Access Tuition

A-Level Chemistry
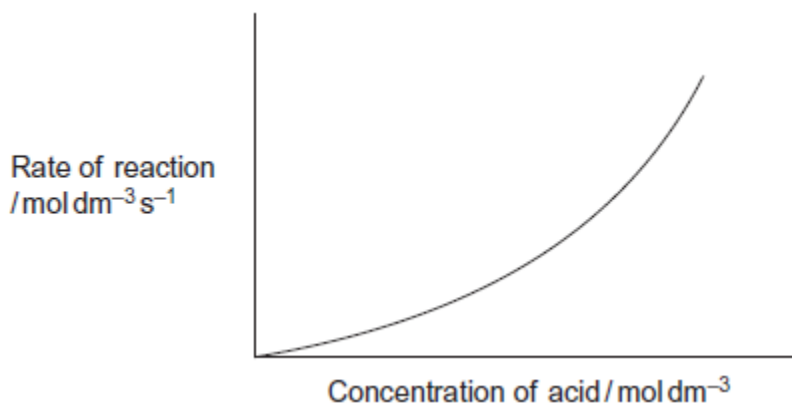
Collision Theory

Question Paper

Time available: 58 minutes
Marks available: 55 marks

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1. (a) In an investigation of the rate of reaction between hydrochloric acid and pure magnesium, a student obtained the following curve.

The reaction of magnesium with dilute hydrochloric acid is exothermic.

Use your understanding of collision theory to explain why the student did **not** obtain a straight line.

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(3)

(b) The magnesium used in a laboratory experiment was supplied as a ribbon. The ribbon was stored in an open plastic bag exposed to the air.

Explain why it is important to clean the surface of this magnesium ribbon when investigating the rate of its reaction with hydrochloric acid.

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(2)

(c)   Magnesium ribbon reacts with hot water. Heated magnesium ribbon reacts with steam.
      State **two** differences between these reactions.

      Difference 1 _____

      _____

      Difference 2 _____

      _____

                                                                                    (2)

(d)   Pure magnesium reacts completely with an excess of dilute sulfuric acid.
      The reaction of pure calcium with an excess of dilute sulfuric acid is very rapid initially.
      This reaction slows down and stops before all of the calcium has reacted.

      Use your knowledge of the solubilities of Group 2 sulfates to explain why these reactions of
   magnesium and calcium with dilute sulfuric acid are so different.

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                                                                                    (3)
                                                                       (Total 10 marks)

2. 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.

$$Na_2S_2O_3 + 2HCl \rightarrow 2NaCl + S + SO_2 + H_2O$$
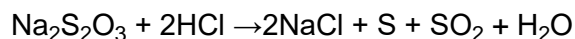
(a)   Identify the insoluble product of this reaction which forms the precipitate.

      _____

                                                                                    (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*.

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(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.

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(2)

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

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_____

(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 $\dfrac{1}{t}$ as a measure of the rate of **this** reaction.

_____

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(1)
(Total 7 marks)

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

_____

_____

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_____

(2)

(b)   Draw, with labelled axes, a curve to represent the Maxwell–Boltzmann distribution of molecular energies in a gas. Label this curve T_1. On the same axes, draw a second curve to represent the same sample of gas at a lower temperature. Label this curve 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.

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(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.
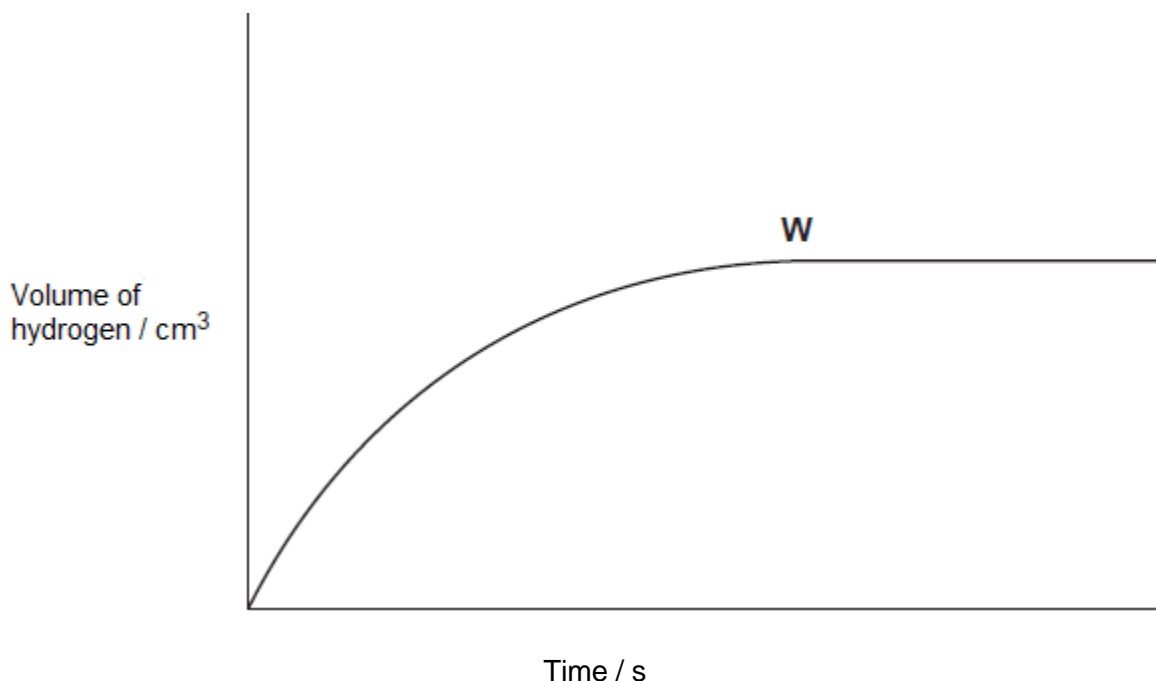
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(5)
(Total 15 marks)

4. (a) **Figure 1** shows the volume of hydrogen gas collected when a sample of magnesium reacted with an excess of dilute hydrochloric acid.

The rate of this reaction can be studied by measuring the time it takes for a given volume of hydrogen to be collected.

Figure 1

(i) State the meaning of the term *rate of reaction*.

_____

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_____

(1)

(ii) State and explain what has happened to the rate of this reaction at point **W** in **Figure 1**.

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(2)

(iii) In terms of collision theory explain why, at a fixed temperature, the rate of this reaction doubles when the concentration of the hydrochloric acid doubles.
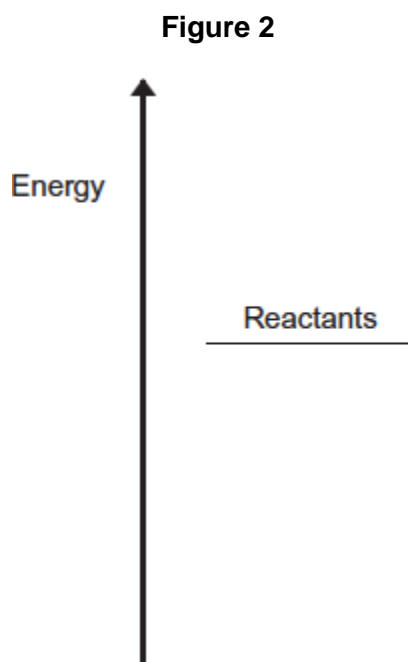
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(2)

(b) In a study of the reaction in part (a), a student referred to activation energy.

(i) State the meaning of the term *activation energy*.

_____

_____

(1)

(ii) Complete **Figure 2** by drawing the shape of the reaction profile from reactants to products for an exothermic reaction.
Show the position of the products. Show and label the activation energy.

Figure 2

Energy

Reactants

(2)

(c)   Barium metal reacts very quickly with dilute hydrochloric acid, but it reacts more slowly with water.

(i)   Write an equation for the reaction of barium with water.

_____

(1)

(ii)   A solution containing barium ions can be used to show the presence of sulfate ions in an aqueous solution of sodium sulfate.

Write the **simplest ionic** equation for the reaction that occurs and state what is observed.

Simplest ionic equation

_____

Observation

_____

(2)

(iii)   State **one** use of barium sulfate in medicine.
Explain why this use is possible, given that solutions containing barium ions are poisonous.

Use _____

_____

Explanation _____

_____

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(2)
(Total 13 marks)

5. A student carried out an experiment to determine the rate of decomposition of hydrogen peroxide into water and oxygen gas.

The student used 100 cm^3 of a 1.0 mol dm^{-3} solution of hydrogen peroxide at 298 K and measured the volume of oxygen collected.

Curve **R**, in each of **Figures 1**, **2** and **3**, shows how the total volume of oxygen collected changed with time under these conditions.

(a) Draw a curve on **Figure 1** to show how the total volume of oxygen collected will change with time if the experiment is repeated at 298 K using 100 cm^3 of a 2.0 mol dm^{-3} solution of hydrogen peroxide.
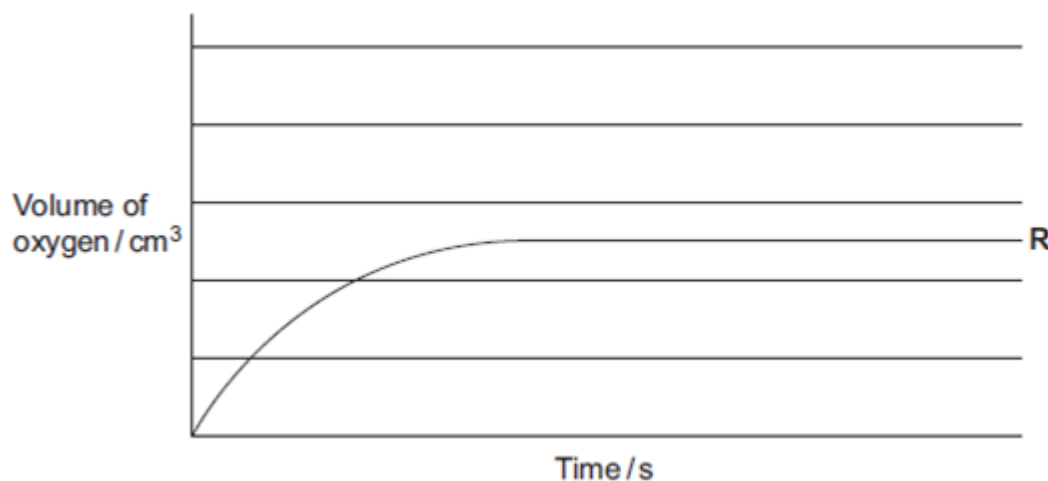
Figure 1
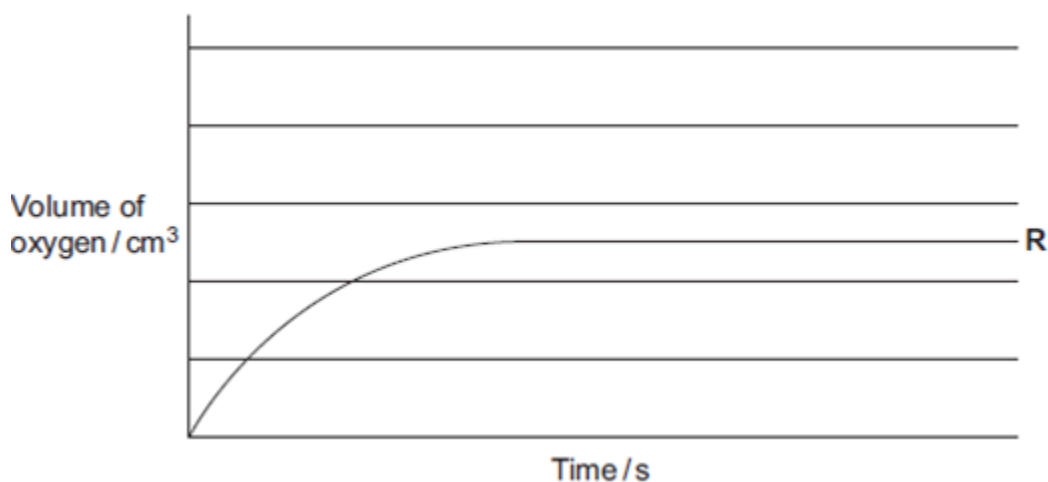
(2)

(b) Draw a curve on **Figure 2** to show how the total volume of oxygen collected will change with time if the experiment is repeated at 298 K using 100 cm^3 of a 0.4 mol dm^{-3} solution of hydrogen peroxide.
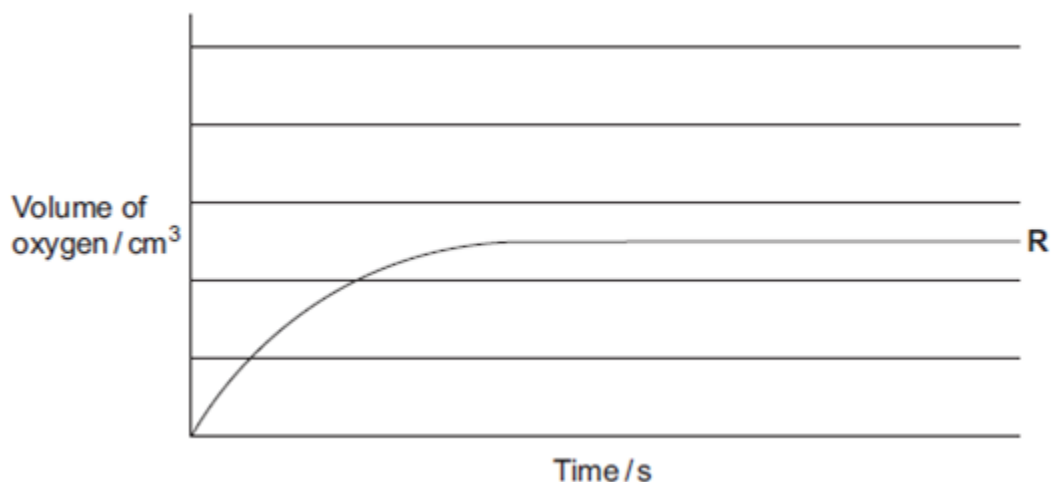
Figure 2

(2)

(c) Draw a curve on **Figure 3** to show how the total volume of oxygen collected will change with time if the **original** experiment is repeated at a temperature higher than 298 K. You should assume that the gas is collected at a temperature of 298 K.

Figure 3

Volume of oxygen / cm^3

R

Time / s

(2)

(d) Explain why the slope (gradient) of curve **R** decreases as time increases.

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(2)

(e) The student discovered that hydrogen peroxide decomposes at a faster rate when a few drops of aqueous hydrogen bromide are added to the solution.
The student found on the Internet that this decomposition is thought to proceed in two steps as shown by the following equations.

Step **1** H_2O_2 + HBr $\longrightarrow$ HBrO + H_2O

Step **2**   HBrO + H_2O_2 $\longrightarrow$ H_2O + O_2 + HBr
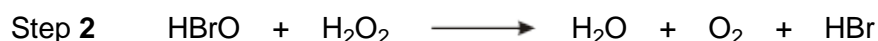
(i) Write an equation for the overall reaction.

_____

(1)

(ii)   Give **one** reason, other than the increase in rate of reaction, why the student was able to deduce that hydrogen bromide behaves as a catalyst in this two-step reaction.

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(1)
(Total 10 marks)