IG.C8 Electrolysis of Molten and Aqueous Compounds

EDEXCEL 4CH1 · Calculator allowed · about 50 minutes

Total Marks

Name: ______________________________ Date: ____ / ____ / ______

Answer ALL questions. Show all your working.

1 Describe, in the context of electrolysis in a chemistry laboratory, what is meant by the term 'electrolysis'.

(Total for Question 1 is 2 marks)

2 Define the term 'electrolyte' as used when discussing molten or aqueous electrolysis.

(Total for Question 2 is 1 mark)

3 Describe how inert electrodes differ from reactive electrodes during electrolysis, giving one example of an inert electrode material used in the laboratory.

(Total for Question 3 is 2 marks)

4 Predict the products formed at the cathode and at the anode during the electrolysis of molten lead(II) bromide, PbBr2, using inert electrodes. Describe briefly what is discharged at each electrode.

(Total for Question 4 is 4 marks)

5 Write balanced half-equations for the electrode reactions that occur during electrolysis of molten lead(II) bromide, showing electrons explicitly.

(Total for Question 5 is 3 marks)

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6 Predict the products at the electrodes when aqueous sodium chloride solution is electrolysed using inert electrodes. State what is formed at the cathode and at the anode.

(Total for Question 6 is 3 marks)

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7 Write balanced half-equations, including electrons, for the electrode reactions that explain the products seen in Question 6 for aqueous sodium chloride electrolysis with inert electrodes.

(Total for Question 7 is 3 marks)

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8 Predict the products at the electrodes when aqueous copper(II) sulfate is electrolysed using inert electrodes, and state the colour change if any in the solution.

(Total for Question 8 is 2 marks)

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9 Describe briefly how electroplating is carried out using copper electrodes and a copper(II) sulfate solution, and explain why using a copper anode is important in this reactive-electrode method.

(Total for Question 9 is 4 marks)

10 Explain, with reference to the ions present and the concept of preferential discharge, why electrolysis of molten lead(II) bromide gives different products from electrolysis of an aqueous solution of lead(II) bromide. Refer to what is discharged at each electrode in both molten and aqueous cases.

(Total for Question 10 is 6 marks)

Mark scheme · IG.C8 Electrolysis of Molten and Aqueous Compounds

Question 1

- **B1** an electrical method that uses an external direct current to cause a chemical change
- **B1** specifically, it causes ions to move to electrodes and be discharged producing elements or new substances
- **Answer: Electrolysis is the use of an external direct current to cause a chemical change by moving ions to electrodes where they are discharged to make elements or new substances.**

Question 2

- **B1** a substance that contains ions and conducts electricity when molten or in solution
- **Answer: A substance that contains ions and conducts electricity when molten or dissolved in water.**

Question 3

- **B1** inert electrodes do not react or dissolve and only provide a surface for electron transfer
- **B1** example: carbon (graphite) or platinum as an inert electrode material
- **Answer: Inert electrodes do not chemically react or dissolve, they only provide a surface for electron transfer; example: carbon (graphite) or platinum.**

Question 4

- **B1** at the cathode: Pb^{2+} ions are discharged to form lead metal
- **B1** at the anode: Br^- ions are discharged to form bromine gas, Br_2
- **B1** states lead metal is produced at the negative electrode and bromine gas at the positive electrode
- **B1** correct mention that electrodes are inert so products come from the molten ions only
- **Answer: Cathode: Pb^{2+} discharged to Pb metal. Anode: Br^- discharged to Br_2 gas. Inert electrodes mean products are from the ions in the melt.**

Question 5

- **M1** correct cathode half-equation: $Pb^{2+} + 2e^- \rightarrow Pb$
- **M1** correct anode half-equation: $2Br^- \rightarrow Br_2 + 2e^-$
- **A1** both half-equations balanced and electrons shown cao
- **Answer: Cathode: $Pb^{2+} + 2e^- \rightarrow Pb$. Anode: $2Br^- \rightarrow Br_2 + 2e^-$.**

Question 6

- **B1** at the cathode: hydrogen gas is produced (H_2), from reduction of water, not Na^+
- **B1** at the anode: chlorine gas is produced (Cl_2), from oxidation of chloride ions
- **B1** states sodium remains in solution as Na^+ and does not discharge at the cathode
- **Answer: Cathode: hydrogen gas (H_2) from reduction of water. Anode: chlorine gas (Cl_2) from oxidation of Cl^-; sodium remains as Na^+ in solution.**

Question 7

- **M1** correct cathode half-equation: $2H_2O + 2e^- \rightarrow H_2 + 2OH^-$ (or $2H^+ + 2e^- \rightarrow H_2$ with explanation of source)
- **M1** correct anode half-equation: $2Cl^- \rightarrow Cl_2 + 2e^-$
- **A1** equations balanced and consistent with stated products cao
- **Answer: Cathode: $2H_2O + 2e^- \rightarrow H_2 + 2OH^-$. Anode: $2Cl^- \rightarrow Cl_2 + 2e^-$.**

Question 8

- **B1** at the cathode: copper metal is deposited from reduction of Cu^{2+}
- **B1** at the anode: oxygen gas is produced from oxidation of water/ OH^-; solution becomes paler as Cu^{2+} is removed
- **Answer: Cathode: copper metal deposited. Anode: oxygen gas produced. The blue colour of Cu^{2+} in solution becomes paler as copper ions are removed.**

Question 9

- **B1** description: the object to be plated is the cathode and a copper block is the anode, both immersed in $CuSO_4$ solution
- **B1** copper ions are reduced at the cathode to coat the object with copper
- **B1** the copper anode dissolves producing Cu^{2+} ions to replace those removed from the solution
- **B1** explanation: using a copper anode keeps the Cu^{2+} concentration steady so plating is even and the solution does not become depleted
- **Answer: The item to be plated is the cathode, a copper block is the anode, and both sit in $CuSO_4$ solution. Cu^{2+} is reduced at the cathode to form a copper coating; the copper anode dissolves to supply more Cu^{2+}, keeping the solution concentration steady for even plating.**

Question 10

- **Level 1** (1-2): Gives a basic statement about different products in molten and aqueous electrolysis, or lists one correct electrode product for one case.
- **Level 2** (3-4): Explains the ions present in molten $PbBr_2$ and in aqueous $PbBr_2$ and identifies which ion is discharged at each electrode in both cases, with partial reasoning about preferential discharge.
- **Level 3** (5-6): Clearly explains that in molten $PbBr_2$ only Pb^{2+} and Br^- are present so Pb^{2+} is reduced at the cathode to Pb and Br^- is oxidised at the anode to Br_2, while in aqueous $PbBr_2$ water is also present so at the cathode H^+ or metal ion is considered and compares reactivity to show Pb^{2+} is discharged rather than H^+, and at the anode explains that OH^- or Br^- may be oxidised, giving justified conclusion on products and mentioning how electrode type can affect the outcome.
- **Indicative content:**
  - Molten $PbBr_2$ contains only Pb^{2+} and Br^-; no water is present so the ions from the compound are discharged at the electrodes.
  - Molten case: at cathode $Pb^{2+} + 2e^- \rightarrow Pb(s)$; at anode $2Br^- \rightarrow Br_2(g) + 2e^-$.
  - Aqueous $PbBr_2$ contains Pb^{2+}, Br^- and H_2O, so water can be involved in electrode reactions.
  - Preferential discharge rules: the less reactive positive ion is discharged at the cathode; compare Pb^{2+} and H^+ relative reactivity to explain which is reduced.
  - In many aqueous cases Pb^{2+} is less reactive than hydrogen and so Pb^{2+} is still reduced to Pb at the cathode, but student should discuss possibility of H_2 if metal is more reactive than H.
  - At the anode in aqueous solution either Br^- or OH^- (from water) may be oxidised; halide ions are often oxidised in preference to OH^- if halide concentration is significant, producing Br_2.
  - Mention that inert versus reactive electrode may change observation, for example a reactive anode could dissolve, altering ion concentrations.