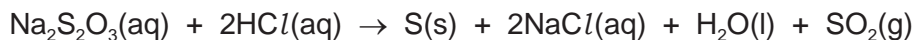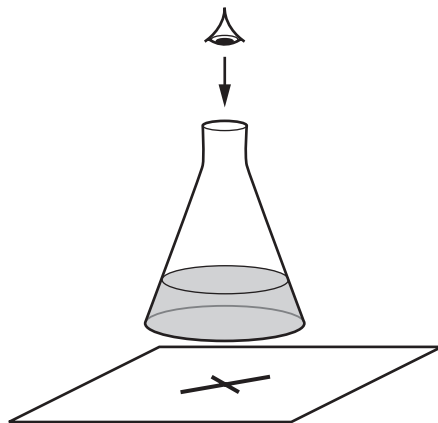**1** When aqueous sodium thiosulfate and dilute hydrochloric acid are mixed, a precipitate of insoluble sulfur is produced. This makes the mixture difficult to see through.

$$Na_2S_2O_3(aq) \ + \ 2HCl(aq) \ \rightarrow \ S(s) \ + \ 2NaCl(aq) \ + \ H_2O(l) \ + \ SO_2(g)$$

The time taken for the cross to disappear from view is measured.

A student adds the following volumes of aqueous sodium thiosulfate, dilute hydrochloric acid and distilled water to the conical flask.

The time taken for the formation of the precipitate of sulfur to make the cross disappear from view is recorded.

experiment number	volume of sodium thiosulfate /cm³	volume of hydrochloric acid /cm³	volume of distilled water /cm³	time taken for cross to disappear from view/s
1	10	10	40	56
2	20	10	30	28
3				

(a) State the order in which the aqueous sodium thiosulfate, hydrochloric acid and distilled water should be added to the flask.

....

.... [1]

(b) In experiment 3 the student wanted the sodium thiosulfate to be double the concentration used in experiment 2.

(i) Complete the table to show the **volumes** which should be used and the **expected** time taken for the cross to disappear from view in experiment 3. [2]

(ii) Use collision theory to explain why increasing the concentration of sodium thiosulfate would change the rate of reaction.

....

....

....

.... [2]
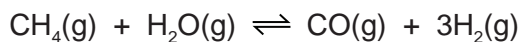
(c) The student repeated experiment 1 at a higher temperature.

Use collision theory to explain why the rate of reaction would increase.

....

....

....

.... [3]

[Total: 8]

2 Hydrogen can be manufactured from methane by steam reforming.

$$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g)$$

The reaction is carried out using a nickel catalyst at temperatures between 700 °C and 1100 °C and using a pressure of one atmosphere.

The forward reaction is endothermic.

(a) What is meant by the term *catalyst*?

....

.... [2]

(b) Suggest **two** reasons why a temperature lower than 700 °C is not used.

....

.... [2]

(c) Suggest **one** advantage of using a pressure greater than one atmosphere.

.... [1]

(d) Suggest **one** disadvantage of using a pressure greater than one atmosphere.

.... [1]

(e) Hydrogen can also be manufactured by electrolysis. The electrolyte is concentrated aqueous sodium chloride. The electrodes are inert.

The products of electrolysis are hydrogen, chlorine and sodium hydroxide.

(i) Define the term *electrolysis*.

....

.... [2]

(ii) Name a substance that can be used as the inert electrodes.

.... [1]

(iii) Write an ionic half-equation for the reaction in which hydrogen is produced.

.... [1]

(iv) Where is hydrogen produced in the electrolytic cell?

.... [1]

(v) Describe a test for chlorine.

test ....

result ....

[2]

(f) The electrolysis of concentrated aqueous sodium chloride can be represented by the following word equation.

sodium chloride + water → sodium hydroxide + hydrogen + chlorine

Construct a chemical equation to represent this reaction. Do not include state symbols.

.... [2]

(g) State one use of

chlorine, ...

sodium hydroxide, ...

hydrogen. ....

[3]

[Total: 18]

3 Hydrogen peroxide, H_2O_2, decomposes into water and oxygen in the presence of a catalyst, manganese(IV) oxide.

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

(a) What is meant by the term *catalyst*?

....

.... [2]

(b) A student studies the rate of decomposition of hydrogen peroxide using the apparatus shown. The student uses $20\,cm^3$ of $0.1\,mol/dm^3$ hydrogen peroxide and $1.0\,g$ of manganese(IV) oxide.

The student measures the volume of oxygen given off at regular time intervals until the reaction stops. A graph of the results is shown.
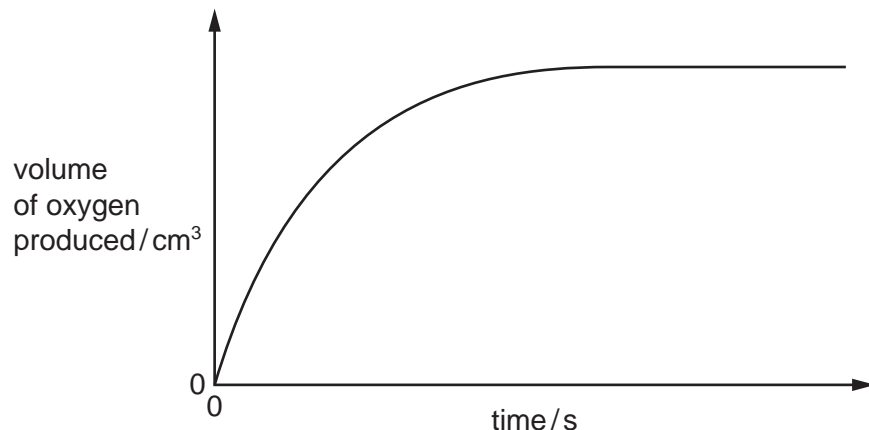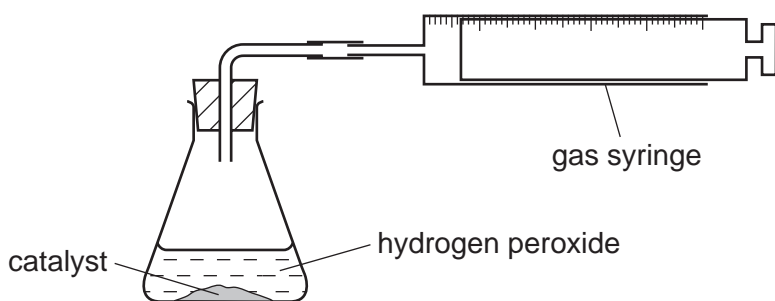
(i) When is the rate of reaction highest?

.... [1]

(ii) Suggest **one** method of increasing the rate of reaction using the same amounts of hydrogen peroxide and manganese(IV) oxide.

.... [1]

(c) (i) Calculate the number of moles of hydrogen peroxide used in this experiment.

.... mol [1]

(ii) Use your answer to **(c)(i)** and the equation to calculate the number of moles of oxygen produced in the reaction.

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

.... mol [1]

(iii) Calculate the volume (at r.t.p.) of oxygen produced.

.... dm^3 [1]

(iv) What would be the effect on the volume of oxygen produced if the mass of catalyst was increased?

.... [1]

(v) Deduce the volume of oxygen that would be produced if 20 cm^3 of 0.2 mol/dm^3 hydrogen peroxide was used instead of 20 cm^3 of 0.1 mol/dm^3 hydrogen peroxide.

.... dm^3 [1]

(d) The student carries out a second experiment to investigate whether another substance, copper(II) oxide, is a better catalyst than manganese(IV) oxide.

Describe how the second experiment is carried out. You should state clearly how you would make sure that the catalyst is the only variable.

....

....

....

....

....

.... [3]

[Total: 12]

4 **(a)** The reactions between metals and acids are redox reactions.

$$Zn + 2H^+ \rightarrow Zn^{2+} + H_2$$

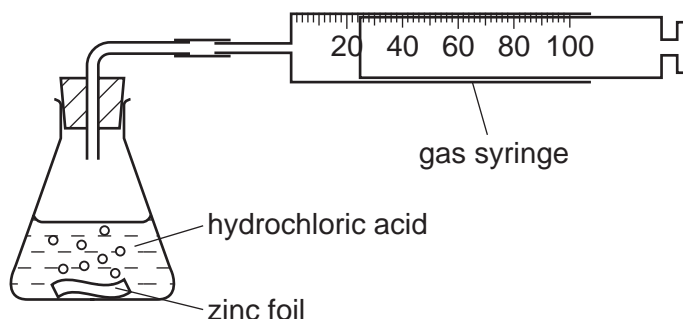**(i)** Which change in the above reaction is oxidation, Zn to Zn^{2+} or $2H^+$ to H_2? Give a reason for your choice.

...

.... [2]

(ii) Which reactant in the above reaction is the oxidising agent? Give a reason for your choice.

....

.... [2]

(b) The rate of reaction between a metal and an acid can be investigated using the apparatus shown below.

A piece of zinc foil was added to $50 \, cm^3$ of hydrochloric acid, of concentration $2.0 \, mol/dm^3$. The acid was in excess. The hydrogen evolved was collected in the gas syringe and its volume measured every minute. The results were plotted and labelled as graph 1.
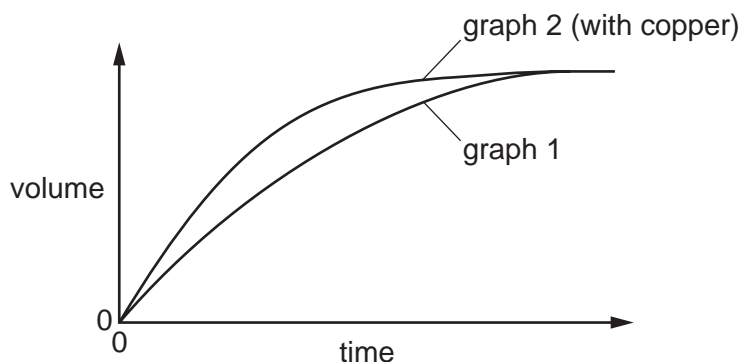
The experiment was repeated to show that the reaction between zinc metal and hydrochloric acid is catalysed by copper. A small volume of aqueous copper(II) chloride was added to the acid before the zinc was added. The results of this experiment were plotted on the same grid and labelled as graph 2.

(i) Explain why the reaction mixture in the second experiment contains copper metal. Include an equation in your explanation.

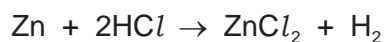...

.... [2]

(ii) Explain how graph 2 shows that copper catalyses the reaction.

....

....

.... [3]

(c) If the first experiment was repeated using ethanoic acid, CH_3COOH, instead of hydrochloric acid, how and why would the graph be different from graph 1?

....

....

....

.... [4]

(d) Calculate the maximum mass of zinc which will react with $50\,cm^3$ of hydrochloric acid, of concentration $2.0\,mol/dm^3$.
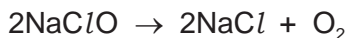
$$Zn + 2HCl \rightarrow ZnCl_2 + H_2$$

Show your working.

[3]

[Total: 16]

5 **(a)** Sodium chlorate(I) decomposes to form sodium chloride and oxygen. The rate of this reaction is very slow at room temperature provided the sodium chlorate(I) is stored in a dark bottle to prevent exposure to light.

$$2NaClO \rightarrow 2NaCl + O_2$$

The rate of this decomposition can be studied using the following experiment.

oxygen collects
in syringe

sodium chlorate(I) solution
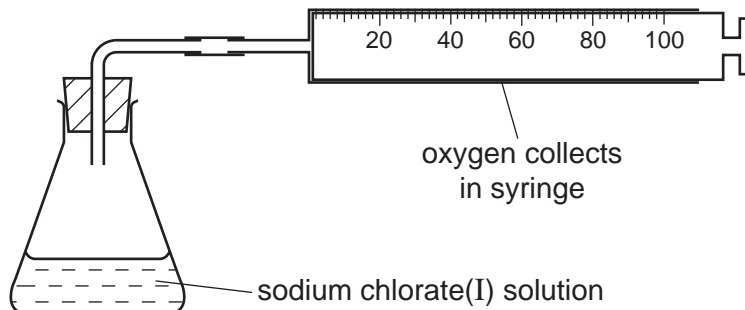
Sodium chlorate(I) is placed in the flask and 0.2 g of copper(II) oxide is added. This catalyses the decomposition of the sodium chlorate(I) and the volume of oxygen collected is measured every minute. The results are plotted to give a graph of the type shown below.
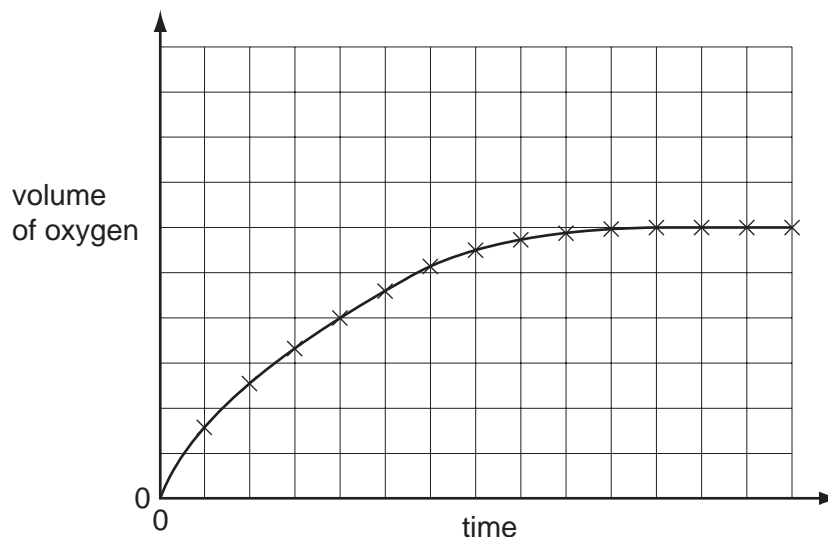
(i) Explain why the gradient (slope) of this graph decreases with time.

....

.... [2]

(ii) Cobalt(II) oxide is a more efficient catalyst for this reaction than copper(II) oxide.
Sketch, on the grid, the graph for the reaction catalysed by cobalt(II) oxide.
All other conditions were kept constant. [2]

(iii) What can you deduce from the comment that sodium chlorate(I) has to be shielded from light?

....

.... [1]

(iv) Explain, in terms of collisions between particles, why the initial gradient would be steeper if the experiment was repeated at a higher temperature.
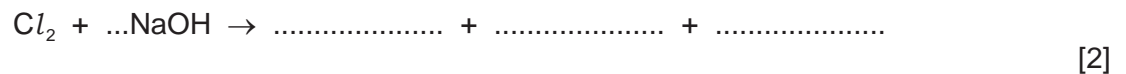
....

....

....

.... [3]

(b) The ions present in aqueous sodium chloride are Na⁺(aq), Cl^-(aq), H⁺(aq) and OH⁻(aq).

The electrolysis of concentrated aqueous sodium chloride forms three products. They are hydrogen, chlorine and sodium hydroxide.

(i) Explain how these **three** products are formed. Give ionic equations for the reactions at the electrodes.

....

....

....

....

.... [4]

(ii) If the solution of the electrolyte is stirred, chlorine reacts with sodium hydroxide to form sodium chlorate(I), sodium chloride and water.
Write an equation for this reaction.

Cl_2 + ...NaOH → .... + ... + ...

[2]

[Total: 14]