C4bD Electrolysis: Exam Drill

AQA 8464 · Calculator allowed · about 90 minutes

Total Marks

Name: _____ Date: ____ / ____ / _____

Answer ALL questions. Show all your working.

1 Electrolysis is the process of using an electric current to drive a non-spontaneous chemical change.

(a) Give the name of the electrode at which reduction occurs during electrolysis. **(1)**

(b) Give the name of the electrode at which oxidation occurs during electrolysis. **(1)**

(Total for Question 1 is 2 marks)

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2 A student electrolyses molten sodium chloride to produce sodium metal and chlorine gas.

(a) State the ion that migrates to the cathode in molten sodium chloride. **(1)**

(b) Write the half-equation that occurs at the cathode to form sodium metal from Na^+ ions. **(1)**

(Total for Question 2 is 2 marks)

3 When molten lead bromide, PbBr2, is electrolysed, bromide ions are oxidised at the anode to form bromine gas.

(a) Write the half-equation for bromide ions forming bromine at the anode. **(1)**

(b) One mole of PbBr2 contains two moles of Br-. Calculate the volume in dm3 of bromine gas, measured at room conditions where 1 mole gas occupies 24.0 dm3, produced from 0.50 mol of PbBr2. **(2)**

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(Total for Question 3 is 3 marks)

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4 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 4 is 3 marks)

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5 A student performs the electrolysis of copper(II) sulfate using a copper anode and a copper cathode. After some time the mass of the cathode increases.

(a) Explain why the mass of the cathode increases during electrolysis. **(2)**

(b) State one change that would be observed at the anode if the copper anode dissolves during electrolysis. **(1)**

(Total for Question 5 is 3 marks)

6 The required practical: electrolysis of copper(II) sulfate using inert electrodes. A student records the mass of the copper cathode at intervals while passing a current of 0.50 A for 10 minutes.

(a) Calculate the total charge in coulombs passed through the cell in 10.0 minutes at 0.50 A. Use Q = I x t. **(2)**

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(b) Using the charge calculated above, calculate the mass of copper deposited at the cathode. (Relative atomic mass Cu = 63.5; Avogadro constant and Faraday constant are not required if you use the fact that 2 mol electrons deposit 1 mol Cu. You may use 1 mol e- = 96500 C.) **(2)**

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(Total for Question 6 is 4 marks)

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7 A solution contains sodium chloride. During electrolysis using inert electrodes, chlorine gas forms at the anode and hydrogen gas may form at the cathode.

(a) State why chloride ions rather than hydroxide ions are oxidised at the anode in concentrated sodium chloride solution. **(2)**

(b) Give the half-equation for hydrogen formation at the cathode from water. **(1)**

(Total for Question 7 is 3 marks)

8 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)**

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(b) Using 1 mol e- = 96500 C and atomic mass Ag = 107.9, calculate the mass of silver deposited. (Ag+ + e- -> Ag). **(2)**

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(Total for Question 8 is 4 marks)

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9 In industry, the electrolysis of aluminium oxide dissolved in molten cryolite is used to produce aluminium.

(a) Describe why cryolite is used when electrolysing aluminium oxide. **(2)**

(b) State one environmental or economic issue associated with aluminium extraction by electrolysis. **(1)**

(Total for Question 9 is 3 marks)

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10 A graph shows the mass of copper cathode 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)**

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

(Total for Question 10 is 4 marks)

11 Halogen gases are produced at the anode when halide salts are electrolysed in aqueous solution.

(a) Give the name of the halogen gas produced at the anode when potassium iodide solution is electrolysed. **(1)**

(b) Give the observable appearance of the halogen produced in part a at room temperature. **(1)**

(Total for Question 11 is 2 marks)

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12 A student sets up electrolysis of dilute sodium sulfate solution with inert electrodes. The expected products are hydrogen at the cathode and oxygen at the anode.

(a) Write the half-equation for oxygen formation from hydroxide ions at the anode. **(1)**

(b) Explain why oxygen, not ozone, is the usual product at the anode in this electrolysis. **(2)**

(Total for Question 12 is 3 marks)

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13 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 13 is 4 marks)

14 Electrolysis is used to produce gases at electrodes in a school experiment. A student collects 20.0 cm3 of hydrogen at the cathode over 120 seconds when passing a current of 0.25 A. (Assume 1 mol gas = 24.0 dm3).

(a) Calculate the theoretical volume of hydrogen that should be produced in 120 s at 0.25 A. Use relevant electrochemical relationships. (H2 formation half-equation: 2H+ + 2e- -> H2). **(3)**

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(b) Evaluate the student's experimental result of 20.0 cm3 compared with the theoretical value, giving two possible reasons for the discrepancy. **(1)**

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(Total for Question 14 is 4 marks)

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15 Extended response (6 marks). A manufacturer uses electrolysis to plate chromium onto steel car parts to improve corrosion resistance. The process is expensive and the manufacturer is considering two changes: using a lower current density to improve coating quality but increasing production time, or keeping current density the same but adding a brightener chemical to the bath that increases cost. Evaluate both options and recommend which the manufacturer should choose. In your answer consider quality of coating, production rate, cost and environmental or safety implications.

(Total for Question 15 is 6 marks)

Mark scheme · C4bD Electrolysis: Exam Drill

Question 1

- (a) **B1** cathode cao
- **(a) Answer: Cathode.**
- (b) **B1** anode cao
- **(b) Answer: Anode.**

Question 2

- (a) **B1** Na+ (sodium ion) cao
- **(a) Answer: Na+ (sodium ion).**
- (b) **B1** Na+ + e- -> Na (cao)
- **(b) Answer: Na+ + e- -> Na**

Question 3

- (a) **B1** 2Br- -> Br2 + 2e- cao
- **(a) Answer: 2Br- -> Br2 + 2e-**
- (b) **M1** calculate moles of Br2 produced: 0.50 mol PbBr2 gives 1.00 mol Br- -> 0.50 mol Br2 or show mole ratio 2Br- -> Br2
- (b) **A1** 12.0 dm3 cao
- **(b) Answer: 12.0 dm3**

Question 4

- (a) **M1** identifies Cu2+ as the ion reduced
- (a) **A1** Cu2+ + 2e- -> Cu cao
- **(a) Answer: Cu2+ is reduced; Cu2+ + 2e- -> Cu**
- (b) **B1** copper ions are less reactive than hydrogen so Cu2+ are discharged in preference to H+ (or equivalent reason mentioning reduction potential)
- **(b) Answer: Because Cu2+ ions are reduced preferentially to H+ since copper is less reactive than hydrogen.**

Question 5

- (a) **M1** states that Cu2+ ions gain electrons and are deposited as copper metal on the cathode
- (a) **A1** mass increases because copper atoms are added to the cathode surface (cao)
- **(a) Answer: Cu2+ ions gain electrons at the cathode and are deposited as copper metal, so copper atoms add to the cathode and its mass increases.**
- (b) **B1** mass of anode decreases or anode becomes thinner or solution colour becomes bluer (due to Cu2+ entering solution) oe
- **(b) Answer: The mass of the anode decreases (the anode becomes thinner) and the solution may turn bluer.**

Question 6

- (a) **M1** substitutes and converts time: Q = 0.50 x (10.0 x 60)
- (a) **A1** 300 C cao
- **(a) Answer: 300 C**
- (b) **M1** calculate moles of electrons: n(e-) = 300 / 96500
- (b) **A1** mass Cu = 0.0987 g (or 0.099 g) cao
- **(b) Answer: 0.0987 g**

Question 7

- (a) **M1** states that chloride ions are discharged in preference to hydroxide when chloride concentration is high
- (a) **A1** because chloride ions oxidise more easily under these conditions so Cl- -> Cl2 occurs rather than 4OH- -> O2 + 2H2O (or mention relative ease / electrode potentials)
- **(a) Answer: Because in concentrated sodium chloride solution chloride ions are present at high concentration and are discharged at the anode in preference to hydroxide ions, so Cl- is oxidised to Cl2 rather than OH- to O2.**
- (b) **B1** 2H2O + 2e- -> H2 + 2OH- cao
- **(b) Answer: 2H2O + 2e- -> H2 + 2OH-**

Question 8

- (a) **M1** converts time and substitutes: Q = 0.75 x (2.0 x 3600)
- (a) **A1** 5400 C cao
- **(a) Answer: 5400 C**
- (b) **M1** calculate moles e- = 5400 / 96500 then moles Ag = moles e- (1:1) and mass = moles x 107.9
- (b) **A1** 6.04 g (to 3 s.f.) cao
- **(b) Answer: 6.04 g**

Question 9

- (a) **M1** states cryolite lowers melting point of aluminium oxide or increases conductivity
- (a) **A1** so melting temperature and energy costs are reduced and the mixture is more conductive, oe
- **(a) Answer: Cryolite lowers the melting point of aluminium oxide and increases the electrical conductivity of the molten mixture, reducing energy cost.**
- (b) **B1** high energy use leading to CO2 emissions or cost; or anode carbon reacts producing CO2; or waste cryolite disposal problem
- **(b) Answer: High energy use leading to significant CO2 emissions and high operating costs.**

Question 10

- (a) **B1** 0.005 g per minute cao
- **(a) Answer: 0.005 g per minute**
- (b) **M1** states that current is rate of flow of charge (or number of electrons per second)
- (b) **M1** states that more electrons per second cause more metal ions to gain electrons and deposit per unit time
- (b) **A1** concludes doubling current doubles deposition rate, so mass increase doubles cao
- **(b) Answer: Current is the flow of charge; doubling current doubles the number of electrons per second so twice as many Cu2+ ions are reduced per minute and twice as much copper is deposited.**

Question 11

- (a) **B1** iodine (I2) cao
- **(a) Answer: Iodine (I2).**
- (b) **B1** brown vapour or dark purple vapour or brown solid sublimes to purple/brown gas (acceptable description)
- **(b) Answer: Brownish purple vapour (iodine vapour) or dark solid that forms purple/brown vapour on warming.**

Question 12

- (a) **B1** 4OH- -> O2 + 2H2O + 4e- cao
- **(a) Answer: 4OH- -> O2 + 2H2O + 4e-**
- (b) **M1** states oxygen is more readily formed and is thermodynamically favoured
- (b) **A1** mentions that ozone formation requires higher energy and specific conditions so O2 is favoured at normal electrode potentials and concentrations
- **(b) Answer: Oxygen is formed because it is the thermodynamically favored product under normal conditions; ozone requires higher energy or special conditions to form, so O2 is produced at the anode instead.**

Question 13

- (a) **B1** contaminated or dirty substrate surface (not properly cleaned) causing poor adhesion
- (a) **B1** impurities or incorrect concentration in the plating solution or presence of dissolved oxygen causing pitting
- **(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) **M1** suggests cleaning and degreasing the substrate or controlling current density or adjusting solution composition
- (b) **A1** links this to improved adhesion or reduced pitting (e.g. 'clean substrate and reduce current density to give smoother, adherent deposit')
- **(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 14

- (a) **M1** calculate total charge: Q = I x t = 0.25 x 120 = 30 C
- (a) **M1** convert to moles electrons: n(e-) = 30 / 96500 = 3.11e-4 mol and moles H2 = n(e-) / 2
- (a) **A1** give volume H2 = mol H2 x 24.0 dm3 = 3.73 cm3 (0.00373 dm3 -> 3.73 cm3) cao
- **(a) Answer: 3.73 cm3**
- (b) **B1** gives two plausible causes such as measurement error, gas lost during collection, incomplete separation of gases, side reactions, or inaccurate current/time
- **(b) Answer: The measured 20.0 cm3 is much larger than the theoretical 3.73 cm3; possible reasons include inaccurate gas collection (gas leakage or wrong reading), side reactions producing additional gas, incorrect current or timing, or dissolved gas coming out of solution.**

Question 15

- **Level 3** (5-6): Detailed evaluation with a clear recommendation. Compares both options across quality, rate, cost and environmental/safety factors. Supports recommendation with reasoned chemistry and consideration of trade-offs.
- **Level 2** (3-4): Some comparison and partial evaluation. Identifies advantages and disadvantages of both options but recommendation is limited or not fully justified.
- **Level 1** (1-2): Simple statements about one or both options with little or no comparison or justification.
- **Indicative content:**
  - Lower current density: produces smoother, more adherent, less pitted coating; reduces defects and rework; increases production time so labour and energy per part may rise; may reduce waste and environmental impact from rejects.
  - Adding brightener: can improve appearance and deposition rate or grain structure allowing same production time; adds chemical cost and may introduce disposal and safety issues; brighteners may require monitoring and can affect bath lifetime.
  - Consider trade-offs: lower current density improves quality but reduces throughput; brightener may preserve throughput but increases recurring chemical costs and environmental burden.
  - Recommendation example: if quality and long-term reduction in rejects and warranty costs are critical choose lower current density; if throughput and short-term profit are critical and brightener disposal can be managed responsibly, choose brightener. Support recommendation with cost-benefit reasoning and safety/environment considerations.