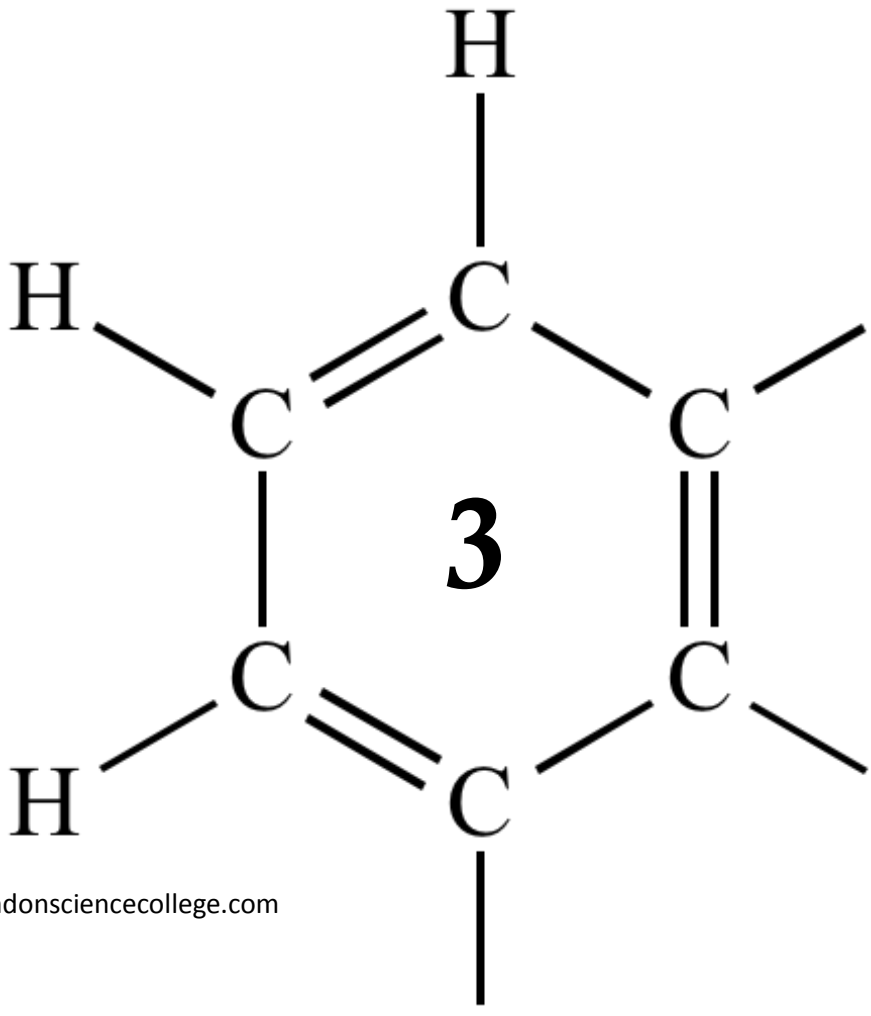
LONDON SCIENCE COLLEGE

AQA AS CHEMISTRY

KINETICS



3

1 The rate of a chemical reaction is influenced by the size of the activation energy. Catalysts are used to increase the rates of chemical reactions but are not used up in the reactions.

(a) Give the meaning of the term *activation energy*.

.....

.....

.....

.....

(2)

(b) Explain how a catalyst increases the rate of a reaction.

.....

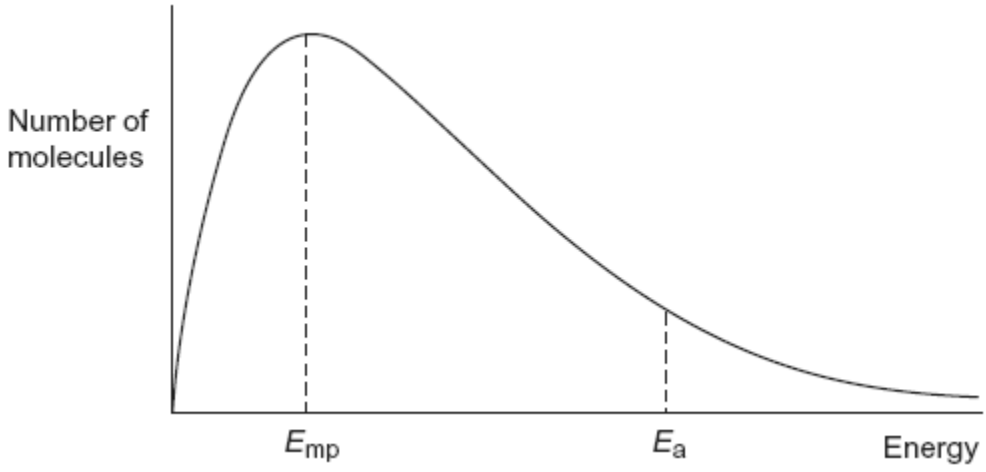
.....

.....

.....

(2)

(c) The diagram 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 shown by the symbol E_{mp}
The activation energy is shown by the symbol E_a



To answer the questions (c)(i) to (c)(iv), you should use the words **increases**, **decreases** or **stays the same**. You may use each of these answers once, more than once or not at all.

(i) State how, if at all, the value of the most probable energy (E_{mp}) changes as the total number of molecules is increased at constant temperature.

.....

(1)

(ii) State how, if at all, the number of molecules with the most probable energy (E_{mp}) changes as the temperature is decreased without changing the total number of molecules.

.....

(1)

(iii) State how, if at all, the number of molecules with energy greater than the activation energy (E_a) changes as the temperature is increased without c hanging the total number of molecules.

.....

(1)

(iv) State how, if at all, the area under the molecular energy distribution curve changes as a catalyst is introduced without changing the temperature or the total number of molecules.

.....

(1)

(d) For each of the following reactions, identify a catalyst and name the organic product of the reaction.

(i) The fermentation of an aqueous solution of glucose.

Catalyst .....

Name of organic product .....

.....

(2)

(ii) The hydration of but-2-ene.

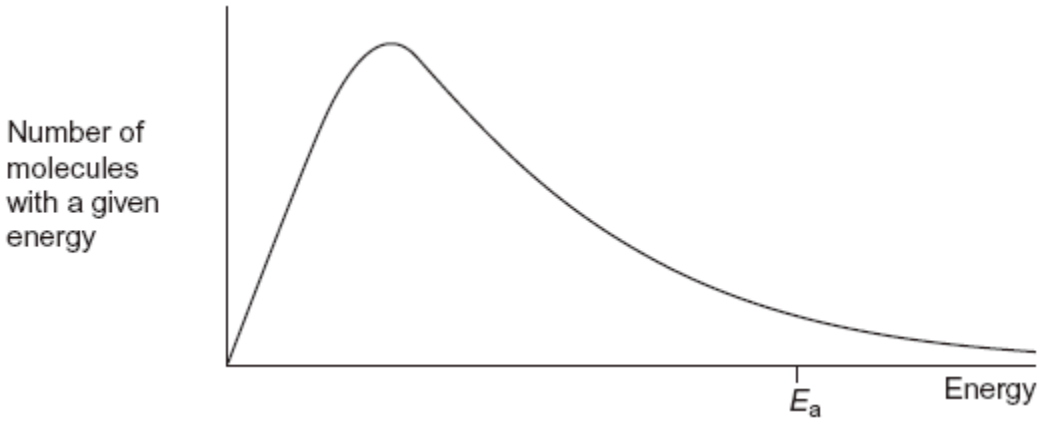
Catalyst .....

Name of organic product .....

.....

(2)
(Total 12 marks)

2 The diagram below shows a Maxwell–Boltzmann distribution for a sample of gas at a fixed temperature.
E_a is the activation energy for the decomposition of this gas.



(a) (i) On this diagram, sketch the distribution for the same sample of gas at a higher temperature.

(2)

(ii) With reference to the Maxwell–Boltzmann distribution, explain why an increase in temperature increases the rate of a chemical reaction.

.....

.....

.....

.....

.....

(2)

(b) Dinitrogen oxide (N_2O) is used as a rocket fuel. The data in the table below show how the activation energy for the decomposition of dinitrogen oxide differs with different catalysts.

$$2N_2O(g) \longrightarrow 2N_2(g) + O_2(g)$$

	Ea / kJ mol^{-1}
Without a catalyst	245
With a gold catalyst	121
With an iron catalyst	116
With a platinum catalyst	136

(i) Use the data in the table to deduce which is the most effective catalyst for this decomposition.

.....

(1)

(ii) Explain how a catalyst increases the rate of a reaction.

.....

.....

.....

.....

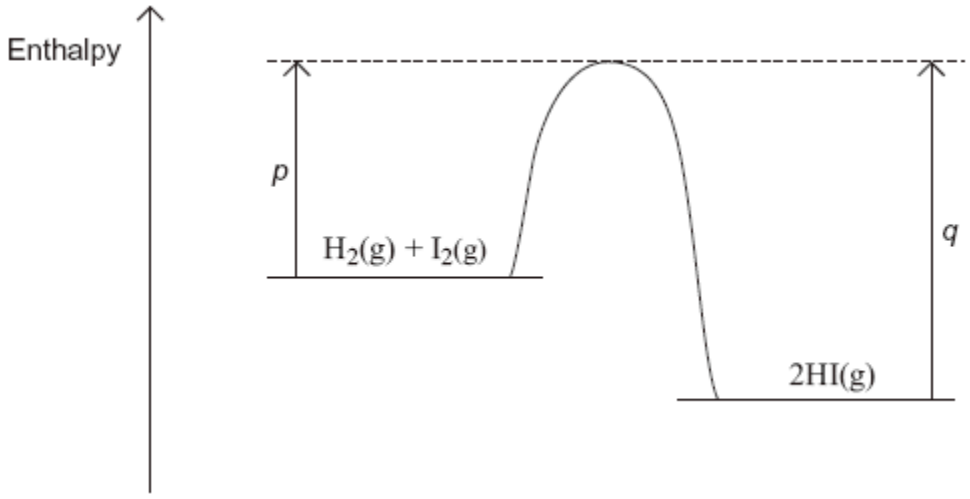
(2)

(Total 7 marks)

3 An equation for the equilibrium reaction between hydrogen, iodine and hydrogen iodide is shown below.

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$$

(a) The curve in the diagram below illustrates the reaction profile for this equilibrium reaction without a catalyst.



(i) Draw on the diagram a curve to illustrate the reaction profile for this equilibrium reaction **with** a catalyst.

(2)

(ii) Use the diagram to deduce whether the formation of hydrogen iodide from hydrogen and iodine is exothermic or endothermic.

.....

(1)

(iii) State what the diagram suggests about the sum of the bond enthalpies for the reactant molecules compared with the product molecules.

.....

.....

(1)

(iv) In terms of *p* and *q*, identify the following for this equilibrium without a catalyst.

A value for the activation energy for the forward reaction .....

A value for the overall enthalpy change for the forward reaction

.....

(2)

(b) A mixture of $H_2(g)$ and $I_2(g)$ was allowed to reach equilibrium.

(i) State the effect of a catalyst on the rate of attainment of this equilibrium.

.....

(1)

(ii) State and explain the effect of an increase in total pressure on the rate of attainment of this equilibrium.

Effect of an increase in pressure on rate .....

Explanation .....

.....

.....

.....

.....

(3)
(Total 10 marks)

4 An equation for the decomposition of hydrogen peroxide is shown below.

$$2H_2O_2 \longrightarrow 2H_2O + O_2$$

State the measurements you would take in order to investigate the rate of this reaction.

.....

.....

.....

.....

(Total 2 marks)

5 Group 2 metals and their compounds are used commercially in a variety of processes and applications.

(a) State a use of magnesium hydroxide in medicine.

.....

(1)

(b) Calcium carbonate is an insoluble solid that can be used in a reaction to lower the acidity of the water in a lake.

Explain why the rate of this reaction decreases when the temperature of the water in the lake falls.

.....

.....

.....

.....

.....

(3)

(c) Strontium metal is used in the manufacture of alloys.

(i) Explain why strontium has a higher melting point than barium.

.....

.....

.....

.....

(2)

(ii) Write an equation for the reaction of strontium with water.

.....

(1)

(d) Magnesium can be used in the extraction of titanium.

(i) Write an equation for the reaction of magnesium with titanium(IV) chloride.

.....

(1)

(ii) The excess of magnesium used in this extraction can be removed by reacting it with dilute sulfuric acid to form magnesium sulfate.

Use your knowledge of Group 2 sulfates to explain why the magnesium sulfate formed is easy to separate from the titanium.

.....

.....

.....

(1)

(Total 9 marks)

6 Nitric acid is manufactured from ammonia in a process that involves several stages.

(a) In the first stage, ammonia is converted into nitrogen monoxide and the following equilibrium is established.

$$4NH_3(g) + 5O_2(g) \rightleftharpoons 4NO(g) + 6H_2O(g) \qquad \Delta H = -905 \text{ kJ mol}^{-1}$$

The catalyst for this equilibrium reaction is a platinum–rhodium alloy in the form of a gauze. This catalyst gauze is heated initially but then remains hot during the reaction.

(i) In terms of redox, state what happens to the ammonia in the forward reaction.

.....

(1)

(ii) Suggest a reason why the catalyst must be hot.

.....

(1)

(iii) Suggest a reason why the catalyst remains hot during the reaction.

.....

(1)

(iv) State how a catalyst increases the rate of a reaction.

.....

.....

.....

.....

(2)

(b) In the second stage, nitrogen monoxide is converted into nitrogen dioxide. The equation for the equilibrium that is established is shown below.

$$2NO(g) + O_2(g) \rightleftharpoons 2NO_2(g) \qquad \Delta H = -113 \text{ kJ mol}^{-1}$$

Explain why the equilibrium mixture is cooled during this stage of the process.

.....

.....

.....

.....

(2)

(c) In the final stage, nitrogen dioxide reacts with water as shown by the following equation.

$$2NO_2(g) + H_2O(l) \rightarrow H^+(aq) + NO_3^-(aq) + HNO_2(aq)$$

Give the oxidation state of nitrogen in each of the following.

NO_2 .....

NO_3^- .....

HNO_2 .....

(3)

(Total 10 marks)

7 Sodium thiosulfate solution ($Na_2S_2O_3$) reacts slowly with dilute hydrochloric acid to form a precipitate. The rate of this reaction can be studied by measuring the time (*t*) that it takes for a small fixed amount of precipitate to form under different conditions. The fixed amount of precipitate is taken as the amount needed to obscure a cross on paper.

The equation for this reaction is shown below.

$$Na_2S_2O_3 + 2HCl \rightarrow 2NaCl + S + SO_2 + H_2O$$

(a) Identify the insoluble product of this reaction which forms the precipitate.

.....

(1)

(b) When this reaction takes place, the collision between the reacting particles requires an activation energy. State what is meant by the term *activation energy*.

.....

.....

(2)

(c) In terms of particles, explain why, at a fixed temperature, you might expect the rate of this reaction to double when the concentration of sodium thiosulfate is doubled and the concentration of hydrochloric acid remains the same.

.....

.....

.....

.....

(2)

(d) (i) State what is meant by the term *rate of reaction*.

.....

.....

(1)

(ii) Consider the description of the way in which this experiment is carried out. Use your understanding of the term *rate of reaction* to explain why it is possible to use a simplified formula $\frac{1}{t}$ as a measure of the rate of **this** reaction.

.....

.....

(1)

(Total 7 marks)

8 In an experiment to determine the rate of a reaction, the volume of gas produced in the reaction was measured at regular intervals for several minutes.

(a) State **one** experimental condition that must be kept constant during the experiment.

.....

.....

(1)

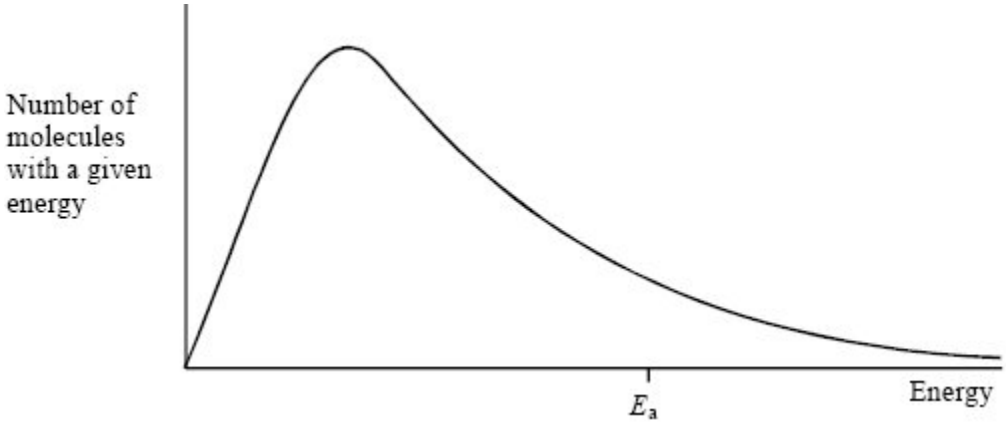
(b) Describe how the initial rate of this reaction can be determined from a graph of volume of gas produced against time.

.....

.....

(1)
(Total 2 marks)

9 The diagram below shows the Maxwell–Boltzmann energy distribution curve for a sample of gas at a fixed temperature. E_a is the activation energy for the decomposition of this gas.



(a) On this diagram sketch the distribution curve for the same sample of gas at a higher temperature.

(3)

(b) (i) What is the effect of an increase in temperature on the rate of a chemical reaction? Explain your answer with reference to the Maxwell–Boltzmann distribution.

Effect .....

Explanation .....

.....

.....

(ii) What is the effect of the addition of a catalyst on the rate of a chemical reaction? Explain your answer with reference to the Maxwell–Boltzmann distribution.

Effect .....

Explanation .....

.....

.....

(6)
(Total 9 marks)

10 A method of synthesising ammonia directly from nitrogen and hydrogen was developed by Fritz Haber. On an industrial scale, this synthesis requires a high temperature, a high pressure and a catalyst and is very expensive to operate.

(a) Use the data given below to calculate a value for the enthalpy of formation of ammonia

Bond	N ≡N	H – H	N – H
Mean bond enthalpy/kJ mol^{-1}	945	436	391

(3)

(b) A manager in charge of ammonia production wished to increase the daily production of ammonia and reduce the production costs. How would a chemist explain the factors that would influence the commercial efficiency of this production process?

(8)
(Total 11 marks)