

ELECTROLYSING BRINE

1 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]

MARKING SCHEME:

(i)	M1 breakdown of an ionic compound when molten or in aqueous solution; M2 (using) electricity/electric current/electrical energy;	1 1	2
(ii)	carbon/graphite/platinum;		1
(iii)	$2\text{H}^+ + 2\text{e}^- \rightarrow \text{H}_2$; OR $2\text{H}_3\text{O}^+ + 2\text{e}^- \rightarrow \text{H}_2 + 2\text{H}_2\text{O}$;		1
(iv)	cathode/negative electrode;		1

2 (a) 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]

(b) State one use of

chlorine,

sodium hydroxide,

hydrogen.

[3]

MARKING SCHEME:

(a)	$2\text{NaCl} + 2\text{H}_2\text{O} \rightarrow 2\text{NaOH} + \text{H}_2 + \text{Cl}_2$ all formulae correct; balancing;	2
(b)	<p>M1 chlorine: treating (drinking) water/treating water in swimming pools/kill bacteria in water/chlorination of water/ (manufacture of) paper products/plastics/PVC/dyes/textiles/medicines/antiseptics/insecticides/herbicides/ fungicides/solvents/paints/disinfectant/bleach/hydrochloric acid;</p> <p>M2 sodium hydroxide: drain cleaner/oven cleaner/extraction of aluminium/purification of bauxite/(manufacture of) biodiesel/paper/ soap/detergents/washing powder/textiles/dyes;</p> <p>M3 hydrogen: fuel/rocket fuel/fuel cells/in welding/(manufacture of) ammonia/NH_3/margarine/methanol/hydrochloric acid/ refrigerants;</p>	3 1 1 1

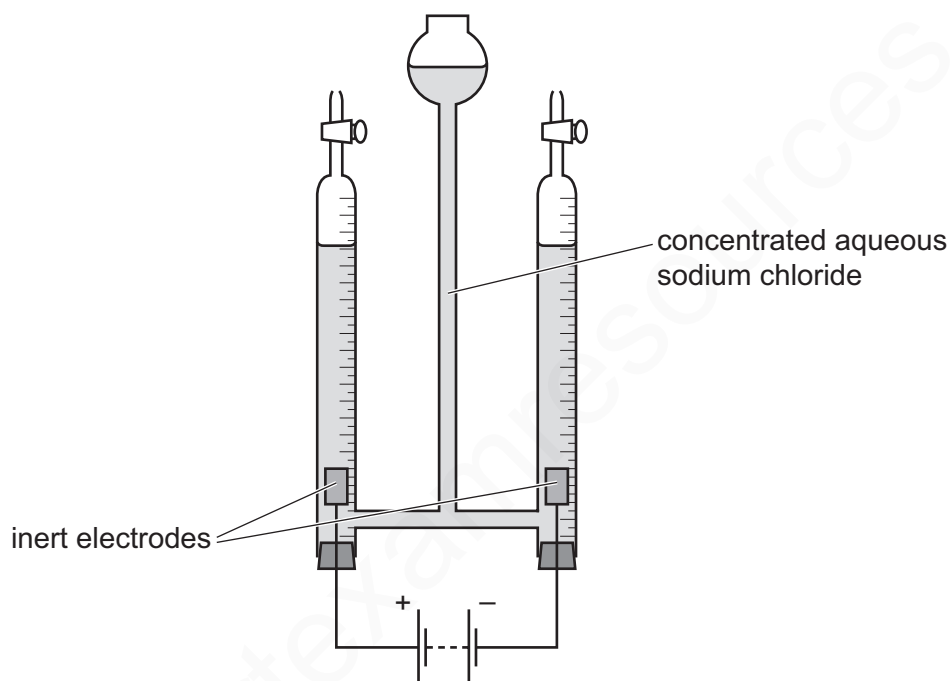
3 Many substances conduct electricity.

(a) Identify all the particles responsible for the passage of electricity in:

- graphite
- magnesium ribbon
- molten copper(II) bromide.

[4]

(b) A student used the following apparatus to electrolyse concentrated aqueous sodium chloride using inert electrodes.



(i) Suggest the name of a metal which could be used as the inert electrodes.

..... [1]

(ii) Name the gas formed at the positive electrode.

..... [1]

(iii) Write an ionic half-equation for the reaction occurring at the negative electrode. Include state symbols.

..... [3]

(iv) How, if at all, does the pH of the solution change during the electrolysis? Explain your answer.

.....
.....
..... [3]

MARKING SCHEME:

(a)	electrons (1) electrons (1) Cu ²⁺ (ions) (1) Br ⁻ (ions) (1)	4
(b)(i)	platinum	1
(b)(ii)	chlorine	1
(b)(iii)	2H ⁺ (aq) + 2e ⁻ → H ₂ (g) H ⁺ + e ⁻ on left hand side (1) rest of equation (1) state symbols of (aq) → (g) (1)	3
(b)(iv)	increases (sodium) hydroxide is formed (sodium) hydroxide is an alkali	3

4 A **concentrated** aqueous solution of sodium chloride is electrolysed using carbon electrodes.

(i) Name the products formed at the electrodes.

product at the positive electrode (anode)

product at the negative electrode (cathode)

[2]

(ii) Write an ionic half-equation for the reaction occurring at the negative electrode.

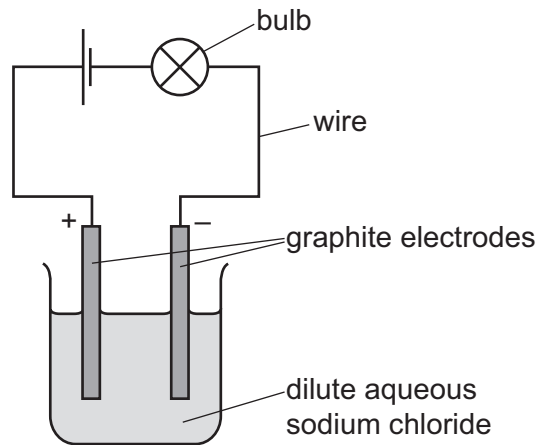
..... [1]

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MARKING SCHEME:

(i)	product at the positive electrode: chlorine product at the negative electrode: hydrogen	1 1
(ii)	$2\text{H}^+ + 2\text{e}^- \rightarrow \text{H}_2$ OR $2\text{H}_3\text{O}^+ + 2\text{e}^- \rightarrow \text{H}_2 + 2\text{H}_2\text{O}$	1

5 A student sets up the following electrolysis experiment.



(a) Define the term *electrolysis*.

.....
..... [2]

(b) The student observes bubbles of colourless gas forming at each electrode.

(i) Name the main gas produced at the positive electrode (anode).

..... [1]

(ii) Describe a test for the gas produced in (b)(i).

test

result

[2]

(iii) Write the ionic half-equation for the reaction taking place at the negative electrode (cathode).

..... [2]

(c) Charge is transferred during electrolysis.

Name the type of particle responsible for the transfer of charge in

the wires,

the electrolyte.

[2]

- (d) The student replaces the dilute aqueous sodium chloride with **concentrated** aqueous sodium chloride.

Suggest **two** differences that the student observes.

1

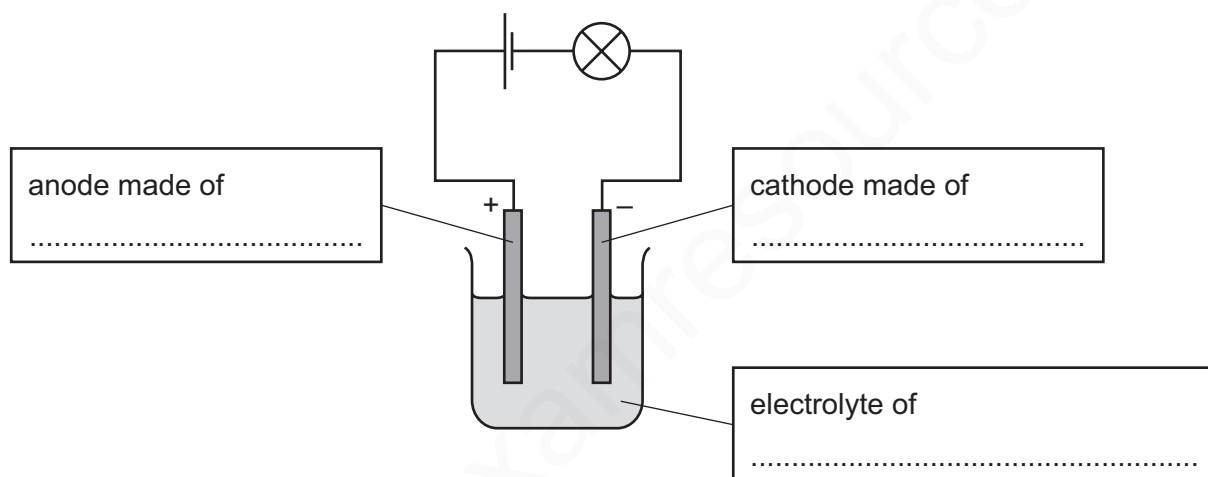
2

[2]

- (e) The student has a small piece of impure copper. The main impurities in the copper are small quantities of silver and zinc.

The student uses electrolysis to extract pure copper from the small piece of impure copper.

- (i) Complete the labels on the diagram of the student's electrolysis experiment.



[3]

- (ii) Use your knowledge of the reactivity series to suggest what happens to the silver and zinc impurities. Explain your answers.

silver impurities

.....

.....

zinc impurities

.....

.....

[3]

[Total: 17]

MARKING SCHEME:

(a)	the breakdown (into elements)	1
	of an (ionic) compound by (the passage of) electricity	1
(b)(i)	oxygen	1
(b)(ii)	glowing splint	1
	relights	1
(b)(iii)	$2\text{H}^+ + 2\text{e}^- \rightarrow \text{H}_2$ M1 gain of electrons by H^+ M2 rest of equation	2
(c)	<i>the wires</i> : electrons	1
	<i>the electrolyte</i> : ions	1
(d)	any 2 from: <ul style="list-style-type: none"> • green gas at positive electrode • bulb is brighter • rate of bubbles increases 	2
(e)(i)	<i>anode made of</i> : impure copper	1
	<i>cathode made of</i> : (pure) copper	1
	<i>electrolyte of</i> : (aqueous) copper sulfate	1
(e)(ii)	silver (impurities) fall to the bottom of the cell	1
	zinc (impurities) (dissolve) into solution (as ions)	1
	because zinc is more reactive than copper AND silver is less reactive than copper	1

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

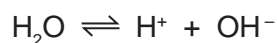
- hydrogen
- chlorine
- sodium hydroxide
- sodium chlorate(I)

(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.



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) (i) State a use of hydrogen.

..... [1]

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

..... [1]

MARKING SCHEME:

- (a) (i)** H₂ on RHS [1]
ignore any other species on RHS
rest of equation fully correct i.e. $2\text{H}^+ + 2\text{e} \rightarrow \text{H}_2$ [1]
- (ii)** H⁺ removed / escapes / discharged / used up / reduced [1]
(equilibrium) moves to RHS / more water molecules ionise or
dissociate / forward reaction favoured [1]
- (iii)** oxygen / O₂ [1]
not O
- (iv)** carbon / graphite / platinum (electrode) [1]
- (b) (i)** to make ammonia / in petroleum processing / balloons / rocket fuel / fuel for cars /
hardening of fats / fuel cells / fuel (unqualified) / making hydrochloric acid [1]
- (ii)** to sterilise / disinfect it / kill bacteria / bugs / microbes / micro-organisms / germs [1]