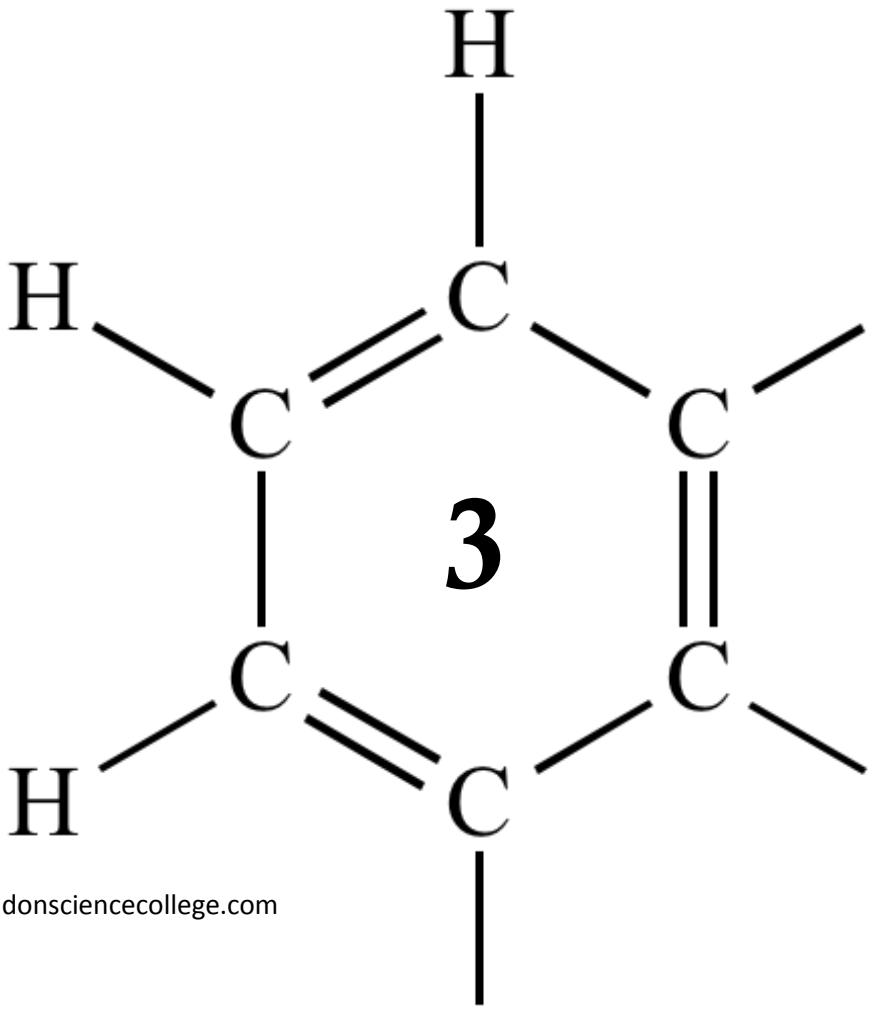
LONDON SCIENCE COLLEGE

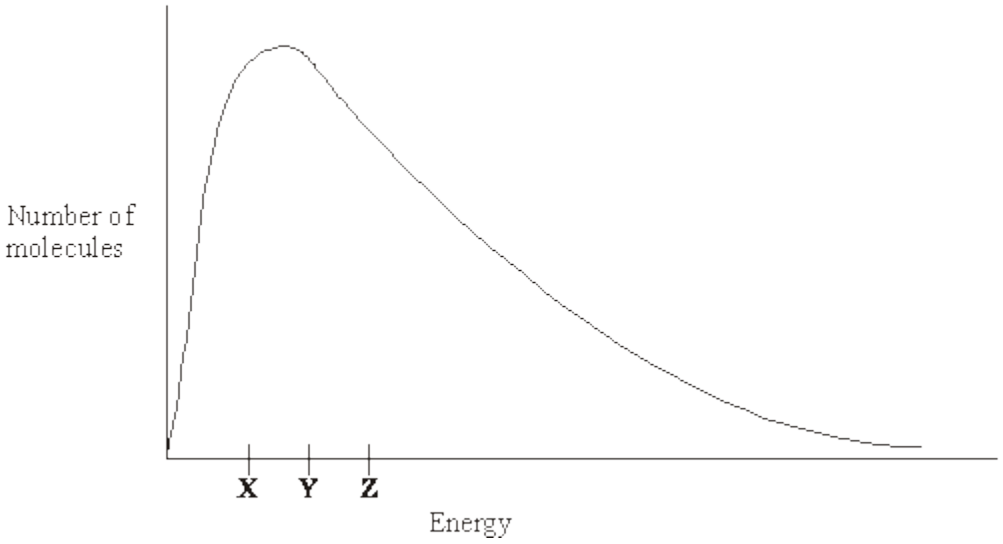
OCR AS CHEMISTRY

MODULE 3

RATES



1 The diagram below shows the Maxwell–Boltzmann distribution of molecular energies in a sample of a gas.



(a) (i) State which one of **X**, **Y** or **Z** best represents the mean energy of the molecules.

.....

(ii) Explain the process that causes some molecules in this sample to have very low energies.

.....

.....

(3)

(b) On the diagram above, sketch a curve to show the distribution of molecular energies in the same sample of gas at a higher temperature.

(2)

(c) (i) Explain why, even in a fast reaction, a very small percentage of collisions leads to a reaction.

.....

.....

(ii) Other than by changing the temperature, state how the proportion of successful collisions between molecules can be increased. Explain why this method causes an increase in the proportion of successful collisions.

Method for increasing the proportion of successful collisions .....

.....

Explanation .....

.....

(4)
(Total 9 marks)

2 The gas-phase reaction between hydrogen and chlorine is very slow at room temperature.

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

(a) Define the term *activation energy*.

.....

.....

(2)

(b) Give **one** reason why the reaction between hydrogen and chlorine is very slow at room temperature.

.....

.....

(1)

(c) Explain why an increase in pressure, at constant temperature, increases the rate of reaction between hydrogen and chlorine.

.....

.....

(2)

(d) Explain why a small increase in temperature can lead to a large increase in the rate of reaction between hydrogen and chlorine.

.....

.....

(2)

(e) Give the meaning of the term *catalyst*.

.....

.....

(1)

(f) Suggest **one** reason why a solid catalyst for a gas-phase reaction is often in the form of a powder.

.....

(1)
(Total 9 marks)

3 (a) Define the term *activation energy* for a chemical reaction.

(2)

(b) Draw, with labelled axes, a curve to represent the Maxwell–Boltzmann distribution of molecular energies in a gas. Label this curve $\mathbf{T}_1$. On the same axes, draw a second curve to represent the same sample of gas at a lower temperature. Label this curve $\mathbf{T}_2$.

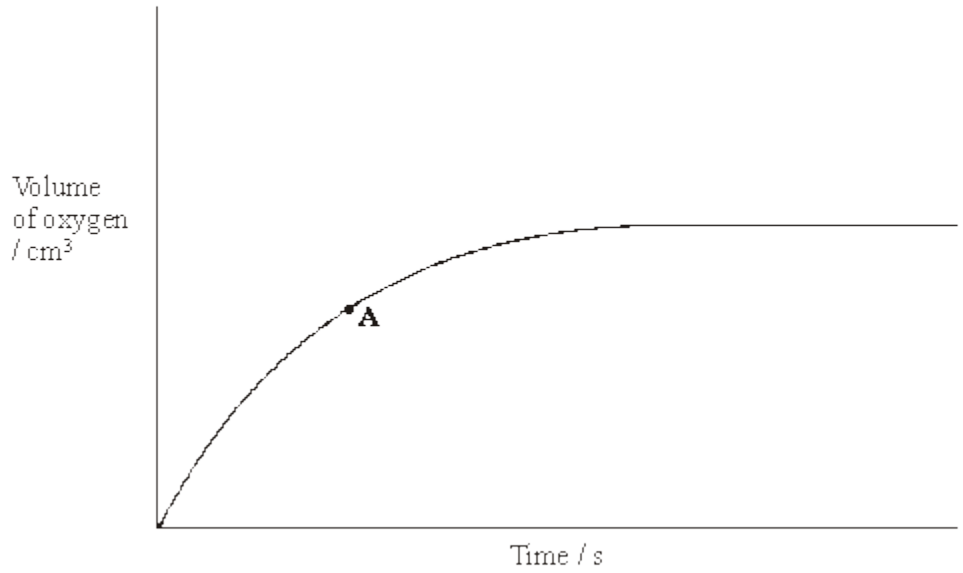
Use these curves to explain why a small decrease in temperature can lead to a large decrease in the rate of a reaction.

(8)

(c) Give **one** reason why most collisions between gas-phase reactants do not lead to a reaction. State and explain **two** ways of speeding up a gas-phase reaction other than by changing the temperature.

(5)
(Total 15 marks)

4 The curve below shows how the volume of oxygen evolved varies with time when 50 cm^3 of a 2.0 mol dm^{-3} solution of hydrogen peroxide, H_2O_2, decomposes at 298 K.



(a) State how you could use the curve to find the rate of reaction at point **A**.

.....

(1)

(b) Sketch curves, on the above axes, to illustrate how the volume of oxygen evolved would change with time if the experiment was repeated at 298 K using the following.

(i) 100 cm^3 of a 1.0 mol dm^{-3} solution of H_2O_2. Label this curve **X**.

(ii) 25 cm^3 of a 2.0 mol dm^{-3} solution of H_2O_2 in the presence of a catalyst. Label this curve **Y**.

(4)

(c) Hydrogen peroxide decomposes more rapidly in the presence of aqueous hydrogen bromide. The decomposition proceeds as shown by the following equations.

$$H_2O_2 + HBr \rightarrow HBrO + H_2O$$

$$HBrO + H_2O_2 \rightarrow H_2O + O_2 + HBr$$

(i) Write an equation for the overall reaction.

.....

(ii) Define the term *catalyst*.

.....

.....

(iii) Give **two** reasons, other than an increase in the reaction rate, why these equations suggest that hydrogen bromide is behaving as a catalyst.

Reason 1 .....

Reason 2 .....

(5)
(Total 10 marks)

5 This question is about the reaction given below.

$$CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g)$$

Enthalpy data for the reacting species are given in the table below.

Substance	CO(g)	$H_2O(g)$	$CO_2(g)$	$H_2(g)$
$\Delta H_f^{\ominus}$ / kJ mol^{-1}	−110	−242	−394	0

Which one of the following statements is **not** correct?

A The value of K_p changes when the temperature changes.

B The activation energy decreases when the temperature is increased.

C The entropy change is more positive when the water is liquid rather than gaseous.

D The enthalpy change is more positive when the water is liquid rather than gaseous.

(Total 1 mark)

6 Gas **G** decomposes as shown in the equation below.

$$G(g) \rightarrow X(g) + Y(g)$$

(a) Draw, on the axes below, a Maxwell–Boltzmann distribution curve for a sample of **G** in which only a small proportion of molecules has energy greater than the activation energy, E_a.

(3)

(b) Define the term *activation energy*.

.....

.....

(2)

(c) At any time, most of the molecules of **G** have energy less than the activation energy. Suggest why, at a constant temperature, most of **G** eventually decomposes.

.....

.....

(2)

(d) State the effect, if any, of adding a catalyst on the time required for **G** to decompose, compared with a similar sample without a catalyst. Explain in general terms how the catalyst has this effect.

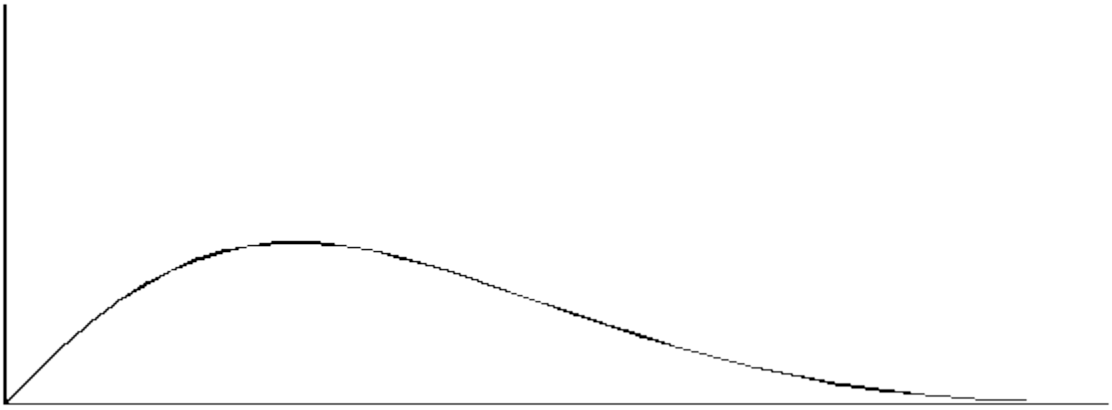
Time for decomposition .....

Explanation .....

.....

(3)
(Total 10 marks)

7 The diagram below represents a Maxwell–Boltzmann distribution curve for the particles in a sample of a gas at a given temperature. The questions below refer to this sample of particles.



(a) Label the axes on the diagram.

(2)

(b) On the diagram draw a curve to show the distribution for this sample at a **lower** temperature.

(2)

(c) In order for two particles to react they must collide. Explain why most collisions do not result in a reaction.

.....

(1)

(d) State one way in which the collision frequency between particles in a gas can be increased without changing the temperature.

.....

(1)

(e) Suggest why a small increase in temperature can lead to a large increase in the reaction rate between colliding particles.

.....

.....

.....

(2)

(f) Explain in general terms how a catalyst works.

.....

.....

.....

(2)
(Total 10 marks)

8 (a) Define the term *activation energy* for a reaction.

.....

.....

(2)

(b) Give the meaning of the term *catalyst.*

.....

.....

(2)

(c) Explain in general terms how a catalyst works.

.....

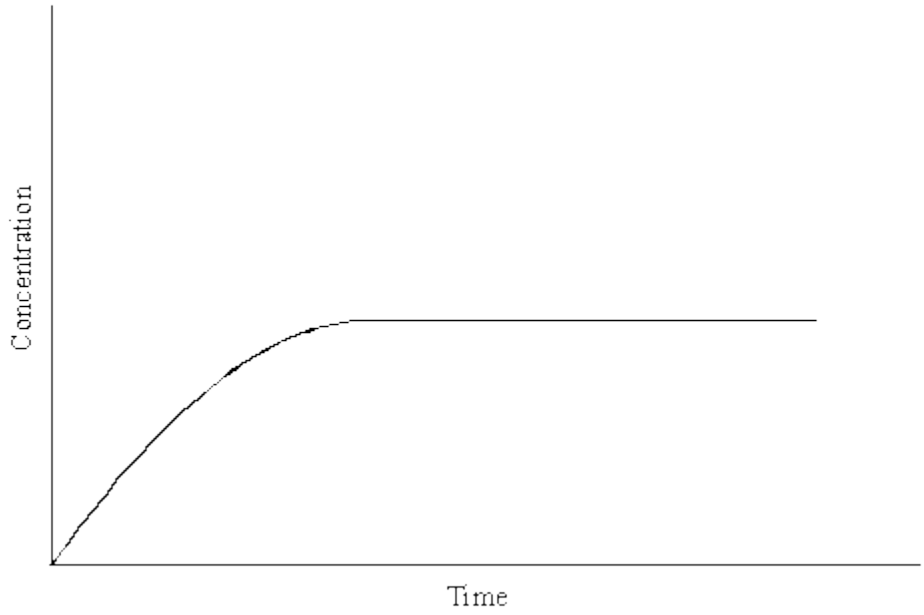
.....

(2)

(d) In an experiment, two moles of gas **W** reacted completely with solid **Y** to form one mole of gas **Z** as shown in the equation below.

$2W(g) + Y(s) \rightarrow Z(g)$

The graph below shows how the concentration of **Z** varied with time at constant temperature.



(i) On the axes above, sketch a curve to show how the concentration of **W** would change with time in the same experiment. Label this curve **W**.

(ii) On the axes above, sketch a curve to show how the concentration of **Z** would change with time if the reaction were to be repeated under the same conditions but in the presence of a catalyst. Label this curve **Z.**

(iii) In terms of the behaviour of particles, explain why the rate of this reaction decreases with time.

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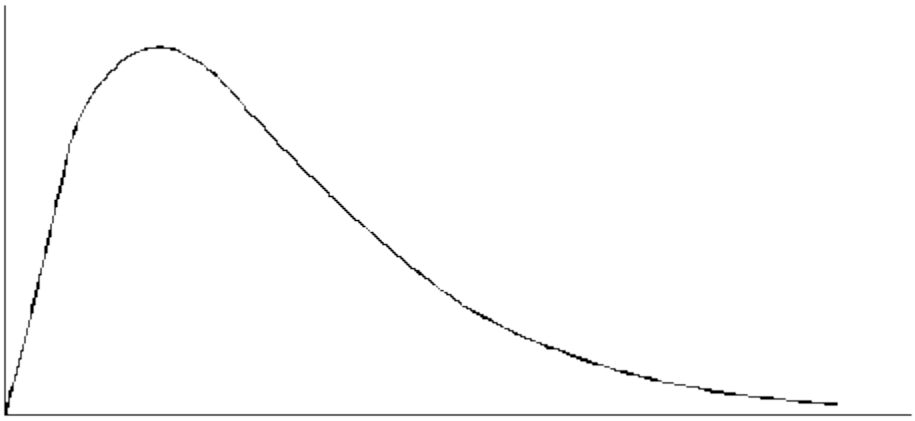
(6)
(Total 12 marks)

9 (a) Below is a Maxwell–Boltzmann curve showing the distribution of molecular energies for a sample of gas at a temperature *T*.



(i) Label the axes on the diagram above.

(ii) What does the area under the curve represent?

.....

(iii) State why this curve starts at the origin.

.....

(4)

(b) (i) State what is meant by the term *activation energy*.

.....

.....

(ii) The rate of a chemical reaction may be increased by an increase in reactant concentration, by an increase in temperature and by the addition of a catalyst.

State which, if any, of these changes involves a different activation energy. Explain your answer.

Change(s) .....

Explanation .....

.....

(5)
(Total 9 marks)

10 Hydrogen is produced by the reaction between steam and methane when the following dynamic equilibrium is established.

$$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g) \qquad \Delta H = +206 \text{ kJ mol}^{-1}$$

(a) Use Le Chatelier's principle to predict the separate effects of an increase in temperature and of an increase in pressure on the yield of hydrogen obtained in the above reaction. In each case, explain your answer.

(6)

(b) State how, and explain why, the use of a catalyst might or might not change the equilibrium yield of hydrogen, and also the amount of hydrogen produced, in a given time.

(4)

(Total 10 marks)

11 The compound lithium tetrahydridoaluminate(III), $LiAlH_4$, is a useful reducing agent. It behaves in a similar fashion to $NaBH_4$. Carbonyl compounds and carboxylic acids are reduced to alcohols. However, $LiAlH_4$ also reduces water in a violent reaction so that it must be used in an organic solvent.

Which one of the following concerning the violent reaction between $LiAlH_4$ and water is **false**?

A A gas is produced.

B The activation energy for the reaction is relatively high.

C The reaction has a negative free-energy change.

D Aqueous lithium ions are formed.

(Total 1 mark)

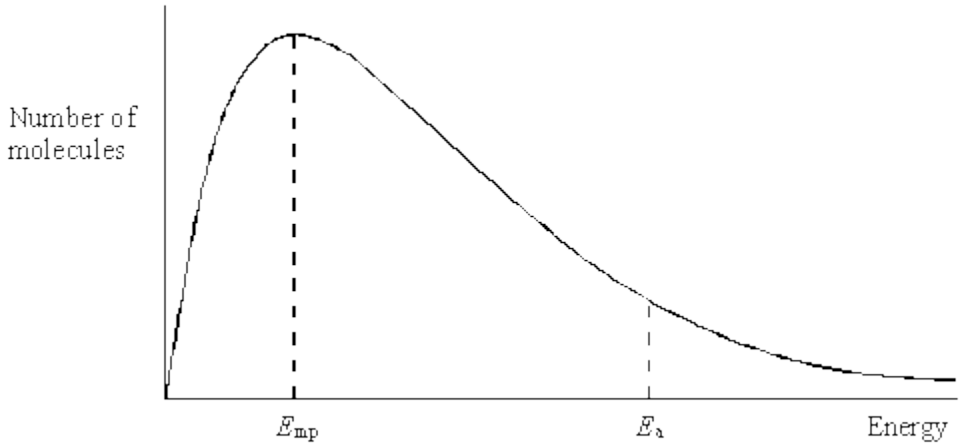
12 (a) State what is meant by the term *activation energy* of a reaction.

(1)

(b) State in general terms how a catalyst increases the rate of a chemical reaction.

(2)

(c) The curve below shows the Maxwell–Boltzmann distribution of molecular energies, at a constant temperature, in a gas at the start of a reaction. On this diagram the most probable molecular energy at this temperature is indicated by the symbol E_{mp} and the activation energy by the symbol E_a.



Consider the following changes.

(i) The number of molecules is increased at constant temperature.

(ii) The temperature is decreased without changing the number of molecules.

(iii) A catalyst is introduced without changing the temperature or the number of molecules.

For **each** of these changes state how, if at all, the following would vary:

- the value of the most probable energy, E_{mp}
- the number of molecules with the most probable energy, E_{mp}
- the area under the molecular energy distribution curve
- the number of molecules with energy greater than the activation energy, E_a

(12)
(Total 15 marks)

13

Summarised directions for recording responses to multiple completion questions			
A (i), (ii) and (iii) only	**B** (i) and (iii) only	**C** (ii) and (iv) only	**D** (iv) alone

Which of the following statements about a catalyst is / are true?

(i) It speeds up the forward reaction and slows down the reversere action.

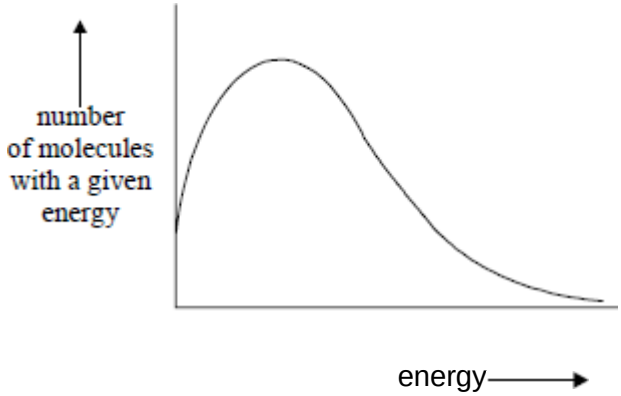
(iii) It increases the proportion of molecules with higher energies.

(iii) A homogeneous catalyst usually acts in the solid state.

(iv) It does not alter the value of the equilibrium constant.

(Total 1 mark)

14



The total area under the distribution curve represents

A total energy.

B activation energy.

C total number of reacting molecules.

D total number of molecules present.

(Total 1 mark)