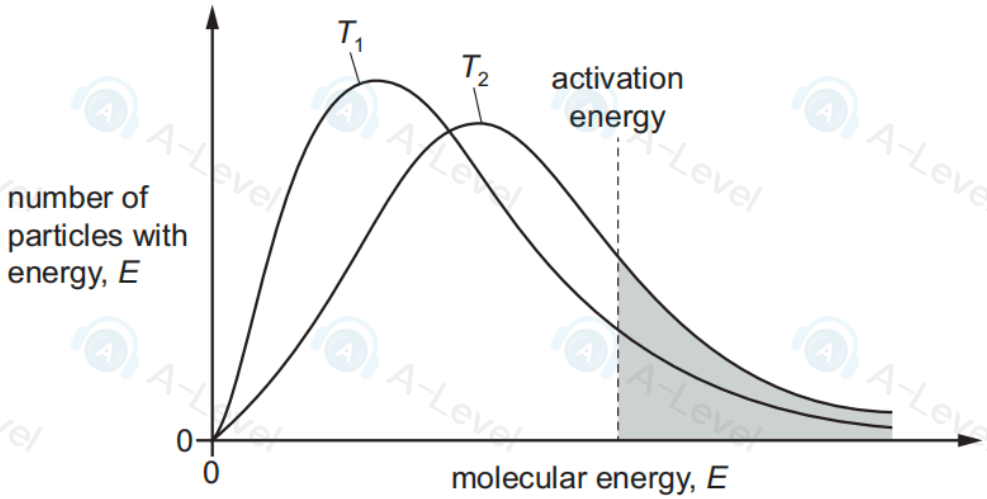
The responses **A** to **D** should be selected on the basis of

A	B	C	D
1, **2** and **3** are correct	**1** and **2** only are correct	**2** and **3** only are correct	**1** only is correct

No other combination of statements is used as a correct response.

Use of the Data Booklet may be appropriate for some questions.

31 The Boltzmann distribution diagram shows a fixed amount of a gas at two different temperatures, T_1 and T_2.



Which statements correctly describe the features of this diagram?

1 Temperature T_1 is lower than temperature T_2.

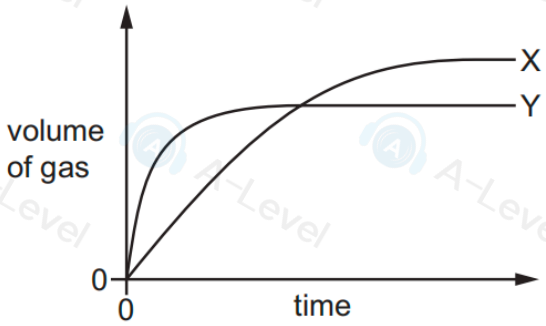
2 The shaded area indicates the particles that have sufficient energy to react at T_2.

3 The total area under each curve is the same for both temperatures.

16 The decomposition of hydrogen peroxide in the presence of MnO_2 produces water and oxygen gas.

$$2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g)$$

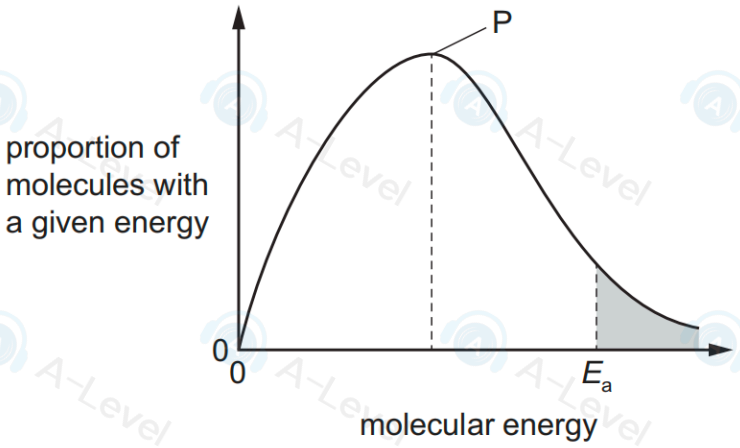
The volume of gas collected when 0.2 g of MnO_2 is added to two different hydrogen peroxide solutions at 20 °C is shown on the graph as curves X and Y.



Which row shows the conditions that will result in curves X and Y?

	curve X			curve Y		
	volume of H_2O_2 / cm^3	concentration of H_2O_2 / mol dm^{-3}	form of MnO_2	volume of H_2O_2 / cm^3	concentration of H_2O_2 / mol dm^{-3}	form of MnO_2
A	50	0.1	lumps	50	0.2	powder
B	25	0.2	powder	25	0.1	lumps
C	50	0.1	lumps	20	0.2	powder
D	20	0.2	powder	40	0.1	lumps

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.



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.

16 In the reaction shown, the concentrations of both X and Y are reduced to half of their original values whilst keeping the total volume of the solution constant.

$$X(aq) + Y(aq) \rightarrow XY(aq)$$

Simultaneously the temperature is increased from 298 K to 348 K.

Which prediction is definitely true?

A A smaller proportion of collisions between particles of X and particles of Y will be successful.

B The average kinetic energy of particles of X and particles of Y will increase.

C The rate of the reaction will be unaffected.

D The frequency of collisions between particles of X and particles of Y will halve.

14 A mixture of hydrogen gas and iodine gas is placed in a reaction vessel of volume V at temperature T.

The reaction $H_2 + I_2 \rightleftharpoons 2HI$ is allowed to come to equilibrium.

All substances remain in the gaseous state.

Argon gas is then pumped into the reaction vessel. The temperature in the vessel is maintained at T.

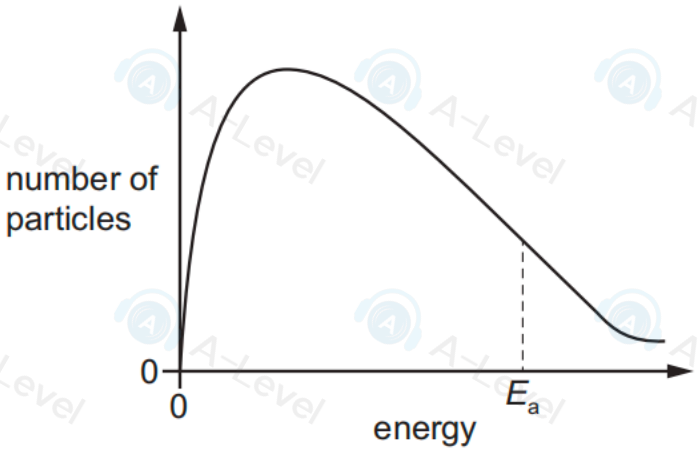
How are the rate of the forward reaction and the partial pressure of HI at equilibrium affected?

	rate of forward reaction	partial pressure of HI at equilibrium
A	increased	increased
B	increased	unaffected
C	unaffected	increased
D	unaffected	unaffected

15 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.

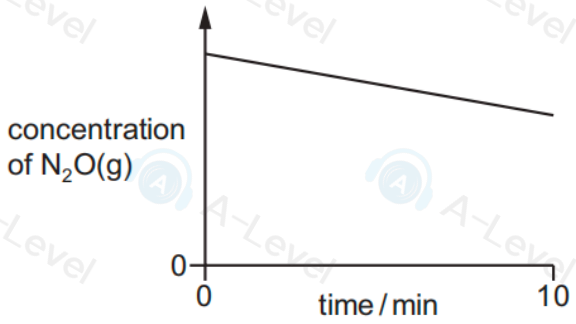
C The kinetic energy of the unreacted particles increases.

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

15 A large amount of $N_2O(g)$ decomposes into nitrogen gas and oxygen gas in the presence of a tiny amount of a gold foil catalyst.

The gold foil provides a solid surface on which the catalysed reaction takes place.

The graph shows the concentration of $N_2O(g)$ against time as it decomposes. The graph is a straight line.



Which row describes:

- the change in rate of reaction as $N_2O(g)$ decomposes from 0 to 10 minutes
- the effect of adding more gold foil catalyst on the rate of decomposition of the same amount and concentration of $N_2O(g)$?

	change in rate of reaction as $N_2O(g)$ decomposes	effect of adding more gold foil on the rate of decomposition
A	none	increases
B	none	none
C	decreases	increases
D	decreases	none

11 Two chemicals, X and Y, react together in solution to give product Z.

The rate of formation of product Z at the start of the reaction was measured in five experiments, 1–5, using various concentrations of X and Y. The results are shown.

experiment number	starting concentration of X / mol dm^{-3}	starting concentration of Y / mol dm^{-3}	rate of formation of Z at the start / mol dm^{-3} s^{-1}
1	0.10	0.10	0.0001
2	0.10	0.20	0.0004
3	0.10	0.40	0.0016
4	0.20	0.10	0.0001
5	0.40	0.10	0.0001

Which statement is correct?

A The rate of the reaction is directly proportional to the concentration of reagent X.

B The rate of the reaction is directly proportional to the concentration of reagent Y.

C The rate of the reaction is **not** affected by the concentration of reagent X.

D The rate of the reaction is **not** affected by the concentration of reagent Y.

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.

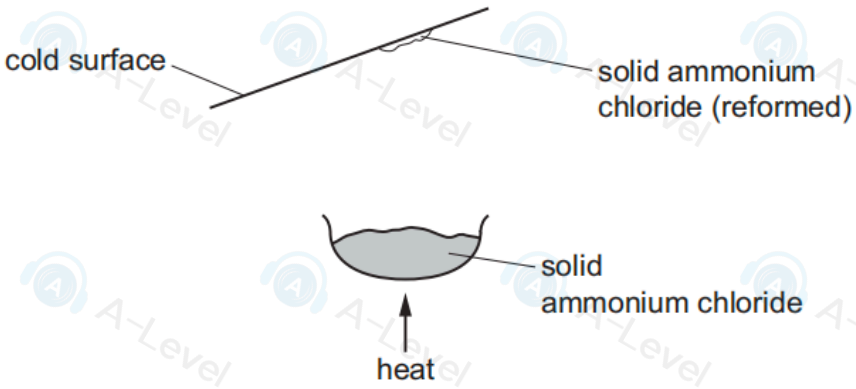
B The iron is removed.

C The nitrogen partial pressure is increased to 150 kPa.

D The temperature is increased to 500 °C.

33 When a sample of ammonium chloride is warmed it decomposes into ammonia and hydrogen chloride gas.

$$NH_4Cl(s) \rightarrow NH_3(g) + HCl(g) \qquad \text{reaction 1}$$



When the mixture of hot ammonia and hydrogen chloride gases hit a cold surface, a white solid of ammonium chloride reforms.

Which statements are correct?

1 Reaction 1 is in dynamic equilibrium.

2 Reaction 1 is reversible.

3 Reaction 1 is an endothermic reaction.

34 Hydrogen chloride gas is formed by the reaction shown.

$$H_2(g) + Cl_2(g) \rightarrow 2HCl(g)$$

What will change the average kinetic energy of the reacting gas particles?

1 increasing the temperature and increasing the concentration of hydrogen

2 cooling the reaction mixture and adding a catalyst

3 adding a catalyst and increasing the concentration of chlorine

33 Many gases do **not** obey the general gas equation at high pressures.

Why is this?

1 At higher pressures the molecules have more energy.

2 At higher pressures the volume of the molecules is a larger proportion of the total volume.

3 At higher pressures the molecules experience greater intermolecular forces.

7 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.

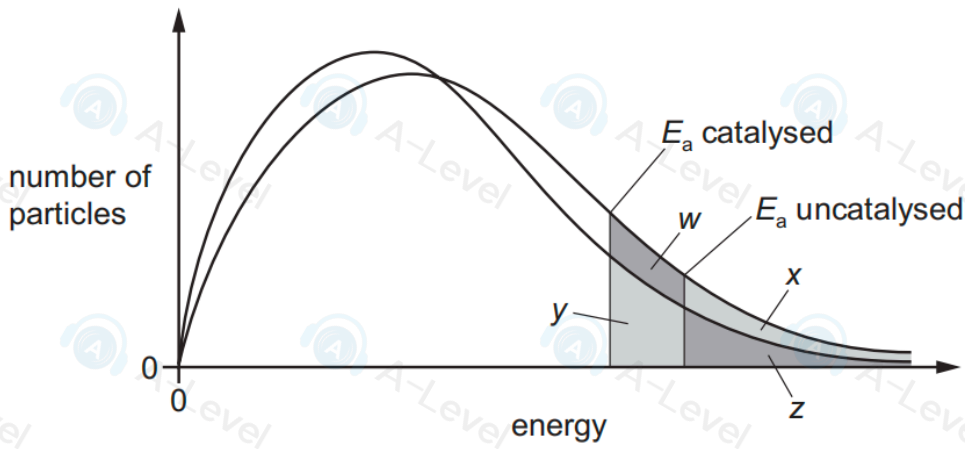
B The catalyst has no effect on the value of K_c.

C The catalyst increases the value of K_c.

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

16 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	$y + z$	$x + z$

16 The Haber process for the manufacture of ammonia is represented by the equation shown.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H = -92\,kJ\,mol^{-1}$$

Which statement is correct about this reaction when the temperature is increased?

A Both forward and backward rates increase.

B The backward rate only increases.

C The forward rate only increases.

D There is no effect on the backward or forward rates.

13 A synthesis for methanol is shown.

$$CO_2 + 3H_2 \rightleftharpoons CH_3OH + H_2O \qquad \Delta H = -49\,kJ\,mol^{-1}$$

Which conditions would produce the greatest yield of methanol at equilibrium?

	pressure	temperature / °C
A	high	80
B	high	20
C	low	80
D	low	20

10 A large excess of marble chips is reacted with 25 cm^3 of 1.0 mol dm^{-3} hydrochloric acid at 40 °C.

How is the result different when the reaction is repeated with 60 cm^3 of 0.5 mol dm^{-3} hydrochloric acid at 40 °C?

A The reaction is faster and more of the products are made when the reaction is complete.

B The reaction is faster and less of the products are made when the reaction is complete.

C The reaction is slower and more of the products are made when the reaction is complete.

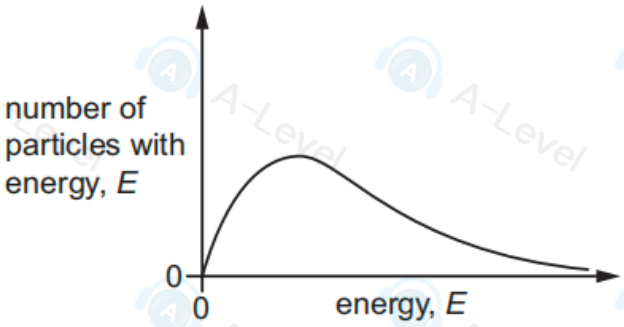
D The reaction is slower and less of the products are made when the reaction is complete.

6 Sodium chloride, water and air represent three states of matter – solid, liquid and gas.

Which row is correct?

	sodium chloride	water	air
A	particles held in rigid structure	can easily be compressed	can easily be compressed
B	particles stationary	particles move	cannot easily be compressed
C	particles stationary	particles stationary	particles move
D	resistant to change of shape	cannot easily be compressed	can easily be compressed

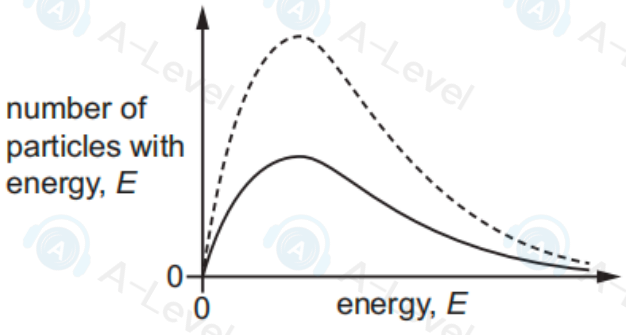
15 The Boltzmann distribution for one mole of a gas at temperature T is shown.



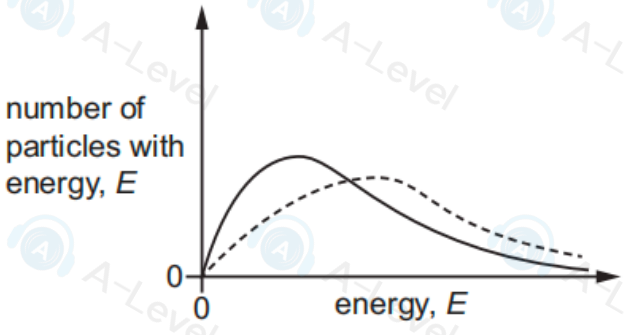
One mole of the same gas is added, and the gas remains at temperature T.

Which dotted curve shows the distribution with the added gas?

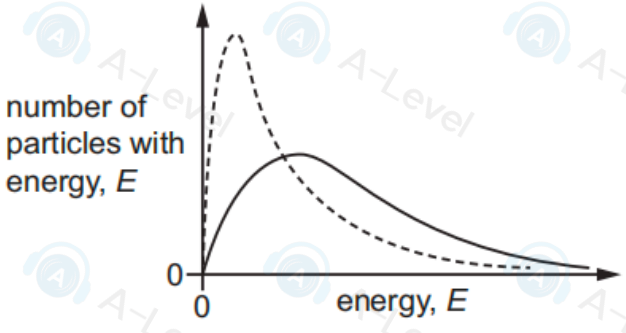
A



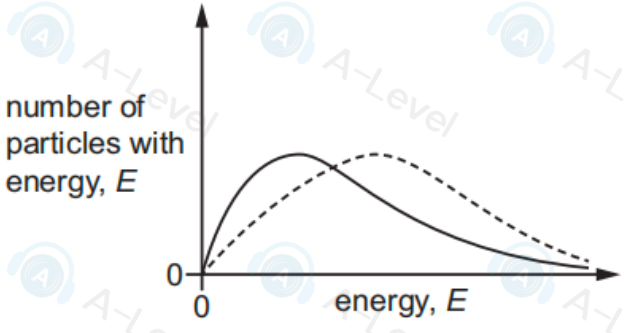
B



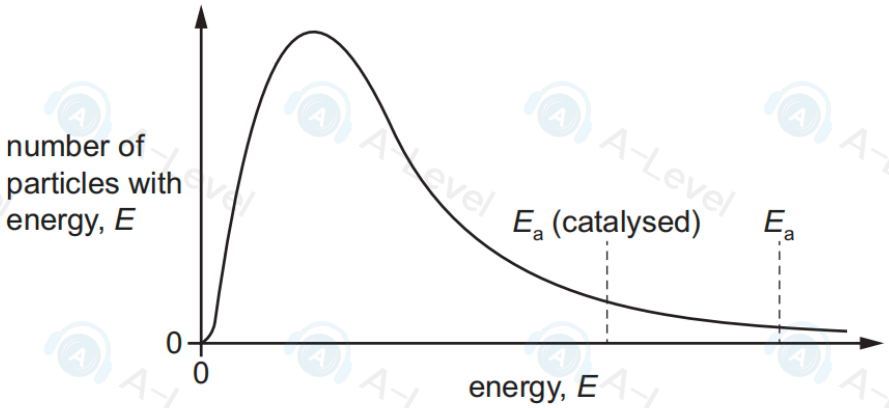
C



D



11 The Boltzmann distribution curve for a gaseous mixture of ethene and hydrogen is shown. Nickel is an effective catalyst for the reaction that occurs.



How does the diagram appear if the same reaction mixture is at a higher temperature?

A The curve is unchanged.

B The values of both E_a (catalysed) and E_a decrease.

C The values of both E_a (catalysed) and E_a increase.

D The values of both E_a (catalysed) and E_a remain the same.

11 NO and NO_2 are both present in the lower atmosphere as pollutants.

The reaction sequence shows the production of ozone from oxygen in the lower atmosphere.

This sequence repeats many times.

$$NO_2(g) \rightarrow NO(g) + O(g)$$

$$NO(g) + \tfrac{1}{2}O_2(g) \rightarrow NO_2(g)$$

$$O_2(g) + O(g) \rightarrow O_3(g)$$

Which statement about this reaction sequence is correct?

A NO is acting as a catalyst, but NO_2 is not acting as a catalyst.

B NO_2 is acting as a catalyst, but NO is not acting as a catalyst.

C Neither NO nor NO_2 are acting as catalysts.

D Both NO and NO_2 are acting as catalysts.