Electrolysis of aqueous solutions

Answers, marking points and revision notes | AQA Combined Science 8464 and AQA GCSE Chemistry 8462

GCSE science required practicals

This practical online

Answers

1 Explain why graphite is used for the electrodes. (2 marks)

Graphite conducts electricity and is inert, so it does not react with the solution or the products. This means the products only come from the ions in the solution.

Marking points

- Conducts electricity
- Inert / does not react, so does not affect the products

2 State the independent variable in this investigation and give one control variable. (2 marks)

Independent variable: the salt solution used. Control variable: the voltage of the power supply (or the type of electrode, or the concentration of the solution).

Marking points

- Independent: the solution / salt used
- Control: voltage, electrode type, concentration, volume or time

3 Chlorine is made when sodium chloride solution is electrolysed. Describe the hazard of chlorine, what could happen, and one way to reduce the risk. (3 marks)

Chlorine is a toxic gas. Breathing it in can irritate the lungs and cause coughing or an asthma attack. Only run the electrolysis for a few minutes in a well-ventilated room or a fume cupboard.

Marking points

- Chlorine is toxic
- Irritates lungs / eyes, may trigger asthma
- Short time, good ventilation or fume cupboard

4 Describe how to test for each of these gases and give the positive result:

a. hydrogen

b. oxygen

c. chlorine (3 marks)

a) Hold a lit splint at the mouth of the tube: a squeaky pop. b) Put a glowing splint into the tube: it relights. c) Hold damp blue litmus paper in the gas: it turns red and then bleaches white.

Marking points

- Hydrogen: lit splint gives a squeaky pop
- Oxygen: glowing splint relights
- Chlorine: damp litmus paper is bleached

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5 Use the table to name the products at the cathode and at the anode when potassium bromide solution is electrolysed. (2 marks)

Cathode: hydrogen. Anode: bromine (it dissolves and makes the solution orange).

Marking points

- Cathode: hydrogen
- Anode: bromine

6 Explain why hydrogen, not sodium, is made at the cathode when sodium chloride solution is electrolysed. (2 marks)

The solution contains hydrogen ions from the water as well as sodium ions. Sodium is more reactive than hydrogen, so the hydrogen ions gain electrons instead and hydrogen gas is made.

Marking points

- Water provides hydrogen ions
- Sodium is more reactive than hydrogen, so hydrogen is discharged

7 Calculate the mean rate at which hydrogen was produced from sodium sulfate solution, in cm^3 per minute. Give your answer to 2 significant figures. (2 marks)

1.7 cm^3/min

Mean rate = volume / time

Mean rate = 8.4 / 5

Mean rate = 1.68

Mean rate = 1.7 cm^3/min (2 significant figures)

Marking points

- 8.4 / 5
- 1.7 cm^3/min

8 For sodium sulfate solution, calculate the ratio of the volume of gas at the cathode to the volume of gas at the anode. Give your answer to 2 significant figures. (2 marks)

2.0 (so about 2 : 1)

Ratio = volume at cathode / volume at anode

Ratio = 8.4 / 4.1

Ratio = 2.04...

Ratio = 2.0, so about 2 : 1

Marking points

- 8.4 / 4.1
- 2.0 (about 2 : 1)

9 The volume of chlorine collected from sodium chloride solution (6.2 cm^3) is less than the volume of hydrogen (8.6 cm^3), although they should be equal. Suggest why. (2 marks)

Chlorine is slightly soluble in water, so some of it dissolves in the solution instead of collecting in the tube. Hydrogen is almost insoluble, so nearly all of it is collected.

Marking points

- Chlorine dissolves in the water / solution
- Hydrogen does not, so more of it is collected

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10 In another experiment, Tom weighed the cathode before and after electrolysing copper(II) sulfate solution for 10 minutes. Its mass went from 12.46 g to 12.71 g. Calculate the mass of copper deposited each minute. Show your working.

(3 marks)

0.025 g per minute

Mass of copper = 12.71 - 12.46 = 0.25 g

Mass per minute = 0.25 / 10

Mass per minute = 0.025 g/min

Marking points

- Mass gained = 12.71 - 12.46 = 0.25 g
- 0.25 / 10
- 0.025 g/min

11 **Higher tier**

Write half equations for the reactions at each electrode when copper(II) chloride solution is electrolysed.

(2 marks)

Cathode: $Cu^{2+} + 2e^- \rightarrow Cu$

Anode: $2Cl^- \rightarrow Cl_2 + 2e^-$

Marking points

- $Cu^{2+} + 2e^- \rightarrow Cu$
- $2Cl^- \rightarrow Cl_2 + 2e^-$ (or $2Cl^- - 2e^- \rightarrow Cl_2$)

12 **Higher tier**

Explain, in terms of electrons, why the reaction at the cathode is reduction and the reaction at the anode is oxidation. Use copper(II) chloride as your example.

(3 marks)

At the cathode, copper ions gain electrons to become copper atoms. Gaining electrons is reduction. At the anode, chloride ions lose electrons to form chlorine molecules, and losing electrons is oxidation.

Marking points

- Copper ions gain electrons at the cathode
- Gain of electrons is reduction
- Chloride ions lose electrons at the anode, which is oxidation

13 The gas tubes are only marked every 1 cm^3, so Aisha and Tom had to estimate each reading between the marks. Suggest one improvement and explain why it helps.

(2 marks)

Collect the gas in a narrower graduated tube or burette marked every 0.1 cm^3. This has a better resolution, so each volume can be read more precisely.

Marking points

- Tube / burette with finer scale divisions
- Higher resolution so volumes are read more precisely

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14 Plan an investigation to find out how the current affects the mass of copper deposited on a graphite cathode when copper(II) sulfate solution is electrolysed. (6 marks)

Clean and dry a graphite cathode and weigh it on a balance to 0.01 g. Set up a beaker of copper(II) sulfate solution with two graphite electrodes, connected in series with a DC supply, an ammeter and a variable resistor. Switch on and use the variable resistor to set the current to 0.2 A. Start a stopwatch and electrolyse for 10 minutes, keeping the current steady. Switch off, carefully remove the cathode, rinse it gently with water then propanone or let it dry, and weigh it again. The increase in mass is the copper deposited. Repeat with fresh solution and a cleaned cathode at 0.4, 0.6, 0.8 and 1.0 A. Keep the time, the volume and concentration of solution and the distance between the electrodes the same. Do each current three times and find the mean mass, then plot mean mass against current. Wear goggles because copper sulfate is harmful.

Marking points (any 6, with the method in a logical order)

- Weigh the clean, dry cathode before
- Graphite electrodes in copper(II) sulfate with DC supply and ammeter in series
- Variable resistor (or power supply setting) used to change current; at least 5 values
- Electrolyse for a fixed time
- Rinse, dry and reweigh the cathode; mass gain = copper deposited
- Control: time, concentration, volume, electrode spacing
- Repeat each current and calculate a mean
- Plot mass of copper against current
- Goggles worn / handle copper sulfate carefully

How it is marked

- 5-6 marks: a clear plan that could be followed, with weighing before and after, a way of changing and measuring current, fixed time, control variables and repeats.
- 3-4 marks: the main idea of weighing the cathode at different currents is there, but some key detail is missing, such as how the current is measured or what is kept the same.
- 1-2 marks: one or two relevant steps, such as electrolysing copper sulfate or weighing an electrode, with no logical plan.

Revision notes: the method

Aim: To find out which products form at each inert electrode when different aqueous salt solutions are electrolysed, and to identify any gases made.

Equipment

- beaker or small plastic electrolysis cell
- two graphite (carbon) rod electrodes
- low-voltage DC power supply (about 4-6 V)
- connecting leads and crocodile clips
- two small graduated tubes to collect gas
- solutions such as copper(II) chloride, copper(II) sulfate, sodium chloride, sodium sulfate and potassium bromide
- blue litmus paper
- wooden splints
- safety goggles

Method

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1. Pour about 50 cm^3 of one salt solution into the beaker.
2. Fix the two graphite electrodes so they dip into the solution without touching each other.
3. Fill two small graduated tubes with the solution and turn one upside down over each electrode so that any gas is collected.
4. Connect the electrodes to the DC supply, set to about 4 V, and switch on.
5. Watch both electrodes. Record any bubbles, a coating on the electrode, or a colour change in the solution nearby.
6. After a few minutes, switch off and test any gas collected: a lit splint for hydrogen, a glowing splint for oxygen, damp blue litmus paper for chlorine.
7. Rinse the electrodes and beaker with water and repeat with each of the other solutions.
8. Record your results in a table showing the product at the cathode (negative) and the anode (positive) for each solution.

Variables

- **Independent:** The salt solution being electrolysed.
- **Dependent:** The product at each electrode, identified by what is seen and by the gas tests.
- **Control:** The type of electrode (graphite, inert) for every solution; The voltage of the power supply; The concentration and volume of each solution; The time the current runs for

Hazards

Hazard	What could happen	How to reduce the risk
Chlorine gas produced at the anode	Toxic; irritates the lungs and eyes, especially for people with asthma	Run the cell for only a short time in a well-ventilated room or fume cupboard and switch off as soon as the test is done
Copper(II) salt solutions	Harmful if swallowed and irritating to the eyes	Wear safety goggles and wash hands after the practical
Hydrogen gas	Small pop when tested with a flame; flammable	Only test very small volumes with a lit splint held at arm's length

Key points

- At the cathode: if the metal is more reactive than hydrogen (sodium, potassium), hydrogen is made instead of the metal.
- At the anode: if a halide ion is present you get the halogen (chlorine, bromine, iodine); otherwise oxygen is made from water.
- Graphite electrodes are inert: they do not react, so they do not change the products.
- Gas tests: hydrogen pops with a lit splint, oxygen relights a glowing splint, chlorine bleaches damp litmus paper.
- Chlorine is slightly soluble in water, so less of it is collected than you might expect.
- Cathode is negative and attracts positive ions; anode is positive and attracts negative ions.

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