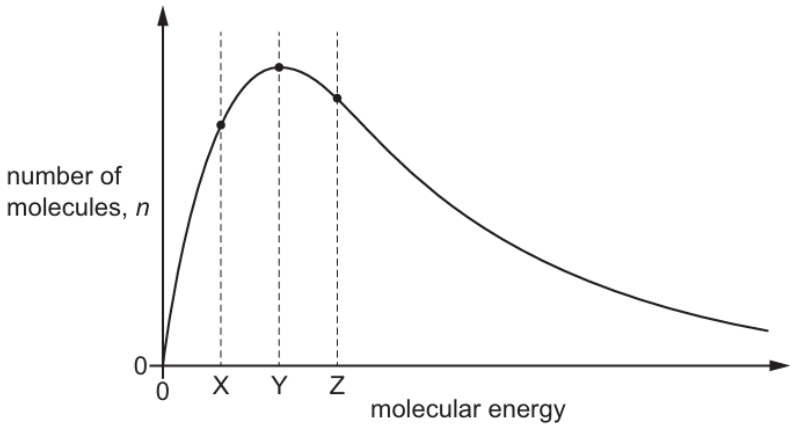
A Both the nitrogen and hydrogen partial pressures are changed to 100 kPa.

B The iron is removed.

C The nitrogen partial pressure is increased to 150 kPa.

D The temperature is increased to 500 °C.

12 The Boltzmann distribution for a gas at a constant temperature of 50 °C is shown.

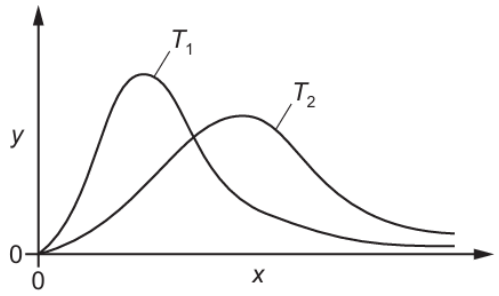


If the temperature of the gas is **reduced** by 10 °C, the graph changes shape.

What happens to the values of *n* for the molecular energies X, Y and Z?

	X	Y	Z
A	higher	lower	higher
B	higher	lower	lower
C	lower	higher	lower
D	lower	lower	lower

13 The diagram shows the Boltzmann distribution for the same gas at two different temperatures, T_1 and T_2.

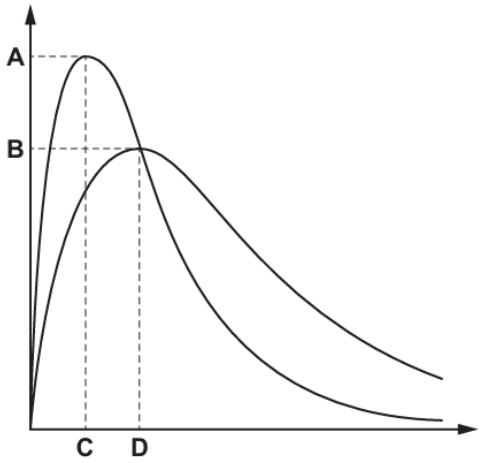


What is plotted on the *y*-axis and which line represents the higher temperature?

	plotted on *y*-axis	higher temperature
A	number of molecules	T_1
B	number of molecules	T_2
C	molecular energy	T_1
D	molecular energy	T_2

14 The diagram shows the Boltzmann energy distribution curves for molecules of a sample of a gas at two different temperatures.

Which letter on the axes represents the most probable energy for molecules of the same sample of gas at the **lower** temperature?



15 The temperature of a sample of an inert gas is increased.

What effect does this have on the number of molecules with the most probable energy and on the number of molecules with high energy?

	number of molecules with the most probable energy	number of molecules with high energy
A	decreases	decreases
B	decreases	increases
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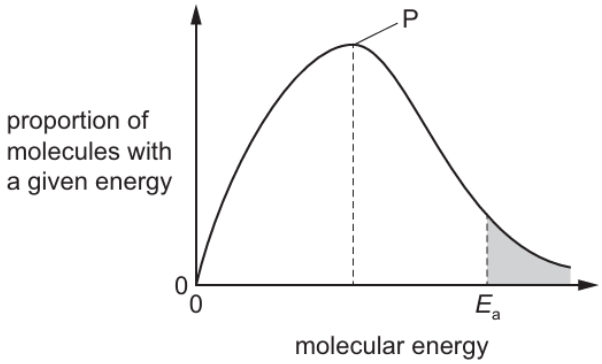
16 The diagram shows the Boltzmann distribution of energies in a gas. The gas can take part in a reaction with an activation energy, E_a. The gas is maintained at a constant temperature.



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17 A chemical company used a catalyst in a chemical process. The company has now decided not to use the catalyst but to increase the temperature so that the rate of the reaction is the same as it was when the catalyst was used.

Which statement about the new conditions compared to the original conditions is correct?

A The activation energy has been decreased.

B The activation energy has been increased.

C There are fewer successful collisions per unit time.

D There are more successful collisions per unit time.