2.15 Electrolysis: 1-hour Pack

AQA 8464 · Calculator allowed · about 60 minutes

Total Marks

Name: _____ Date: ____ / ____ / _____

Answer ALL questions. Show all your working.

1 Electrolysis of aqueous copper(II) sulfate with inert electrodes is used to plate copper onto the cathode.

(a) State which ion is reduced at the cathode and write the half-equation. **(2)**

(b) Give one reason why hydrogen gas is not produced at the cathode in this electrolysis. **(1)**

(Total for Question 1 is 3 marks)

2 Aluminium is extracted from aluminium oxide by electrolysis on a large industrial scale. Explain how this process works and why it is necessary, including reference to reactivity, the role of cryolite, the reactions occurring at each electrode, and why the process is costly.

(Total for Question 2 is 6 marks)

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3 Required practical: Callum investigates the electrolysis of potassium bromide solution using inert electrodes, as an extension of the standard investigation.

(a) Predict the product formed at the cathode, and explain your prediction. **(2)**

(b) Predict the product formed at the anode, and describe how Callum could test for this product, including the result of a positive test. **(3)**

(Total for Question 3 is 5 marks)

4 When an aqueous solution is electrolysed, the product formed at the cathode depends on the reactivity of the metal ion present.

(a) State the general rule used to predict whether a metal or hydrogen gas forms at the cathode during the electrolysis of an aqueous solution. **(2)**

(b) Dilute sulfuric acid and copper sulfate solution are separately electrolysed using inert electrodes. Predict the product formed at the cathode in each case, and justify your answer. **(3)**

(Total for Question 4 is 5 marks)

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5 Priya runs the electrolysis for several minutes and records her observations at each electrode.

(a) Describe what Priya observes at the cathode during the experiment. **(2)**

(b) Describe what Priya observes at the anode, and describe a test she could use to confirm the identity of the gas produced there, including the result of a positive test. **(3)**

(c) Explain why the blue colour of the copper sulfate solution gradually fades during this experiment. **(1)**

(Total for Question 5 is 6 marks)

6 The mass of a copper cathode was measured over time during electrolysis for two different currents. At 0.50 A the mass increased by 0.10 g in 20 minutes. At 1.00 A the mass increased by 0.20 g in 20 minutes.

(a) Calculate the rate of deposition of copper in g per minute at 0.50 A. **(1)**

(b) Explain why doubling the current to 1.00 A doubles the rate of mass increase, using electrolysis principles. **(3)**

(Total for Question 6 is 4 marks)

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7 In an electroplating demonstration, a student notices pitting and poor adhesion of the silver coating.

(a) Suggest two possible causes of pitting or poor adhesion in electroplated coatings, linked to the procedure or solutions used. **(2)**

(b) Give one improvement to the procedure that would reduce pitting and improve coating adhesion. **(2)**

(Total for Question 7 is 4 marks)

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8 A school electrolysis experiment uses dilute sulfuric acid with inert graphite electrodes. A student passes a current of 0.25 A for 120 seconds and collects gas at both electrodes, measuring 20.0 cm^3 of hydrogen at the cathode and 8.0 cm^3 of oxygen at the anode.

(a) Calculate the total charge passed through the cell in 120 s at 0.25 A. Use Q = I x t. Then predict, giving a reason based on the electrolysis of water, which gas should be collected in the greater volume. **(3)**

(b) The student's results (20.0 cm^3 hydrogen to 8.0 cm^3 oxygen) give a ratio of about 2.5:1 rather than the expected 2:1. Suggest two possible reasons for this discrepancy. **(1)**

(Total for Question 8 is 4 marks)

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9 Electroplating silver onto a metal object uses silver ions in solution. A current of 0.75 A is passed through a silver nitrate solution for 2 hours to plate silver onto an object.

(a) Calculate the total charge in coulombs passed in 2.0 hours at 0.75 A. **(2)**

(b) In this electroplating cell a pure silver anode is used instead of an inert electrode ($Ag^+ + e^- \rightarrow Ag$ at the cathode). State what happens to the silver anode as electrolysis proceeds, and explain why an active silver anode, rather than an inert one, is used for electroplating. **(2)**

(Total for Question 9 is 4 marks)

10 Higher tier only. Copper sulfate solution is electrolysed using inert (graphite) electrodes.

(a) Write the half equation for the reaction at the cathode. **(2)**

(b) Write the half equation for the reaction at the anode. **(2)**

(Total for Question 10 is 4 marks)

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Mark scheme · 2.15 Electrolysis: 1-hour Pack

Question 1

(a) identifies Cu^{2+} as the ion reduced **M1**

(a) Cu^{2+} + 2e- -> Cu cao **A1**

(a) Answer: Cu^{2+} is reduced; Cu^{2+} + 2e- -> Cu

(b) copper ions are less reactive than hydrogen so Cu^{2+} are discharged in preference to H^+ (or equivalent reason mentioning reduction potential) **B1**

(b) Answer: Because Cu^{2+} ions are reduced preferentially to H^+ since copper is less reactive than hydrogen.

Question 2

Level 1 Simple, isolated statements are made, such as naming aluminium oxide or electrolysis, with little or no explanation of why electrolysis is necessary, or of what happens at the electrodes. **1-2**

Level 2 A logical explanation is given covering some of the required points (e.g. why electrolysis rather than carbon reduction is used, and/or the products formed at the electrodes), with some detail, but coverage of the role of cryolite, the electrode reactions and the cost factor is incomplete. **3-4**

Level 3 A complete, logically structured explanation is given, correctly linking the reactivity of aluminium (compared with carbon) to the need for electrolysis, the role of cryolite in lowering the melting point, the products formed at the cathode and anode, and the reasons the process is energy-intensive and costly (including the need to replace carbon anodes). **5-6**

Indicative content:

- Aluminium is more reactive than carbon, so carbon cannot reduce (displace) aluminium from aluminium oxide; electrolysis must be used instead.
- Pure aluminium oxide has a very high melting point (over 2000°C), so it is dissolved in molten cryolite, which lowers the operating temperature to around 900-1000°C and reduces the energy needed.
- At the cathode (negative electrode), Al^{3+} ions gain electrons (are reduced) and are deposited as molten aluminium, which is tapped off from the bottom of the cell.
- At the anode (positive electrode, made of carbon), O^{2-} ions lose electrons (are oxidised) to form oxygen gas.
- The hot oxygen gas produced reacts with the hot carbon anodes, forming carbon dioxide gas, so the anodes gradually burn away and must be replaced regularly, adding to the running cost.
- The process requires a very large amount of electrical energy (to melt the cryolite mixture and to drive the electrolysis reaction), which makes extracting aluminium considerably more expensive than extracting a metal such as iron by reduction with carbon.

Question 3

(a) hydrogen gas forms at the cathode **B1**

(a) potassium is more reactive than hydrogen, so hydrogen is produced in preference to potassium metal oe **B1**

(a) Answer: Hydrogen gas forms at the cathode, because potassium is more reactive than hydrogen, so hydrogen is discharged in preference to potassium metal.

(b) bromine forms at the anode; an orange (red-brown) colouration appears in the solution around the anode oe **B1**

(b) test: hold a piece of damp (blue or red) litmus paper close to the anode, or dip it into a sample of solution taken from near the anode oe **B1**

(b) positive result: the damp litmus paper is bleached (turns white), confirming a halogen (bromine) is present **B1**

(b) Answer: Bromine forms at the anode, seen as an orange colouration in the solution near the electrode. Holding damp litmus paper close to the anode tests for this: if it bleaches (turns white), this confirms bromine is present.

Question 4

(a) if the metal is less reactive than hydrogen, the metal is produced (deposited) at the cathode oe **M1**

(a) if the metal is more reactive than hydrogen, hydrogen gas is produced instead oe **A1**

(a) Answer: If the metal is less reactive than hydrogen, the metal is deposited at the cathode. If the metal is more reactive than hydrogen, hydrogen gas is produced at the cathode instead.

(b) dilute sulfuric acid: hydrogen gas forms at the cathode (the only positive ion available is H^+) **B1**

(b) copper sulfate solution: copper metal forms at the cathode **B1**

(b) justification: copper is less reactive than hydrogen, so Cu^{2+} ions are discharged (deposited) at the cathode in preference to hydrogen oe **B1**

(b) Answer: Dilute sulfuric acid gives hydrogen gas at the cathode, since H^+ is the only cation present. Copper sulfate solution gives copper metal at the cathode, because copper is less reactive than hydrogen, so Cu^{2+} ions are discharged in preference to H^+.

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Question 5

(a) a reddish-brown (pink-brown) solid coating gradually builds up on the electrode oe **B1**

(a) this deposit is copper metal **B1**

(a) Answer: A reddish-brown solid coating (copper metal) gradually builds up on the cathode.

(b) colourless gas bubbles (effervescence) are produced at the anode **B1**

(b) test: collect a sample of the gas and insert a glowing splint into it oe **B1**

(b) positive result: the glowing splint relights, confirming the gas is oxygen **B1**

(b) Answer: Colourless gas bubbles are produced at the anode. Collecting a sample and inserting a glowing splint tests for the gas: if it relights, this confirms the gas is oxygen.

(c) Cu^{2+} ions are removed from solution (deposited as copper at the cathode) and are not replaced, since the graphite electrodes are inert and do not dissolve, so the concentration of Cu^{2+} ions (and the blue colour) decreases oe **B1**

(c) Answer: Cu^{2+} ions are steadily removed from solution as they are deposited as copper at the cathode, and are not replaced (since the inert electrodes do not dissolve), so the concentration of Cu^{2+} ions and the blue colour both decrease.

Question 6

(a) 0.005 g per minute cao **B1**

(a) Answer: 0.005 g per minute

(b) states that current is rate of flow of charge (or number of electrons per second) **M1**

(b) states that more electrons per second cause more metal ions to gain electrons and deposit per unit time **M1**

(b) concludes doubling current doubles deposition rate, so mass increase doubles cao **A1**

(b) Answer: Current is the flow of charge; doubling current doubles the number of electrons per second so twice as many Cu^{2+} ions are reduced per minute and twice as much copper is deposited.

Question 7

(a) contaminated or dirty substrate surface (not properly cleaned) causing poor adhesion **B1**

(a) impurities or incorrect concentration in the plating solution or presence of dissolved oxygen causing pitting **B1**

(a) Answer: Any two: dirty or oily substrate not cleaned; impurities in solution or incorrect concentration; rapid deposition from too high current density causing pitting; dissolved oxygen or unstable bath chemistry.

(b) suggests cleaning and degreasing the substrate or controlling current density or adjusting solution composition **M1**

(b) links this to improved adhesion or reduced pitting (e.g. 'clean substrate and reduce current density to give smoother, adherent deposit') **A1**

(b) Answer: Clean and degrease the substrate thoroughly and use a lower, controlled current density; adjust plating solution concentration to recommended values to give a smooth adherent coating.

Question 8

(a) substitutes: Q = 0.25 x 120 **M1**

(a) 30 C cao **A1**

(a) predicts hydrogen is collected in the greater volume because electrolysis of water produces hydrogen and oxygen in a 2:1 mole (and volume) ratio, from $2H_2O \rightarrow 2H_2 + O_2$, oe **B1**

(a) Answer: 30 C. Hydrogen should be collected in the greater volume, since electrolysis of water produces hydrogen and oxygen in a 2:1 ratio ($2H_2O \rightarrow 2H_2 + O_2$).

(b) gives two plausible causes such as oxygen being more soluble in water than hydrogen so some dissolves rather than being collected, imprecise reading of the gas syringe/measuring cylinder scale, a small gas leak from the apparatus, or a side reaction at an electrode, oe **B1**

(b) Answer: Oxygen is more soluble in water than hydrogen, so some of the oxygen produced dissolves rather than being collected; there may also be small errors in reading the gas volumes, or a slight gas leak from the apparatus.

Question 9

(a) converts time and substitutes: Q = 0.75 x (2.0 x 3600) **M1**

(a) 5400 C cao **A1**

(a) Answer: 5400 C

(b) states that the silver anode dissolves/loses mass as silver atoms lose electrons to form Ag^+ ions: $Ag \rightarrow Ag^+ + e^-$ **M1**

(b) explains that this continuously replenishes Ag^+ ions in the solution, keeping its concentration constant so plating can continue, oe **A1**

(b) Answer: The silver anode dissolves as silver atoms lose electrons to form Ag^+ ions ($Ag \rightarrow Ag^+ + e^-$). An active silver anode is used, rather than an inert one, because it continuously replaces the Ag^+ ions removed from solution at the cathode, keeping the silver ion concentration in the bath constant so plating can continue.

Question 10

(a) correct species and direction: $Cu^{2+} + 2e^- \rightarrow Cu$ **M1**

(a) fully balanced, including the correct number of electrons cao **A1**

(a) Answer: $Cu^{2+} + 2e^- \rightarrow Cu$

(b) correct species and direction: $4OH^- \rightarrow O_2 + 2H_2O + 4e^-$ **M1**

(b) fully balanced (4 O and 4 H on each side; charge -4 on each side) cao **A1**

(b) Answer: $4OH^- \rightarrow O_2 + 2H_2O + 4e^-$

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