For Examiner's Use

Section A

Answer **all** questions in this section in the spaces provided.
The total mark for this section is 50.

A1 The diagram shows part of the Periodic Table.

					He
B	C	N	O	F	Ne
Al	Si	P	S	Cl	Ar
Ga	Ge	As	Se	Br	Kr
				I	Xe

Answer the questions using only the elements shown in the diagram.
Each element may be used once, more than once or not at all.

Write the symbol for an element which:

(a) **(i)** forms an ion of type X^{2-},

……. [1]

(ii) is a diatomic green gas at room temperature,

……. [1]

(iii) is a gas used for weather balloons,

……. [1]

(iv) is a gas which occupies 78% by volume of dry air,

……. [1]

(v) can have lubricating properties.

……. [1]

(b) Modern chemists have discovered that some noble gases can form compounds.

A 1.000 g sample of one such compound is found to contains 0.549 g of xenon, 0.134 g of oxygen and 0.317 g of fluorine.

(i) Calculate the empirical formula of this compound.

[2]

(ii) What additional information is needed to deduce the molecular formula of this compound?

……. [1]

(c) Draw a 'dot-and-cross' diagram to show the bonding in a molecule of oxygen. Show the outer electrons only.

[2]

(d) Aluminium and sulfur can react with oxygen to form oxides.

Suggest one **difference** in physical property and one **difference** in chemical property between the **oxide of aluminium** and the **oxide of sulfur**.

physical property

……..….

……..…. [1]

chemical property

……..….

……..…. [1]

[Total: 12]

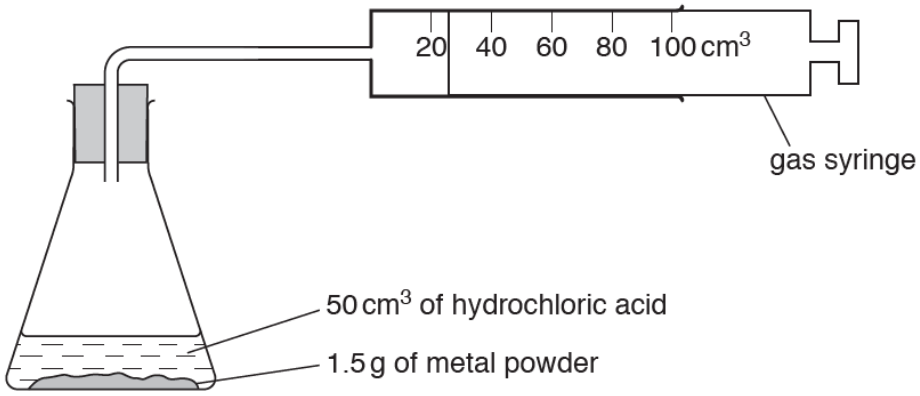
For Examiner's Use

A2 **(a)** A student investigated the reaction between different metals and hydrochloric acid.

He reacted 1.5 g of iron and 1.5 g of zinc separately with excess hydrochloric acid.

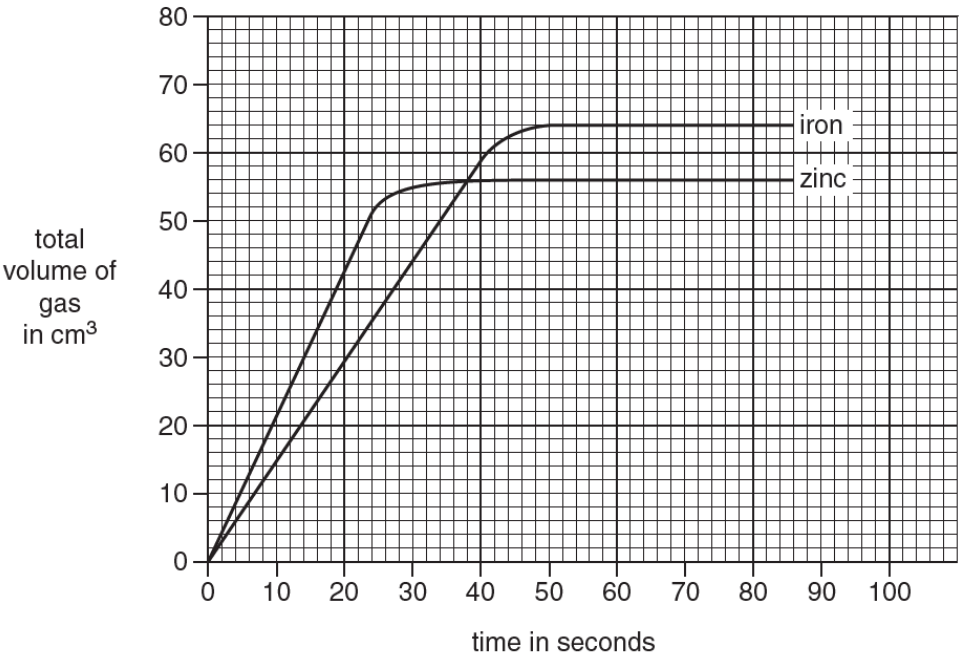
$$Fe(s) + 2HCl(aq) \rightarrow FeCl_2(aq) + H_2(g)$$

$$Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$$



Every 10 seconds, he measured the volume of gas in a gas syringe.

The graph shows the results.



(i) Explain why 1.5 g of iron produces more hydrogen gas than 1.5 g of zinc.

……

……

…… [2]

(ii) Explain how you can tell from the graph which is the more reactive metal.

…… [1]

(iii) When the reaction stops, the student adds aqueous sodium hydroxide drop by drop to the solution in the conical flask until it is in excess.

Describe what you would observe during the addition of aqueous sodium hydroxide for each experiment.

experiment with iron:

……

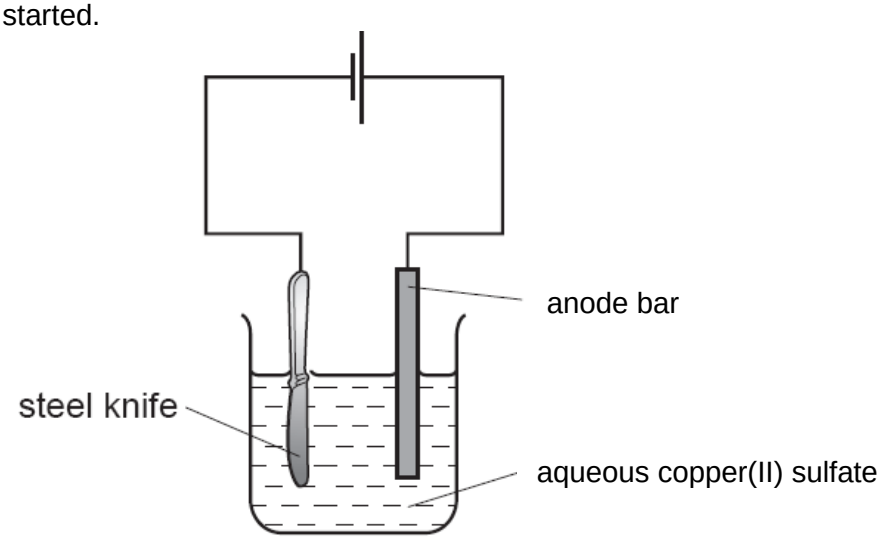
……

experiment with zinc:

……

…… [3]

(b) Another student used the apparatus below to coat a thin layer of copper on a steel knife. The knife was cleaned carefully and all grease removed before the process started.



(i) The steel blade of the knife acts as a cathode.
Copper(II) ions from the solution form copper on the blade surface.
Write an equation, with state symbols, for this reaction.

…… [2]

(ii) What will happen to the concentration of the copper(II) in the solution during electrolysis if the anode bar is made of carbon?

…… [1]

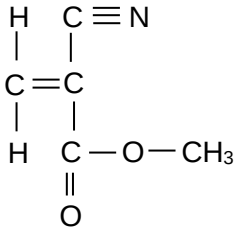
(iii) What will happen to the concentration of the copper(II) ions in the solution during electrolysis if the anode bar is made of copper?

…… [1]

[Total: 10]

For Examiner's Use

A3 (a) 'Superglue' contains the following monomer.



The monomer is rapidly polymerised by traces of bases on the surfaces of objects to be stuck together, causing the glue to set solid.

(i) What type of polymerisation takes place when the glue is in use?

……. [1]

(ii) Draw a repeat unit of the polymerised form of the glue.

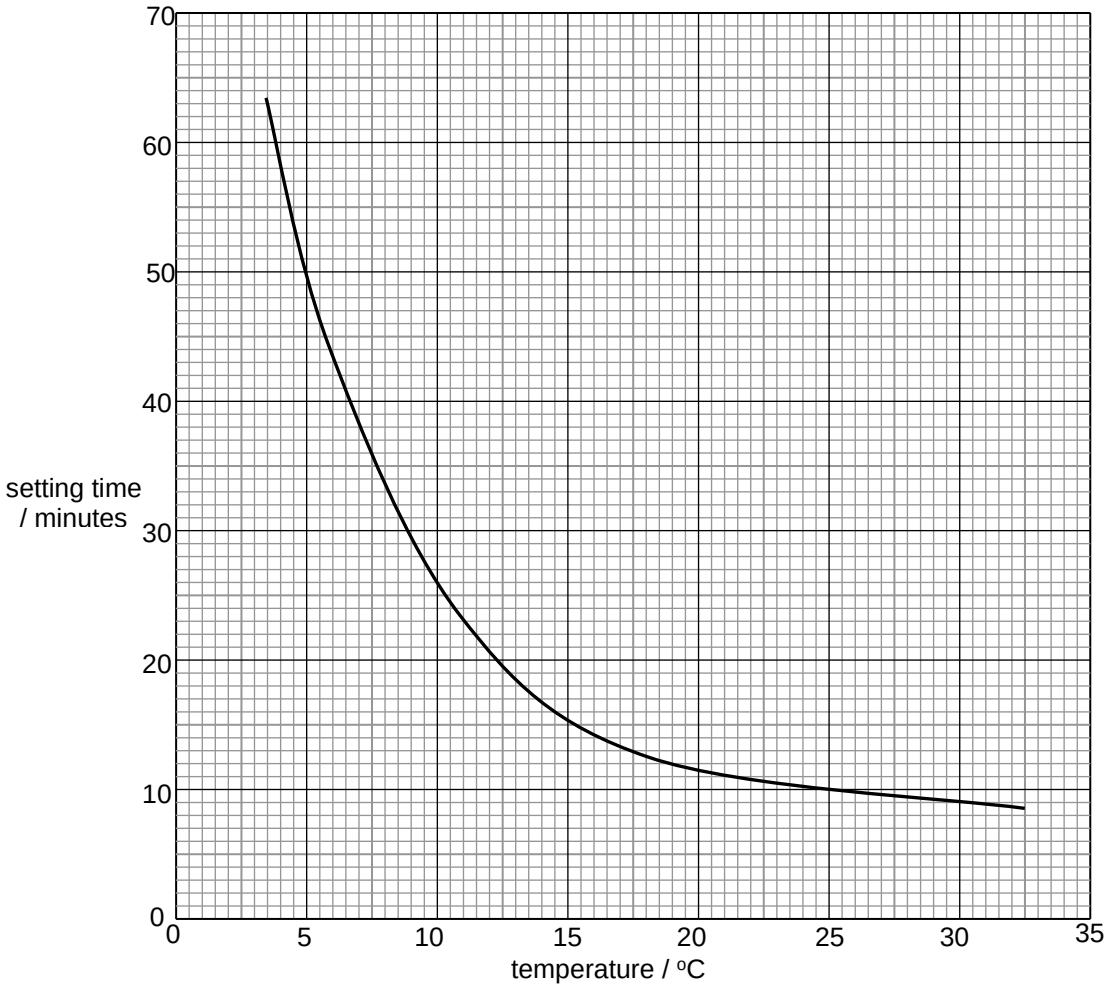
[1]

(iii) Show by calculations that the polymer contains more than 50% by mass of carbon.

[2]

For Examiner's Use

(b) An experiment is carried out to find out how changing the temperature changes the time taken for the glue to harden (the setting time). The graph below shows the results of the experiment.



(i) At what temperature does the glue take 10 minutes to set?

……. [1]

(ii) Describe how the setting time changes as the temperature increases. Explain your answer in terms of particles.

……

……

……

……

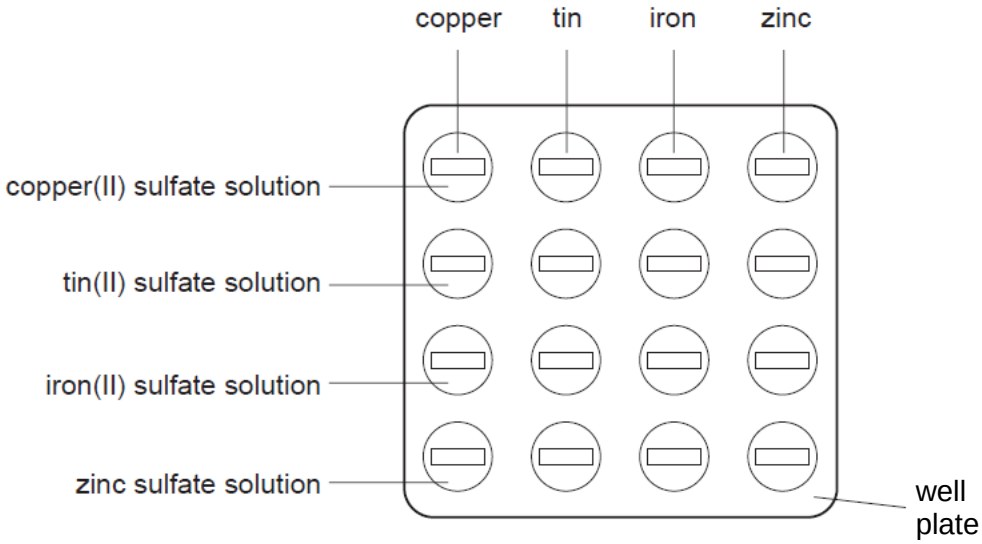
……. [3]

(iii) The experiment is repeated using glue containing a higher monomer concentration. Draw a curve on the graph to show the results you would expect. Label the curve '**higher concentration'**. [1]

[Total: 9]

For Examiner's Use

A4 **(a)** A student was given tin, iron, copper and zinc and solutions of the metal sulfates. Using a dropper, she put a little of one of the sulfate solutions in four of the depressions of a well plate. She did this for each solution in turn. She then put a piece of metal foil in each of the solutions, as shown below.



(i) Put a tick (✓) next to the question which **best** describes the investigation the student is carrying out.

Which displacement is the most exothermic?	☐
Which metal can displace copper from solution?	☐
What is meant by the reactivity series?	☐
What are the positions of the four metals in the reactivity series?	☐

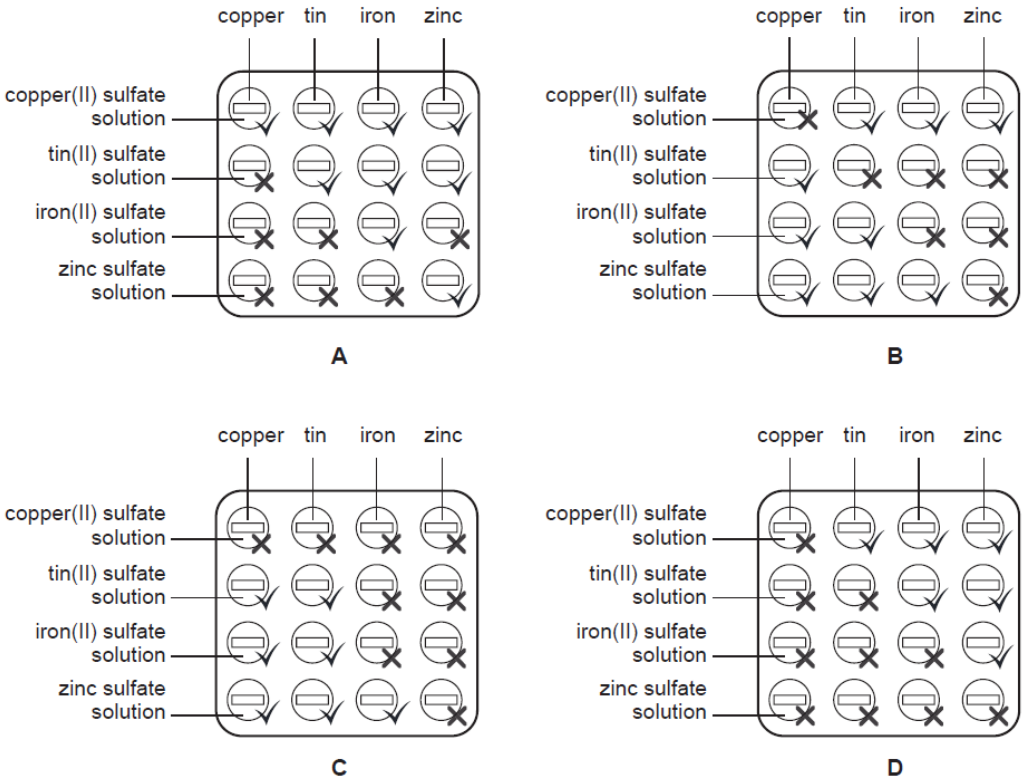
[1]

(ii) The student recorded the results by putting a tick (✓) next to a mixture which showed signs of a reaction and a cross (X) next to a mixture which showed no signs of a reaction.

The student concluded that:
tin displaces copper
iron displaces tin
iron displaces copper
zinc displaces iron

Give the **letter** of the plate below which shows her results.

…….. [1]



(iii) Write an ionic equation for any of the reactions.

[1]

(iv) Another student said that not all of the tests carried out were necessary. Give one example of a test **not** needed. Explain your choice.

example …….

explanation …… [2]

(b) When a mixture of iron(III) oxide and aluminium powder (Thermit mixture) is heated, there is a violent reaction. The reaction is carried out in a tube surrounded by a mound of sand because the temperature reaches 2500 °C. A bead of iron is recovered from the sand. The picture below shows the reaction taking place in a darkened room.

$$Fe_2O_3(s) + Al(s) \rightarrow 2Fe(l) + Al_2O_3(s)$$

(i) Give a reason why the iron formed in the reaction is molten.

……. [1]

(ii) Calculate the maximum mass of molten iron that can be formed from 1 kg of iron(III) oxide.

[2]

(iii) Explain in terms of electron transfer, why aluminium is the reducing agent in this reaction.

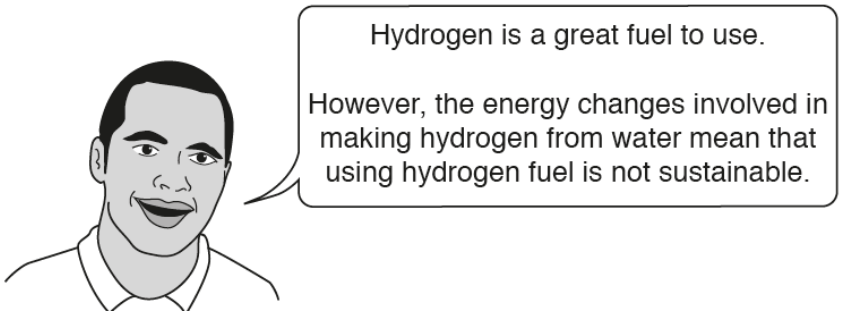
…….

……. [1]

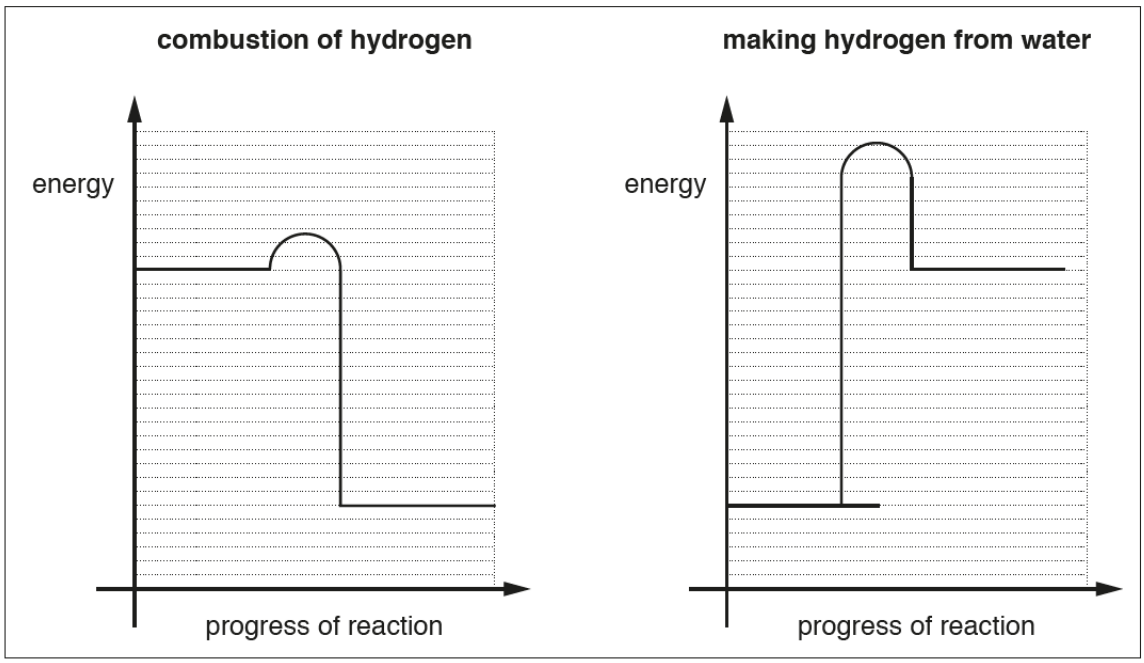
[Total: 9]

For Examiner's Use

A5 **(a)** A scientist gives a talk about making hydrogen from water by electrolysis to use as a fuel.



He uses a slide showing these energy level diagrams to support his points.



(i) Label the **formulae** of the reactants and products for **both** processes in the diagrams. [2]

(ii) Using single-headed arrows, label the activation energy for **both** processes in the diagrams. [1]

(iii) Using the energy changes shown on both diagrams, give **two** reasons to explain **each** of the following:

Hydrogen is a '**great fuel to use**' but using it as a fuel is **not sustainable if it is made from water**.

……

……

……

……

…… [4]

(b) Ethanol is used as a car fuel.

$C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$

The complete combustion of one mole of ethanol releases 1350 kJ of energy.

A sample of ethanol reacts with excess oxygen to make 0.240 dm^3 of carbon dioxide, measured at room temperature and pressure.

Calculate the energy released, in kJ, in this reaction.

[3]

[Total: 10]

For Examiner's Use

Section B

Answer all **three** questions from this section.
The last question is in the form of an either/or and only one of the alternatives should be attempted.

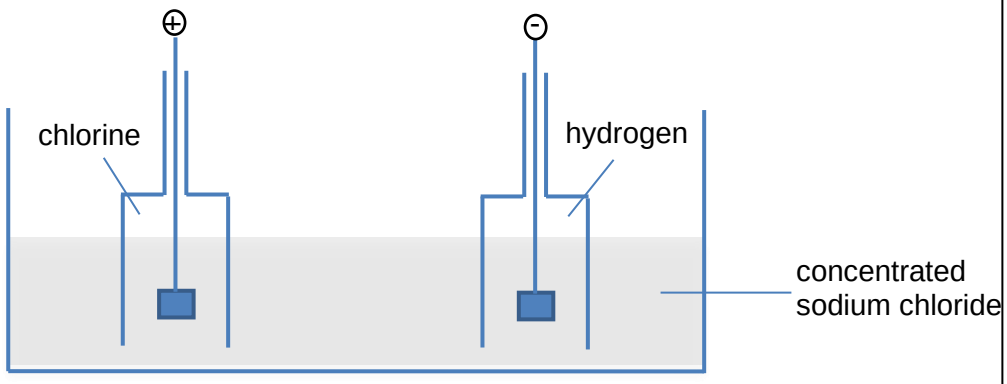
B6 The chlor-alkali industry

The chlor-alkali is the industry that produces **chlor**ine (Cl_2) and sodium hydroxide (NaOH), an **alkali**, by the electrolysis of concentrated sodium chloride solution. The annual production of both chemicals is measured in millions of tonnes, making the chlor-alkali industry one of the largest electrochemical industries in the world.

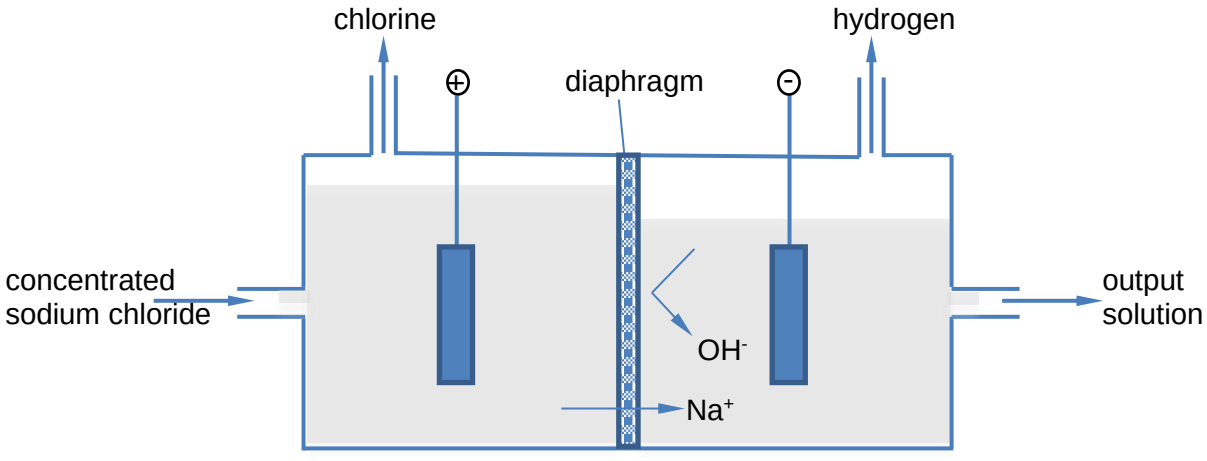
Chlorine is known for its use in sterilising drinking water and in particular swimming pool water. Chlorine is also widely used in the manufacture of plastics. Sodium hydroxide is used extensively in the making of soap, detergents, paper and textiles.

Sodium chloride is commonly found in rock salt which occurs naturally in plentiful supplies. In the electrolysis of concentrated sodium chloride solution, three products (H_2, Cl_2 and NaOH) are produced. It is important that the products are not allowed to mix, to avoid unwanted side reactions. For example, hydrogen and chlorine react vigorously, forming hydrogen chloride if in contact.

Electrolysis of concentrated sodium chloride using a 'one-pot' cell
The main difficulty during the electrolysis of concentrated sodium chloride in a simple vessel (known as a 'one-pot' vessel) is that of achieving continuous separation of chlorine generated at the anode and sodium hydroxide produced in the vessel. While it is easy to keep the chlorine and hydrogen gases in separate tubes, the sodium hydroxide formed during electrolysis reacts with chlorine to form sodium hypochlorite (NaC*l*O).



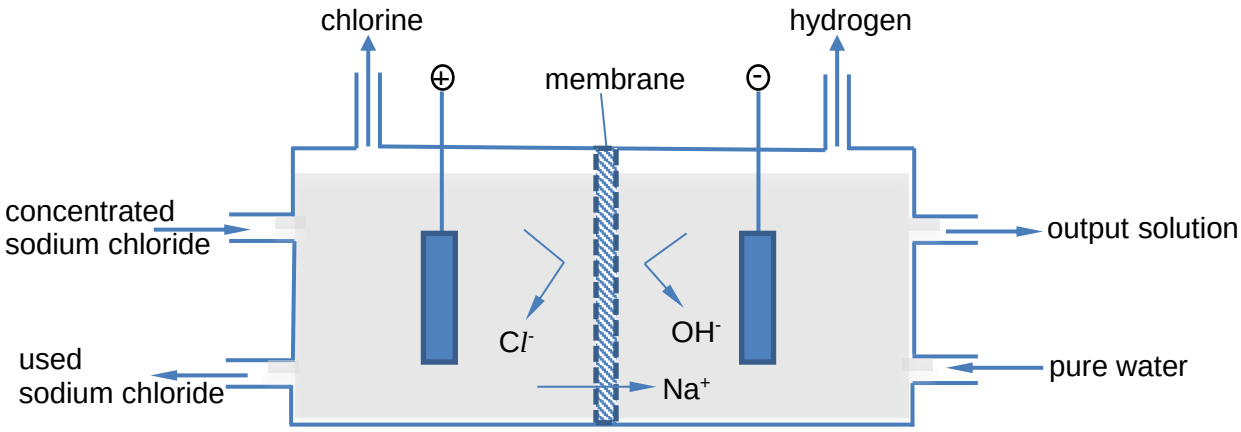
Electrolysis of concentrated sodium chloride using a diaphragm cell
The British scientist Charles Watt devised the concept of a separator (called a diaphragm) to keep all the products separate, and the diaphragm cell was invented in 1851.



The diaphragm is a barrier between the anode and cathode compartments intended to keep the chlorine and hydrogen gases separate. The diaphragm cell is designed such that while all ions can pass through the diaphragm from the anode to the cathode compartments, the hydroxide ions are prevented from flowing back to the anode compartment. In this way, the reaction between sodium hydroxide and chlorine is minimised. But some chloride ions may move across the diaphragm, resulting in a mixture of sodium hydroxide and sodium chloride being produced in the output solution. The concentration of sodium hydroxide in this solution is typically 12 g/dm^3. To obtain sodium hydroxide of a high concentration, water needs to be evaporated from this solution until the concentration is about 50 g/dm^3 sodium hydroxide. At this stage, most of the sodium chloride has crystallised so it can be removed by filtration, and the solution of nearly pure sodium hydroxide can be sold or evaporated to dryness to produce solid sodium hydroxide. The product still contains about 1 to 2% sodium chloride.

Electrolysis of concentrated sodium chloride using a membrane cell

A modern alternative to the diaphragm cell is the membrane cell, which was developed in the 1970s.



The membrane is an improved separator, which allows sodium ions to move through freely but not anions (chloride and hydroxide ions) or water molecules. This increases the purity of the output solution of sodium hydroxide produced in comparison with the diaphragm cell. The disadvantage of the membrane cell is that the sodium chloride solution entering the cell must be of a high purity, which requires purification steps prior to electrolysis. The sodium chloride solution often contains impurity ions such as SO_4^{2-} and Mg^{2+} which need to be removed before it is being fed into the membrane cell.

In all three cells, the equation for the overall main reaction taking place is

$$2NaCl(aq) + 2H_2O(l) \rightarrow H_2(g) + Cl_2(g) + 2NaOH(aq),$$

and the theoretical mass ratio of the output of sodium hydroxide to chlorine is 1.13.

(a) Construct an equation for the reaction at the **cathode** in all the three cells.

…….. [1]

(b) What is the disadvantage of carrying out electrolysis of concentrated sodium chloride solution in a 'one-pot' cell?

……

…… [1]

For Examiner's Use

(c) In a diaphragm cell, the output solution contains typically 12 g/dm^3 of sodium hydroxide. Show that 760 dm^3 of water needs to be evaporated from every 1000 dm^3 of the output solution to increase the concentration of the sodium hydroxide to 50 g/dm^3.

[3]

(d) A student comments that sodium hydroxide solution from the membrane cell would not be contaminated with sodium chloride. Explain why the student is correct.

……..….

……..…. [1]

(e) The sodium chloride solution entering the membrane cell often contains impurity ions such as SO_4^{2-} and Mg^{2+}. These ions can be removed by precipitation. Suggest **two** reagents and a separation method to remove the SO_4^{2-} and Mg^{2+} ions from the solution by precipitation.

reagents: ……..……..

……..….

separation method:……..…….. [3]

(f) Using the equation for the overall main reaction in all three cells, show by calculations that 1.13 kg of sodium hydroxide is made for every kg of chlorine obtained.

[2]

(g) Write an **ionic** equation for the overall main reaction in all three cells.

[1]

[Total: 12]

For Examiner's Use

B7 There are three types of giant structure - ionic, metallic and covalent.

(a) In an ionic compound, the ions are held in a lattice by strong forces.

Explain how the ions are held together by strong forces.

……

…… [1]

(b) Describe the bonding in a typical metal.

……

……

……

……

…… [2]

(c) The general electrical conductivities of the three types of giant structure are shown in the following table.

type of structure	conductivity of solid	conductivity of liquid
giant ionic	poor	good
giant metallic	good	good
giant covalent	poor	poor

Explain the differences in the general electrical conductivity between the three types of giant structure and the difference, if any, between the solid and liquid states of the same structure.

……

……

……

……

……

……

……

……

……

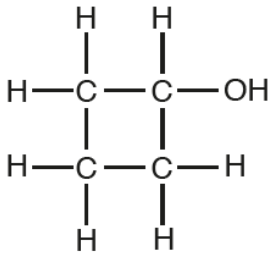
…… [5]

[Total: 8]

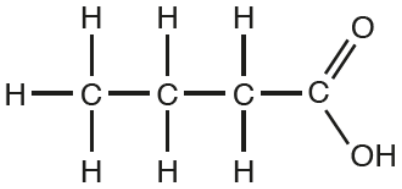
For Examiner's Use

EITHER

B8 **(a)** The structures of cyclobutanol and butanoic acid are shown.



cyclobutanol



butanoic acid

(i) Explain why cyclobutanol and butanoic acid are **not** isomers.

……

…… [1]

(ii) Describe a chemical test that can distinguish cyclobutanol from butanoic acid.

test ……..

……

observations ……..

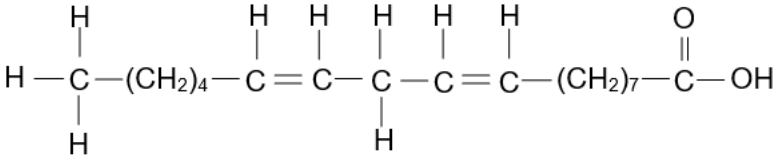
……

……

…… [2]

For Examiner's Use

(b) Linoleic acid is a fatty acid used in cosmetic and personal care products.



linoleic acid

Iodine reacts with C=C bonds in an addition reaction, just like bromine.

The iodine value is a measure of how unsaturated a compound is.

The iodine value of a compound is the number of grams of iodine which react with 100 g of the compound.

Given that the molecular formula of linoleic acid is $C_{18}H_{32}O_2$, show by calculations that the iodine value of linoleic acid is 181.

[3]

(c) When linoleic acid is **fully** hydrogenated in an addition reaction with hydrogen, stearic acid is formed.

(i) Determine the molecular formula of stearic acid and suggest its iodine value.

molecular formula ……

iodine value …….. [2]

(ii) Describe how aqueous bromine can distinguish linoleic acid from stearic acid.

observations with linoleic acid ……..……..

…….

observations with stearic acid ……

……. [2]

[Total: 10]

OR

B8 Hydrogen reacts with halogens to form hydrogen halides.

(a) The table gives some data on bond energies.

bond	bond energy in kJ/mol
H – H	436
F – F	158
H – F	562

Use the above data to predict if the following reaction is exothermic or endothermic.

$$H - H + F - F \rightarrow 2H - F$$

……

……

……

……

……

…… [3]

(b) HF and HI dissolve in water to form acidic solutions.

$$HF \rightleftharpoons H^+ + F^-$$
$$HI \rightleftharpoons H^+ + I^-$$

Only 1% of the hydrogen iodide exists as molecules, the rest forms ions.
97% of the hydrogen fluoride exists as molecules, only 3% forms ions.

What does this tell you about the strength of **each** acid?

……

…… [1]

(c) **(i)** Describe how you could distinguish between hydriodic, HI(aq), and hydrofluoric, HF(aq) acids, by bubbling chlorine through these two acids.

observations with hydriodic acid ……..

…….

observations with hydrofluoric acid ……..

…… [2]

For Examiner's Use

(ii) Describe how you could distinguish between hydriodic, HI(aq), and hydrochloric, HC*l*(aq) acids, by adding aqueous silver nitrate to these two acids.

observations with hydriodic acid ……

……

observations with hydrochloric acid ……..

……. [2]

(d) Use oxidation states to explain whether lithium is oxidised, reduced or neither when it reacts with hydriodic acid.

$$2Li + 2HI \rightarrow 2LiI + H_2$$

……..….

……..…. [2]

[Total: 10]

**********End of Paper**********