Q1. 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.

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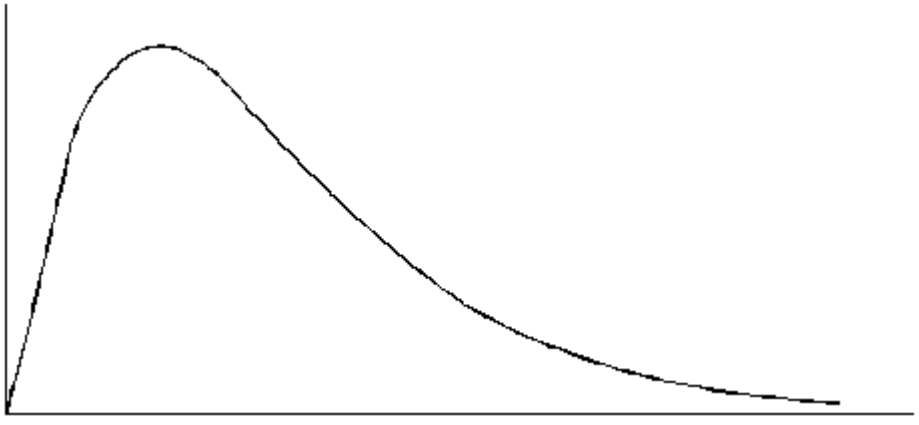
(Total 2 marks)

Q2. (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)

Q3. 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.

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.....

(1)
(Total 7 marks)

Q4. (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.

.....

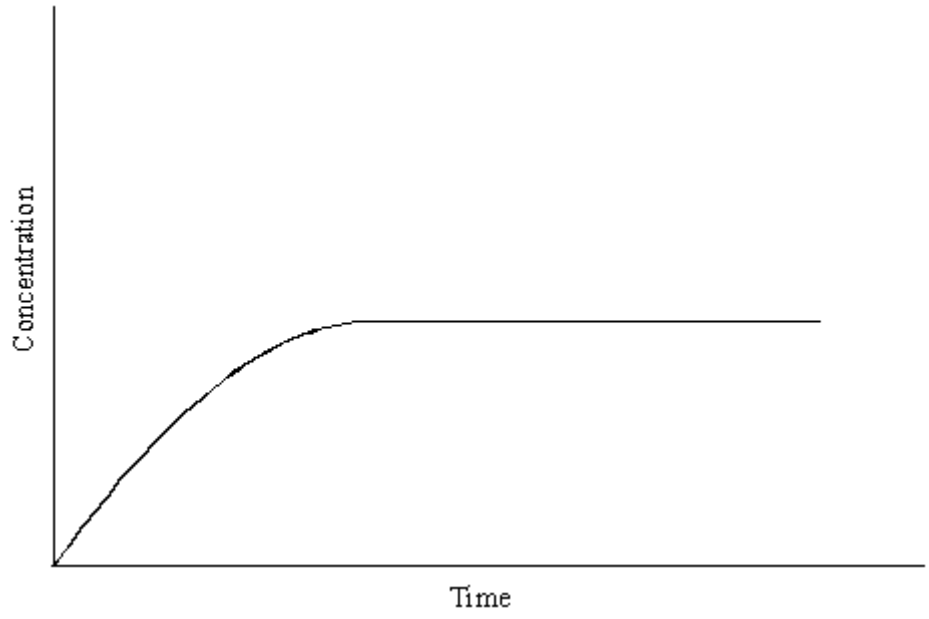
.....

(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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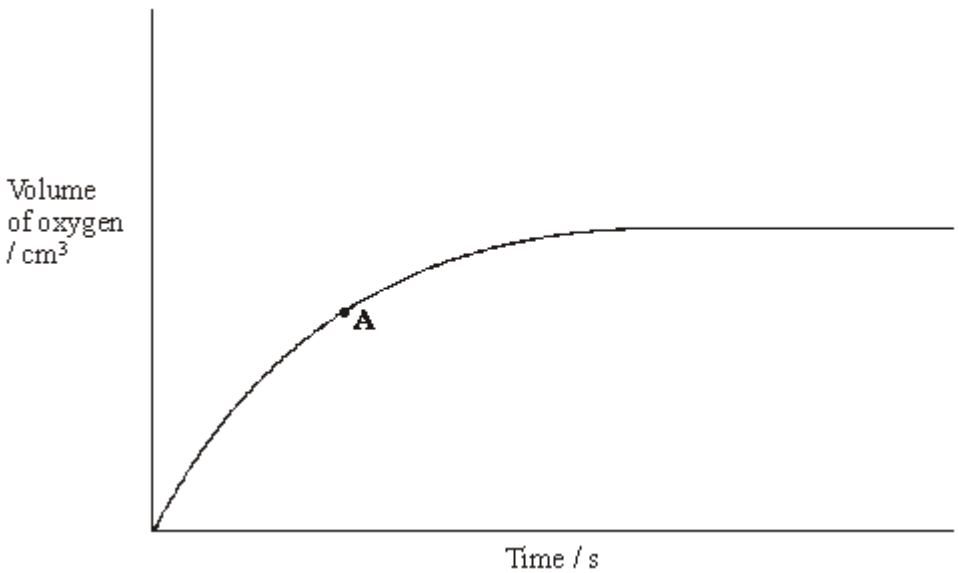
(6)
(Total 12 marks)

Q5. 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)

Q6. 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.

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(1)

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

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(2)

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

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(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.

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(1)
(Total 9 marks)