1 The electrolysis of concentrated aqueous sodium chloride, between inert electrodes, is used to make four important chemicals.

hydrogen
chlorine
sodium hydroxide
sodium chlorate(I)

(a) The ions present in the electrolyte are Na^+, H^+, Cl^- and OH^-.

(i) Hydrogen ions are discharged at the negative electrode (cathode).
Write an equation for this reaction.

..... [2]

(ii) The hydrogen ions are from the water.

$$H_2O \rightleftharpoons H^+ + OH^-$$

Suggest an explanation why the concentration of hydroxide ions increases.

.....

..... [2]

(iii) When a dilute solution of sodium chloride is used, chlorine is not formed at the positive electrode (anode), a different gas is produced. Name this gas.

..... [1]

(iv) State an example of an inert electrode.

..... [1]

(b) State a use of hydrogen.

..... [1]

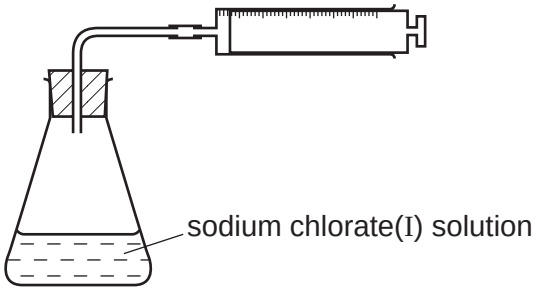
(ii) Why is chlorine used to treat the water supply?

..... [1]

(c) Sodium chlorate(I) is made by the reaction between chlorine and sodium hydroxide. It is used as bleach but over time it decomposes.

$$2NaClO(aq) \rightarrow 2NaCl(aq) + O_2(g)$$

The rate of decomposition can be studied using the apparatus shown below.



(i) How could you measure the rate of decomposition of sodium chlorate(I)?

..... [1]

(ii) Describe how you could show that the rate of decomposition of sodium chlorate(I) is a photochemical reaction.

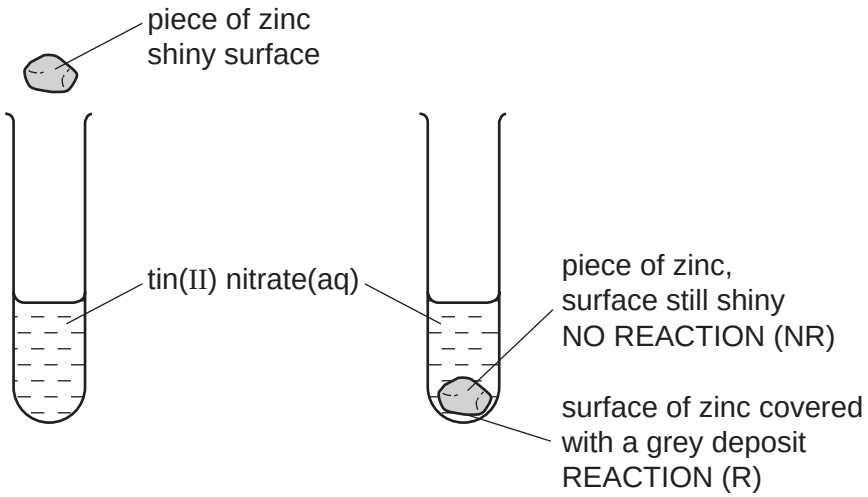
.....

..... [2]

[Total: 11]

2 The reactivity series lists metals in order of reactivity.

(a) To find out which is the more reactive metal, zinc or tin, the following experiment could be carried out.



This experiment could be carried out with other metals and the results recorded in a table. Then the order of reactivity can be deduced.

(i) The order was found to be:

manganese	most reactive
zinc	
tin	
silver	least reactive

Complete the table of results from which this order was determined.

aqueous solution	**tin Sn**	**manganese Mn**	**silver Ag**	**zinc Zn**
tin(II) nitrate		R	NR	R
manganese(II) nitrate				
silver(I) nitrate				
zinc nitrate				

[3]

(ii) Write the ionic equation for the reaction between tin atoms and silver(I) ions.

.....

[2]

(iii) The following is a redox reaction.

$$Mn + Sn^{2+} \longrightarrow Mn^{2+} + Sn$$

Indicate on the equation the change which is oxidation.
Give a reason for your choice.

..... [2]

(iv) Explain why experiments of this type cannot be used to find the position of aluminium in the reactivity series.

.....

..... [2]

(b) Potassium and calcium are very reactive metals at the top of the series. Because their ions have different charges, K^+ and Ca^{2+}, their compounds behave differently when heated.

(i) Explain why the ions have different charges.

.....

..... [2]

(ii) Their hydroxides are heated.
If the compound decomposes, complete the word equation.
If it does not decompose, write "no reaction".

Potassium hydroxide ⟶ .....

Calcium hydroxide ⟶ ..... [2]

(iii) Complete the equations for the decomposition of their nitrates.

$2KNO_3 \longrightarrow$ ..... + ...

$2Ca(NO_3)_2 \longrightarrow$ ..... + ... + ... [4]

[Total: 17]

3 An organic compound decomposes to form nitrogen.

$C_6H_5N_2Cl(aq) \rightarrow C_6H_5Cl(l) + {}_2(g)$

(a) Explain the state symbols.

aq .....

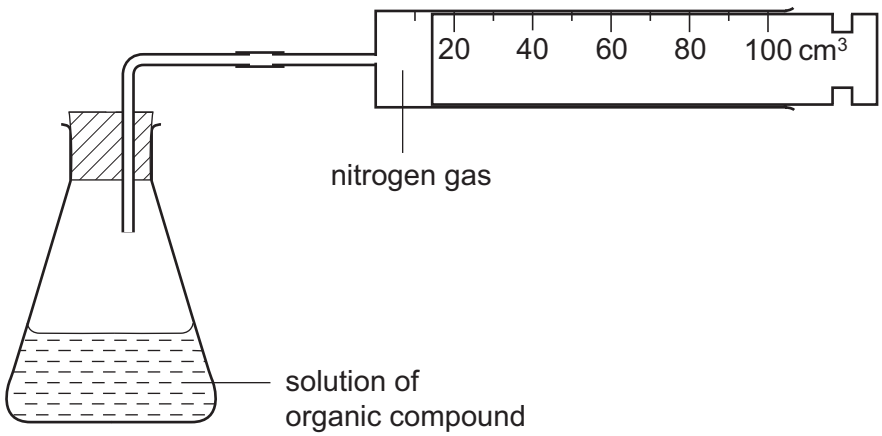
l .....

g ..... [2]

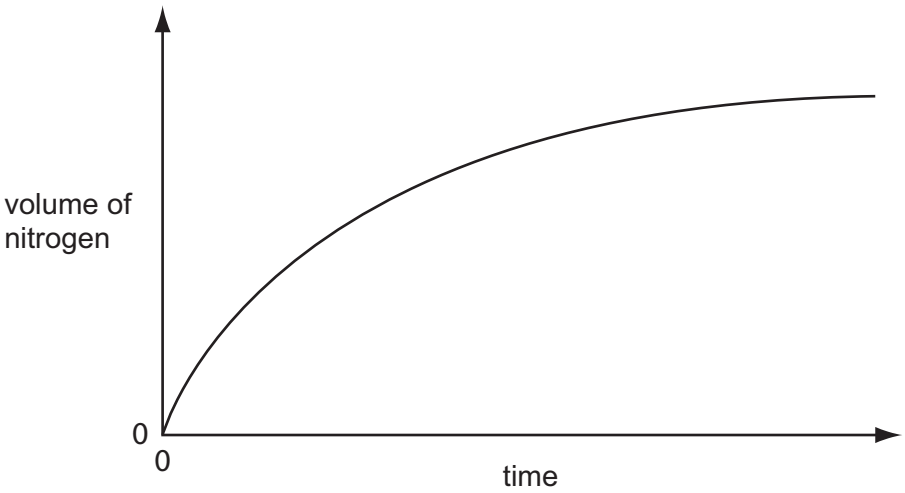
(b) Draw a diagram to show the arrangement of the valency electrons in **one** molecule of nitrogen.

[2]

(c) The rate of this reaction can be measured using the following apparatus.



The results of this experiment are shown on the graph below.



(i) How does the rate of this reaction vary with time?

.....

..... [1]

(ii) Why does the rate vary?

.....

..... [2]

(iii) The reaction is catalysed by copper powder. Sketch the graph for the catalysed reaction on the same grid. [2]

(iv) Why is copper powder more effective as a catalyst than a single piece of copper?

..... [1]

4 Manganese is a transition element. It has more than one valency and the metal and its compounds are catalysts.

(a) **(i)** Predict **three** other properties of manganese that are typical of transition elements.

.....

.....[3]

(ii) Complete the electron distribution of manganese by inserting one number.

2 + 8 + ... + 2 [1]

(b) It has several oxides, three of which are shown below.
Manganese(II) oxide, which is basic.
Manganese(III) oxide, which is amphoteric.
Manganese(IV) oxide, which is acidic.

(i) Complete the word equation.

manganese(II) oxide + hydrochloric acid → ..... + ... + ...
[2]

(ii) Which, if any, of these oxides will react with sodium hydroxide?

.....[1]

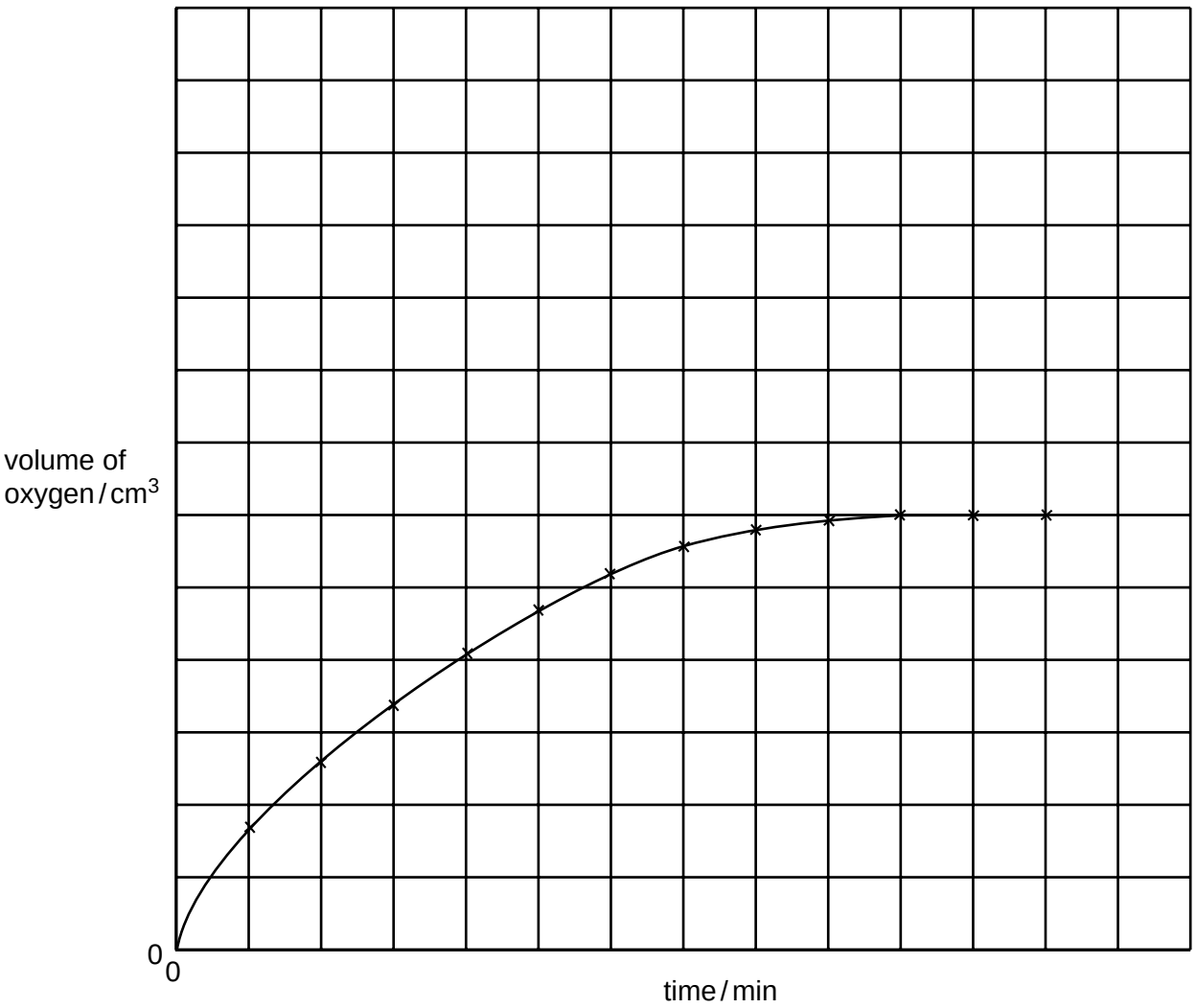
(c) Aqueous hydrogen peroxide decomposes to form water and oxygen.

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

This reaction is catalysed by manganese(IV) oxide

The following experiments were carried out to investigate the rate of this reaction.

A 0.1 g sample of manganese(IV) oxide was added to 20 cm^3 of 0.2 M hydrogen peroxide solution. The volume of oxygen produced was measured every minute. The results of this experiment are shown on the graph.



(i) How does the rate of reaction vary with time? Explain why the rate varies.

.....

.....[3]

(ii) The following experiment was carried out at the same temperature.

0.1 g of manganese(IV) oxide and 20 cm^3 of 0.4 M hydrogen peroxide

Sketch the curve for this experiment on the same grid. [2]

(iii) How would the shape of the graph differ if only half the mass of catalyst had been used in these experiments?

.....

.....

.....[2]