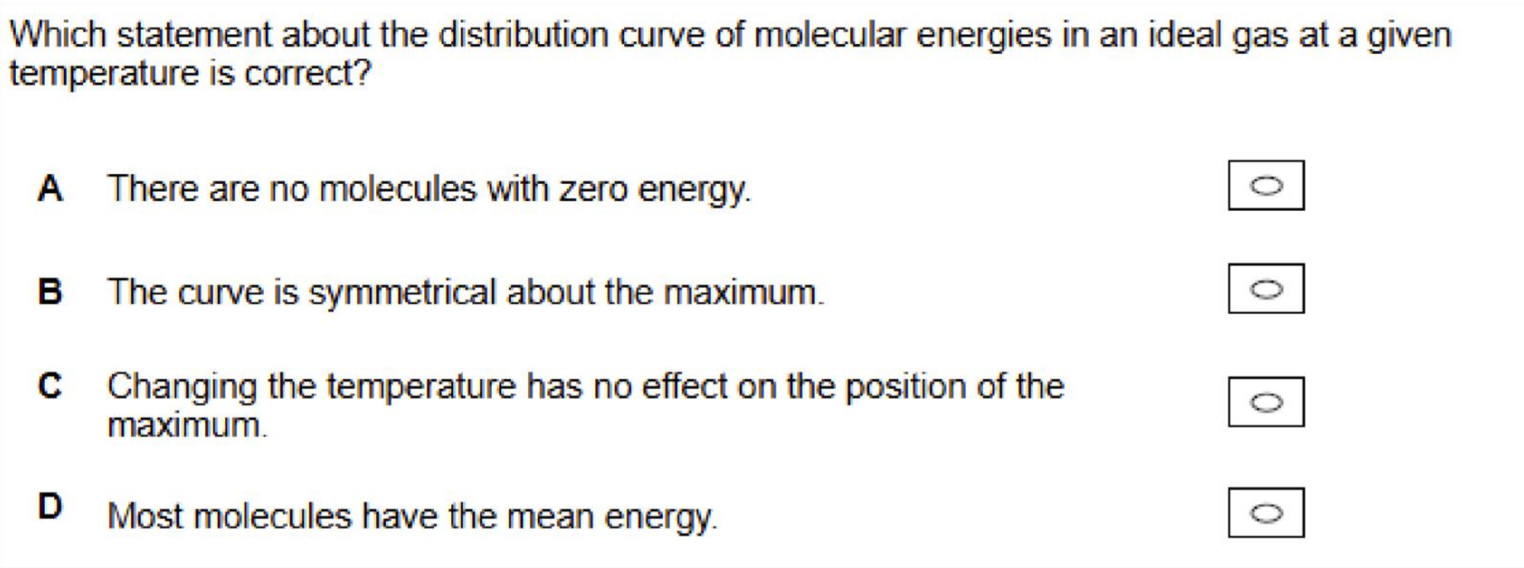
Question - 01



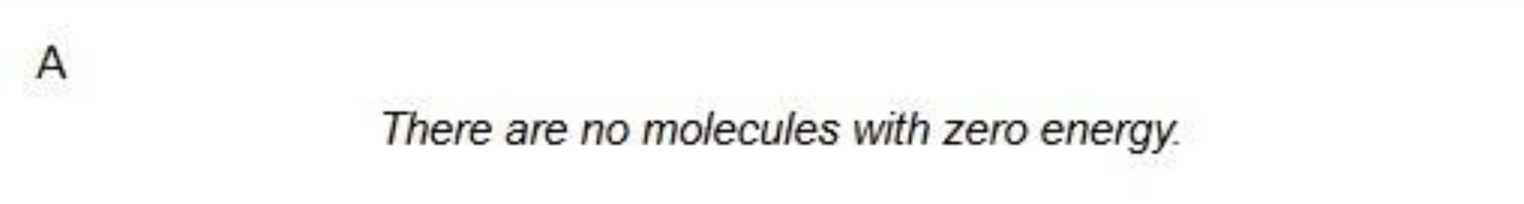
Which statement about the distribution curve of molecular energies in an ideal gas at a given temperature is correct?

A There are no molecules with zero energy. ○

B The curve is symmetrical about the maximum. ○

C Changing the temperature has no effect on the position of the maximum. ○

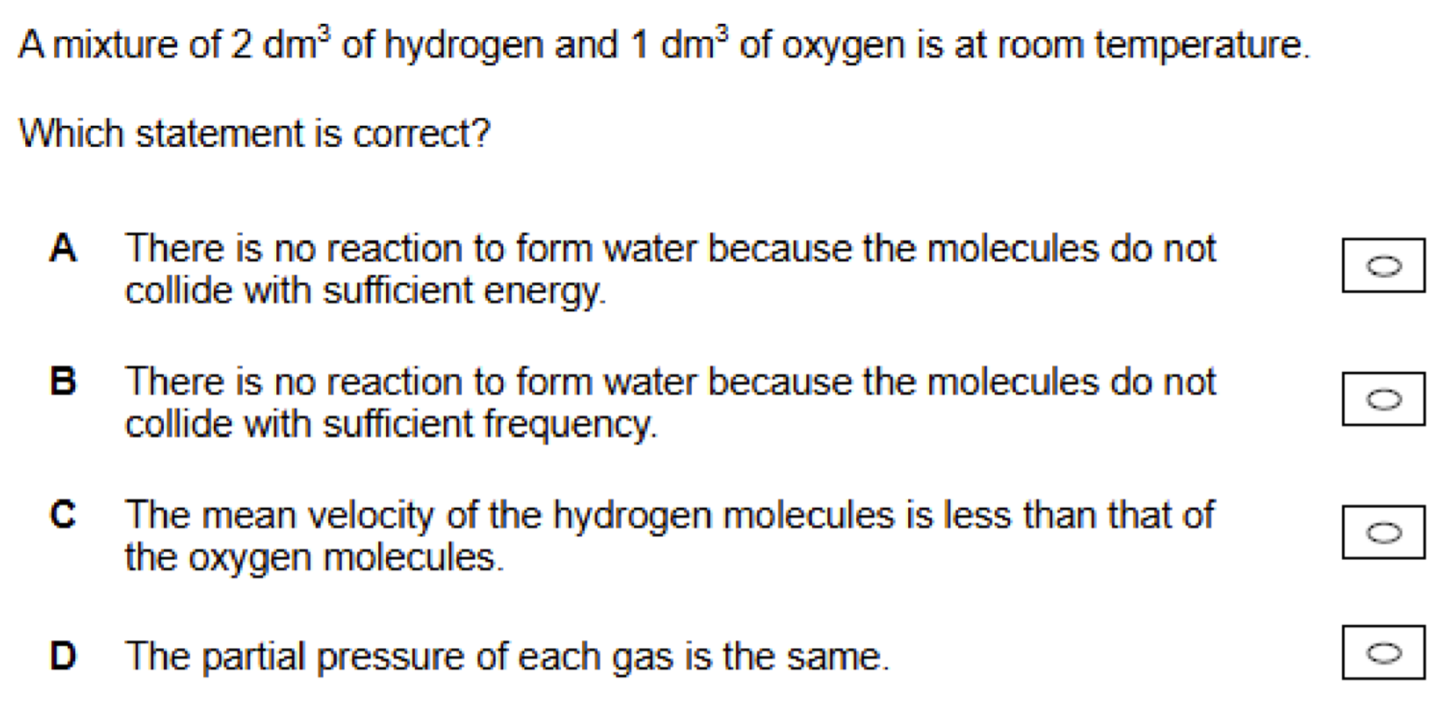
D Most molecules have the mean energy. ○



A

There are no molecules with zero energy.

Question - 02



A mixture of 2 dm^3 of hydrogen and 1 dm^3 of oxygen is at room temperature.

Which statement is correct?

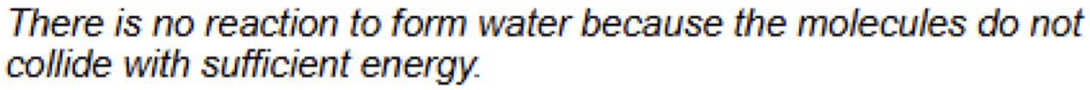
A There is no reaction to form water because the molecules do not collide with sufficient energy. ○

B There is no reaction to form water because the molecules do not collide with sufficient frequency. ○

C The mean velocity of the hydrogen molecules is less than that of the oxygen molecules. ○

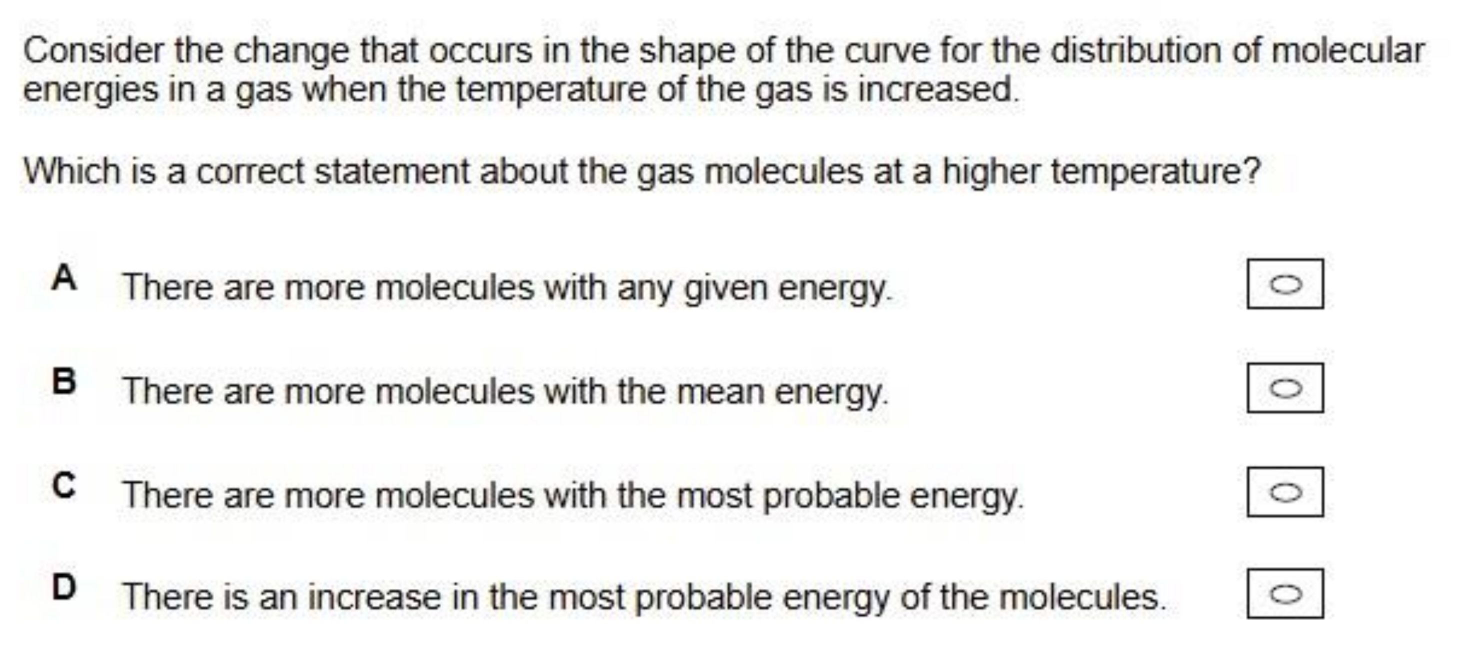
D The partial pressure of each gas is the same. ○

A



There is no reaction to form water because the molecules do not collide with sufficient energy.

Question - 03



Consider the change that occurs in the shape of the curve for the distribution of molecular energies in a gas when the temperature of the gas is increased.

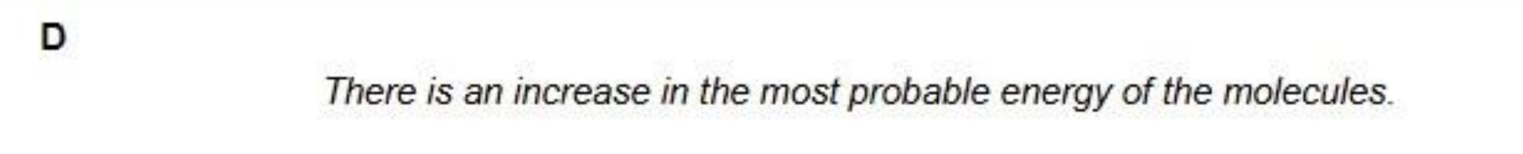
Which is a correct statement about the gas molecules at a higher temperature?

A There are more molecules with any given energy. ○

B There are more molecules with the mean energy. ○

C There are more molecules with the most probable energy. ○

D There is an increase in the most probable energy of the molecules. ○



D

There is an increase in the most probable energy of the molecules.

Hydrogen peroxide solution decomposes to form water and oxygen.

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

The reaction is catalysed by manganese(IV) oxide.

A student determines the order of this reaction with respect to hydrogen peroxide. The student uses a continuous monitoring method in the experiment.

The student places hydrogen peroxide solution in a conical flask with the catalyst and uses a gas syringe to collect the oxygen formed. The student records the volume of oxygen every 10 seconds for 100 seconds.

(a) Explain why the reaction is fastest at the start.

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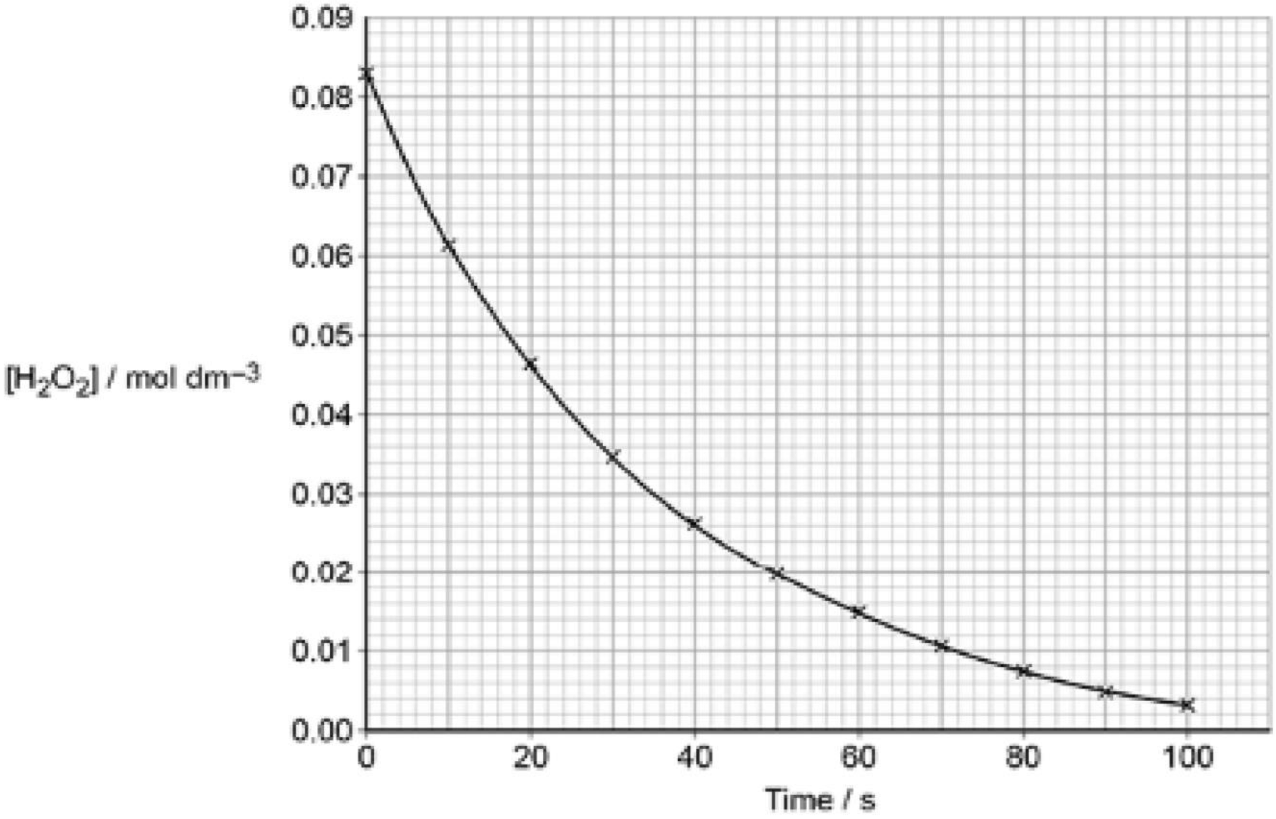
(2)

(b) The graph in **Figure 1** shows how the concentration of hydrogen peroxide changes with time in this experiment.

Figure 1



Tangents to the curve in **Figure 1** can be used to determine rates of reaction.

Draw a tangent to the curve when the concentration of hydrogen peroxide solution is 0.05 mol dm^{-3}

Use your tangent to calculate the gradient of the curve at this point.

Gradient ______________ mol dm^{-3} s^{-1}

(2)

(c) The concentration of hydrogen peroxide solution at time *t* during the experiment can be calculated using this expression.

$$[H_2O_2]_t = [H_2O_2]_{\text{initial}}\left(\frac{V_{\text{max}} - V_t}{V_{\text{max}}}\right)$$

$[H_2O_2]_t$ = concentration of hydrogen peroxide solution at time *t* / mol dm^{-3}

$[H_2O_2]_{\text{initial}}$ = concentration of hydrogen peroxide solution at the start / mol dm^{-3}

V_{max} = total volume of oxygen gas collected during the whole experiment / cm^3

V_t = volume of oxygen gas collected at time *t* / cm^3

In this experiment, V_{max} = 100 cm^3

Use **Figure 1** and the expression to calculate $[H_2O_2]_t$ when 20 cm^3 of oxygen has been collected.

$[H_2O_2]_t$ ______________ mol dm^{-3}

(2)

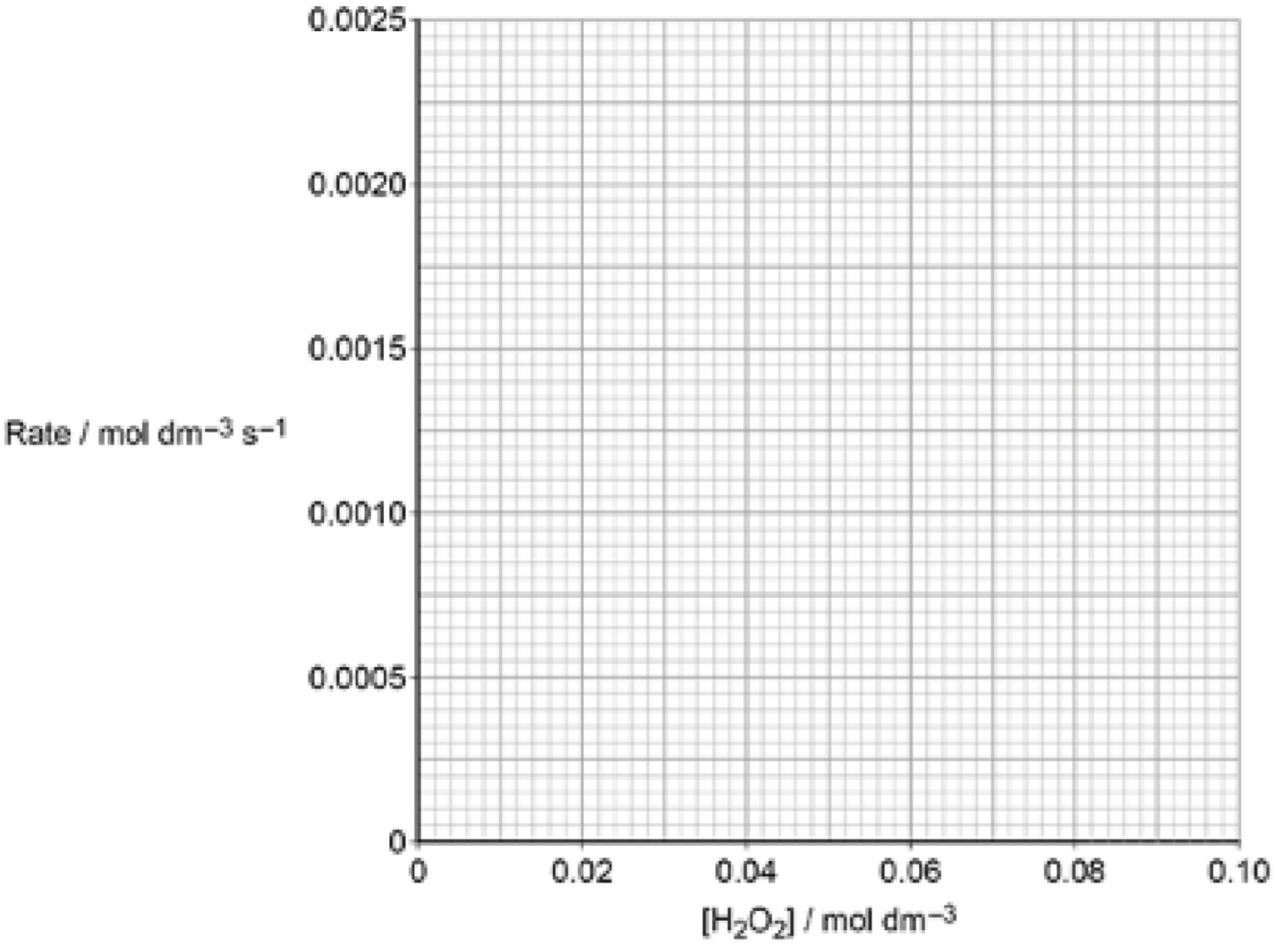
The table below shows data from a similar experiment.

$[H_2O_2]$ / mol dm^{-3}	0.02	0.03	0.05	0.07	0.09
Rate / mol dm^{-3} s^{-1}	0.00049	0.00073	0.00124	0.00168	0.00219

(d) Plot the data from the table above on the grid in **Figure 2**.

Draw a line of best fit.

Figure 2



(2)

(e) Use **Figure 2** to determine the order of reaction with respect to H_2O_2

State how the graph shows this order.

Order ____

How the graph shows this order ______________________________

____

____

(2)

(a) **M1** High**er**/**est** concentration of / more H_2O_2 / particles / molecules / reactants

1

M2 More frequent successful collisions

Alternative approach

M1 *Lower/**est** concentration of / fewer particles / molecules / reactants as time goes on*

M2 *Less frequent successful collisions (look for both ideas even if separated)*

Ignore *'chance' / 'probability'*

1

(b) **M1** Suitable tangent drawn

M1 *Tangent must be drawn with ruler and touch line at 0.05 mol dm^{-3} (± 1 square) and not cross the curve (if white seen between lines it crosses)*

1

M2 -0.00120 to -0.00155 (mol dm^{-3} s^{-1})

M2 Ignore *units*

Allow *ecf from unsuitable tangent i.e if M1 not awarded*

Ignore *sign of gradient*

1

(c) **M1** $[H_2O_2]_{initial} = 0.083$ mol dm^{-3}

Allow *0.082 − 0.084*

1

M2 $[H_2O_2]_t = 0.0664$ (mol dm^{-3})

Allow *0.0656 − 0.0672 (scores 2/2)*

2SF minimum

Allow *ecf from **M1** (M2 = M1 × 0.8)*

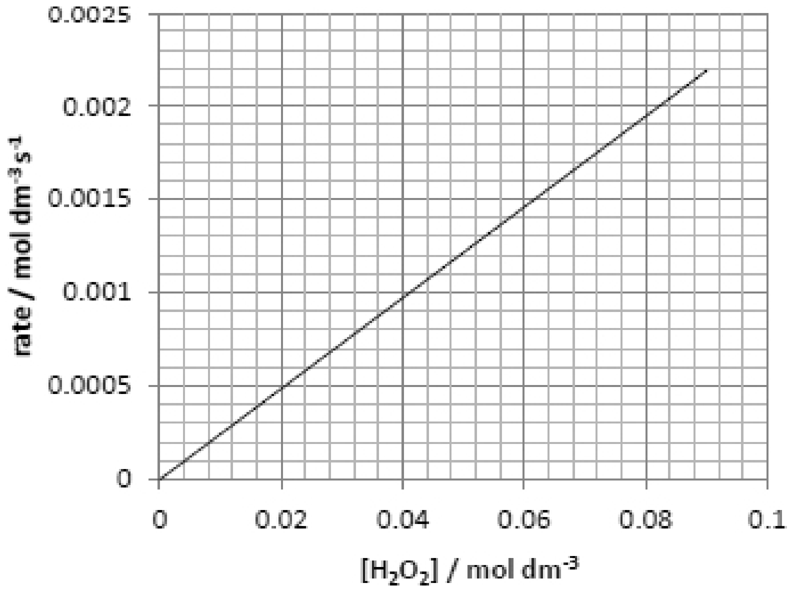
1

(d) **M1** Points plotted

M1 *allow each point (± 1/2 square)*

1

M2 best fit straight line drawn



M2 *line should be drawn with a ruler and cover the five points given going within 1 square of each point, no doubles no kinks. The line does not need to be extended to the origin*

Allow *reasonable best fit line if points plotted incorrectly*

1

(e) **M1** 1st order

1

M2 straight line graph through the origin

Ignore *rate is (directly) proportional to [H_2O_2]*

Allow *constant gradient line through the origin*

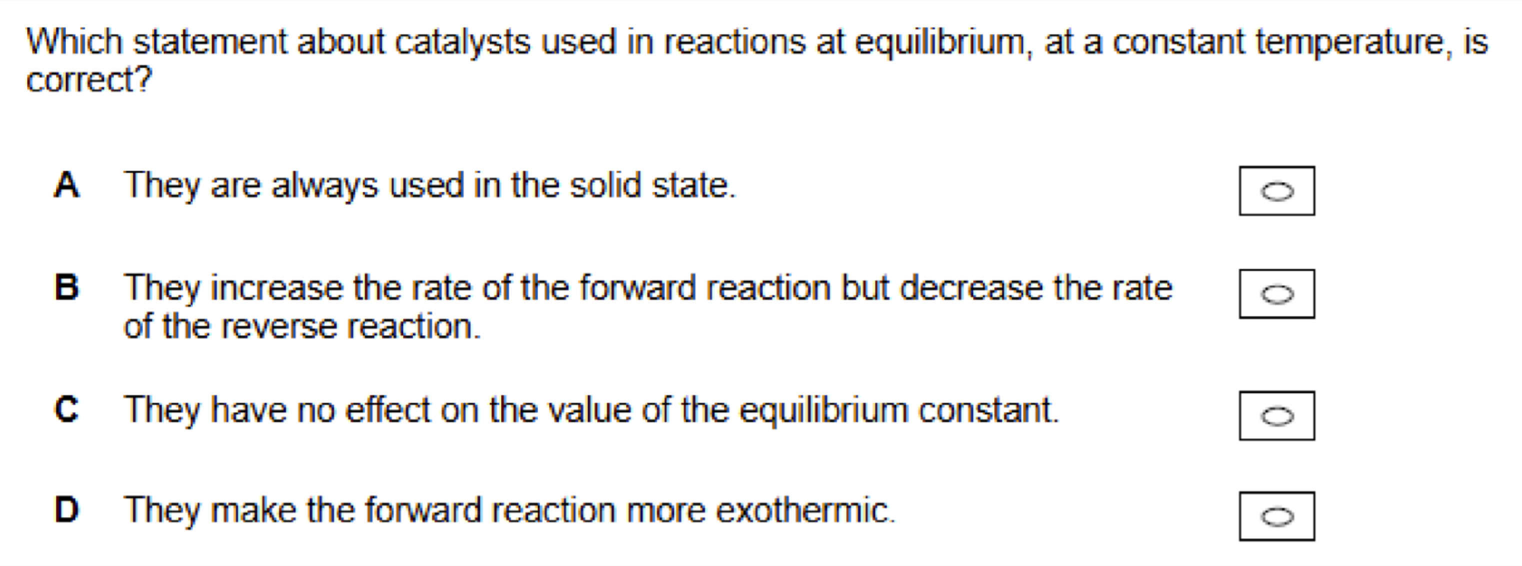
Allow *use of data from line to show e.g. x2 conc = x2 rate*

Allow *if M1 missing*

Not *if M1 wrong*

1

Question - 05



Which statement about catalysts used in reactions at equilibrium, at a constant temperature, is correct?

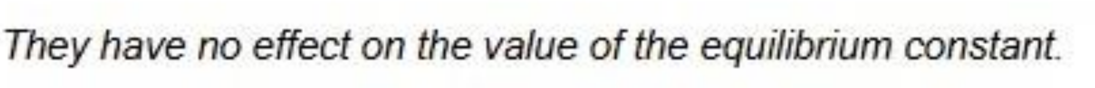
A They are always used in the solid state. ○

B They increase the rate of the forward reaction but decrease the rate of the reverse reaction. ○

C They have no effect on the value of the equilibrium constant. ○

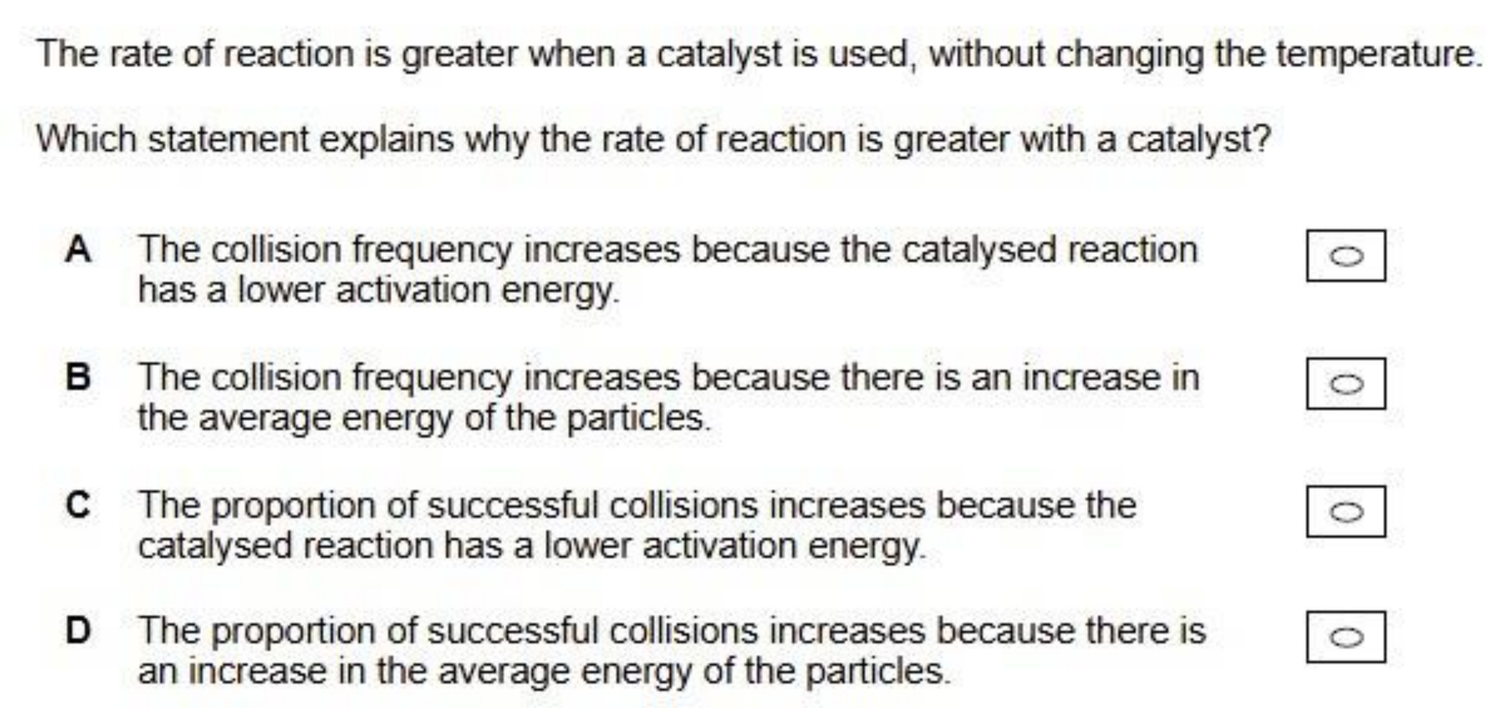
D They make the forward reaction more exothermic. ○

C



They have no effect on the value of the equilibrium constant.

Question - 06



The rate of reaction is greater when a catalyst is used, without changing the temperature.

Which statement explains why the rate of reaction is greater with a catalyst?

A The collision frequency increases because the catalysed reaction has a lower activation energy. ○

B The collision frequency increases because there is an increase in the average energy of the particles. ○

C The proportion of successful collisions increases because the catalysed reaction has a lower activation energy. ○

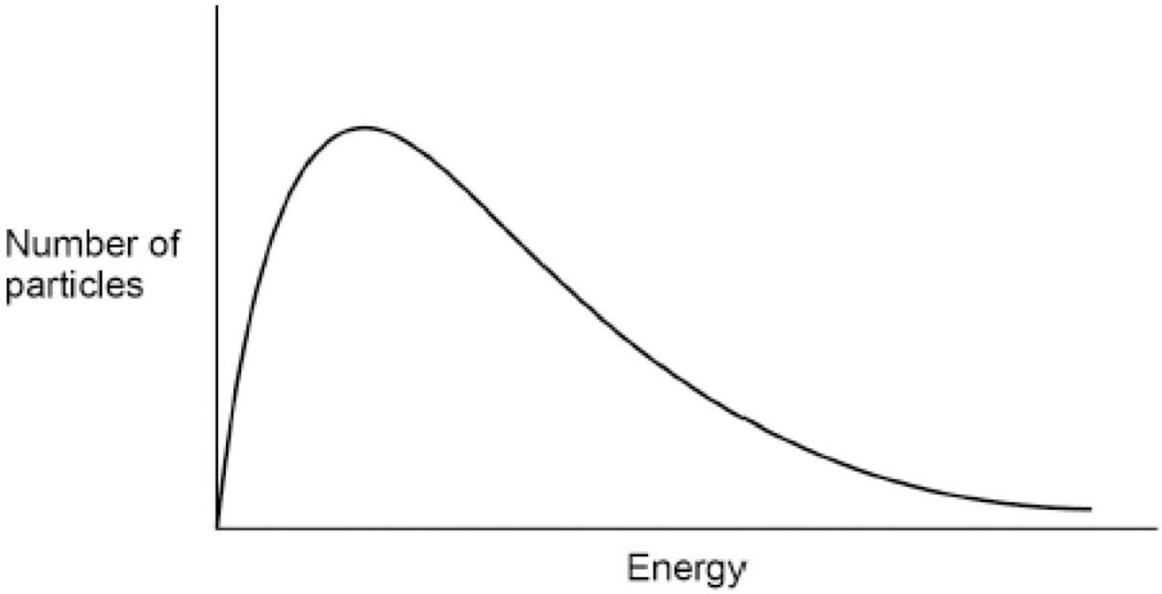
D The proportion of successful collisions increases because there is an increase in the average energy of the particles. ○

C

The proportion of successful collisions increases because the catalysed reaction has a lower activation energy.

Question - 07

This is a Maxwell–Boltzmann distribution for a gaseous reactant.



What is represented by the total area under the curve?

A total energy of the particles ○

B activation energy for the reaction ○

C total number of reacting particles ○

D total number of particles present ○

D

total number of particles present

Question - 08

This question is about ethanoic anhydride.

In the gas phase, ethanoic anhydride $(CH_3CO)_2O$ decomposes to form ethenone.

The equation is

$$(CH_3CO)_2O \rightarrow \underset{\text{Ethenone}}{H_2C{=}C{=}O} + CH_3COOH$$

(a) Ethenone is the simplest member of the ketene homologous series. Ketenes all contain one C=C double bond and one C=O double bond.

Deduce the general formula for the ketene homologous series.

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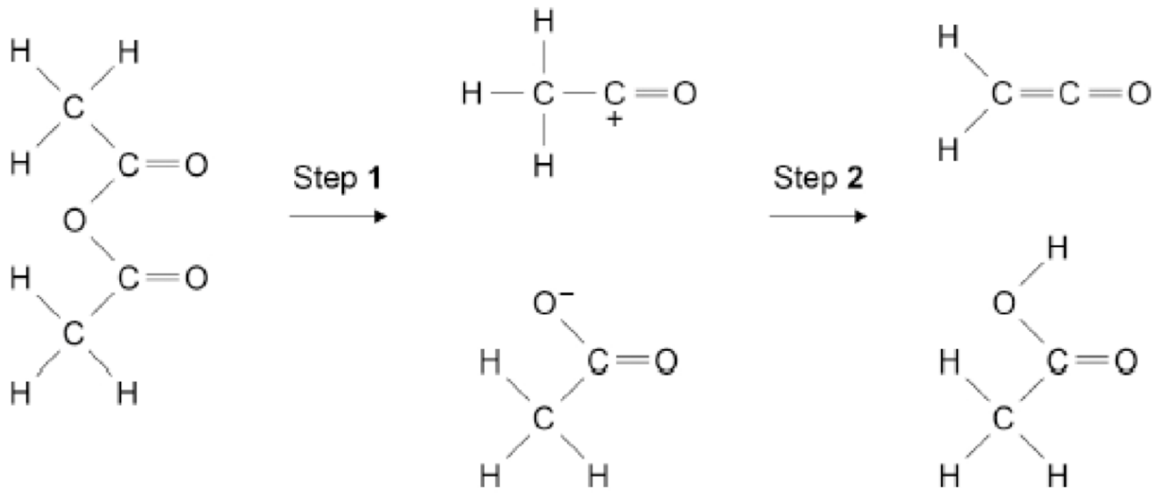
(1)

(b) The figure below shows an incomplete suggested mechanism for the decomposition of ethanoic anhydride.



Complete the mechanism in the figure above by adding three curly arrows and any relevant lone pairs of electrons.

(3)

(c) For a chemical reaction the relationship between the rate constant, *k*, and the temperature, *T*, is shown by the Arrhenius equation.

$$k = Ae^{\frac{-E_a}{RT}}$$

For the decomposition of gaseous ethanoic anhydride

the activation energy, $E_a = 34.5\ \text{kJ mol}^{-1}$

the Arrhenius constant, $A = 1.00 \times 10^{12}\ \text{s}^{-1}$

At temperature T_1 the rate constant, $k = 2.48 \times 10^{8}\ \text{s}^{-1}$

Calculate T_1

The gas constant, $R = 8.31\ \text{J K}^{-1}\ \text{mol}^{-1}$

T_1 ____________________ K

(3)

(d) Sketch the Maxwell–Boltzmann distribution of molecular energies for gaseous ethanoic anhydride at temperature T_1 and at a higher temperature T_2

Include a label for each axis, and mark on the appropriate axis a typical position for the activation energy.

Explain why the rate of reaction is faster at T_2

Explanation

____

____

____

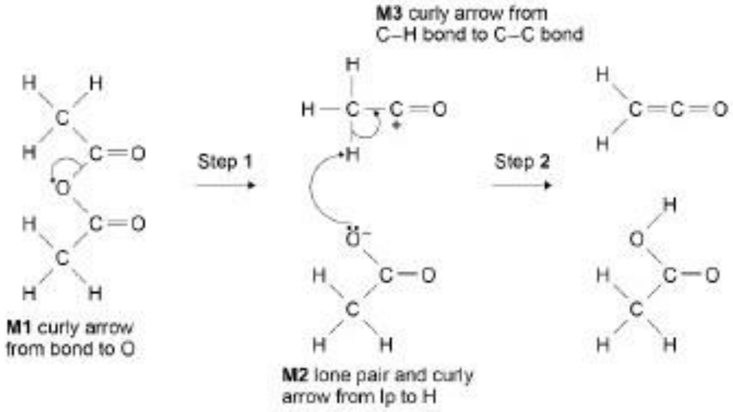
(5)

(a) $C_nH_{2n-2}O$

Allow $C_nH_{2n}CO$ or $(CH_2)_nCO$ or $C_nH_{2(n-1)}O$

1

(b)



Allow other C-O bond breaking for M1

3

(c) M1 $\frac{k}{A} = e^{-Ea/RT}$

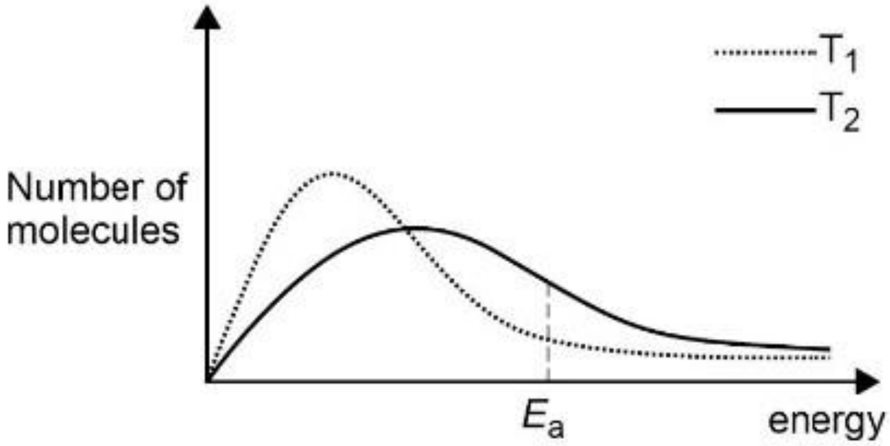
M2 $8.302 = \frac{34500}{8.31 \times T}$

M3 T = 500 K

OR via $\ln k = \ln A - \frac{Ea}{RT}$ or shown with numbers

3

(d)



M5 At T_2 (many) more particles have $E \geq E_a$

M1 x axis labelled correctly (kinetic not required)

AND y axis labelled correctly allow particles

M2 Ea labelled on x axis

M3 Distribution correct shape for T_1

M4 Peak at T_2 lower with max shifted right and only crosses once

5

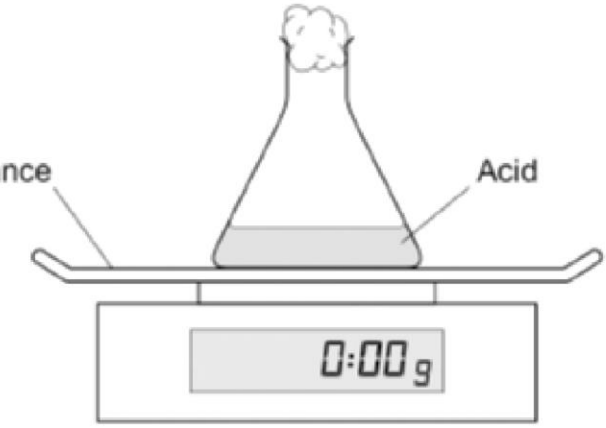
This question is about rates of reaction.

Figure 1 shows apparatus used to measure the rate of reaction when an acid reacts with an excess of solid sodium hydrogencarbonate, $NaHCO_3$

When different monoprotic organic acids are used, the rates at which gas escapes can be used to compare the strengths of the acids.

A timer is started when the $NaHCO_3$ is added to the acid and the mass of CO_2 gas lost is recorded at regular intervals.
(It is assumed that any change in mass is due to the loss of CO_2)

Figure 1



(a) Suggest a reason why using a conical flask instead of a beaker would give more accurate results in this experiment.

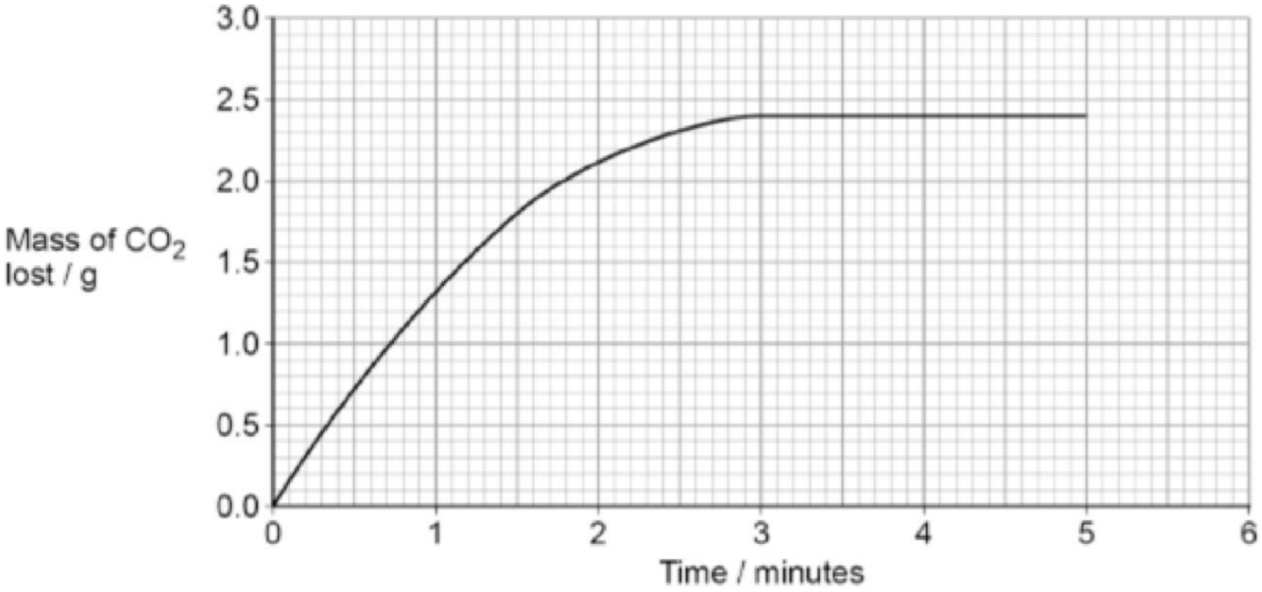
____

____

(1)

Figure 2 shows the results of this experiment when 25.0 cm^3 of a 2.23 mol dm^{-3} solution of ethanoic acid reacts with an excess of $NaHCO_3$

Figure 2



(b) Use **Figure 2** to calculate the rate of reaction at 2 minutes.

Deduce the units of your calculated rate.

Rate _______________ Units _______________

(3)

(c) Chloroethanoic acid is a stronger acid than ethanoic acid.

Sketch, on **Figure 2**, the curve you would expect when 25.0 cm^3 of a 2.23 mol dm^{-3} solution of chloroethanoic acid reacts with an excess of $NaHCO_3$

Suggest why chloroethanoic acid is a stronger acid than ethanoic acid.

____

____

____

____

(3)

(a) Reduces loss of liquid droplets

Allow description of reduction of loss of liquid

1

(b) M1 Tangent drawn at 2 mins

M2 Gradient of tangent = (0.50 +/- 0.05)

M3 g min^{-1}

Conseq to their M1

If convert mins to sec M2 = 7.80 x 10^{-3} (7.0 x 10^{-3} to 8.6 x 10^{-3}) and award M3 conseq

If M1 not awarded then allow average rate calculated M2 = 1.05

If M1 not awarded then allow average rate and if 120 sec used for time allow M2 =0.0175 and can score M3 for g s^{-1}

Penalise g/min

3

(c) M1 Curve steeper at first & flattens at same point on y axis

M2 Cl is an electron withdrawing group or negative inductive effect

M3 Weakens the O-H bond / increase polarity of O-H bond

Allow opposite argument

M2 CH_3 electron donating or positive inductive effect

M3 Makes O-H bond stronger / decrease polarity of O-H bond

Also allow answers that discuss the carboxylate ion

M2 Cl Electron withdrawing group

M3 makes $RCOO^-$ less negative / delocalises the negative charge more / more stable ion (so $RCOO^-$ less likely to accept H^+)

3