

# Splitting compounds with electricity

Chemistry grades 9-10 (GCSE · IGCSE · O Level · Class 9-10) · Worksheet answers

Each answer shows the method first and then the result in bold. Compare your half equations carefully, because a missing electron or a wrong sign loses marks. Where a calculation has several steps, check that each step uses the right ratio.

**Level:** Chemistry grades 9-10 (GCSE · IGCSE · O Level · Class 9-10) · **Curriculum:** GCSE C4

## Problem 1 Key words

1. A molten or dissolved ionic compound that conducts because its ions move. 2. The negative electrode, where positive ions gain electrons (reduction). 3. The positive electrode, where negative ions lose electrons (oxidation). **Electrolyte = ions free to move; cathode negative; anode positive.**

## Problem 2 Why molten or dissolved?

1. In the solid the ions are held in fixed positions in the lattice, so no charge can flow. 2. When molten the ions are free to move, so positive ions go to the cathode and negative ions to the anode, carrying charge. **Mobile ions are needed for current.**

## Problem 3 Molten potassium iodide

1.  $K^+$  (positive ions go to the negative cathode). 2. Cathode: potassium metal; anode: iodine. 3.  $2I^- \rightarrow I_2 + 2e^-$ . **Cathode: potassium; anode: iodine.**

## Problem 4 Reading a cell diagram

1. Electrode B. 2. The long thin line of the battery symbol is the positive terminal and the short thick line is the negative terminal. B is joined to the short thick line, so B is negative, the cathode. 3. Positive ions move to B, to the right. **B is the cathode.**

## Problem 5 Products from molten salts

1. Cathode zinc, anode chlorine. 2. Cathode sodium, anode bromine. 3. Cathode magnesium, anode oxygen. **Metal at the cathode, non-metal at the anode.**

## Problem 6 Complete the half equations

1. Na. 2.  $2e^-$ , giving  $2Cl^- \rightarrow Cl_2 + 2e^-$ . 3. Cu. 4. Equations 1 and 3 gain electrons, so they are reductions at the cathode. **Reductions:  $Na^+$  and  $Cu^{2+}$ .**

**Problem 7 Three aqueous electrolytes**

1. Copper is less reactive than hydrogen, so copper forms at the cathode; chloride is a halide, so chlorine forms at the anode. 2. Hydrogen at the cathode; no halide, so oxygen at the anode. 3. Sodium is more reactive than hydrogen, so hydrogen forms; nitrate is not a halide, so oxygen forms. **1: Cu and Cl<sub>2</sub>; 2: H<sub>2</sub> and O<sub>2</sub>; 3: H<sub>2</sub> and O<sub>2</sub>.**

**Problem 8 Why hydrogen, not sodium?**

1. Na<sup>+</sup> and H<sup>+</sup> (from water). 2. Sodium is more reactive than hydrogen, so H<sup>+</sup> gains electrons more readily and hydrogen gas is released. 3. Na<sup>+</sup> and OH<sup>-</sup> remain, that is sodium hydroxide solution. **Sodium hydroxide solution.**

**Problem 9 Gas volumes from acid**

1. X is hydrogen (cathode, larger volume); Y is oxygen. 2.  $2\text{H}^+ + 2\text{e}^- \rightarrow \text{H}_2$ . 3. Two electrons make one H<sub>2</sub>, but four electrons are needed for one O<sub>2</sub> ( $4\text{OH}^- \rightarrow \text{O}_2 + 2\text{H}_2\text{O} + 4\text{e}^-$ ). The same electrons therefore give two H<sub>2</sub> for every one O<sub>2</sub>. **X: hydrogen 18 cm<sup>3</sup>; Y: oxygen 9 cm<sup>3</sup>, ratio 2 : 1.**

**Problem 10 Matching products to uses**

1. Hydrogen, chlorine and sodium hydroxide. 2. Chlorine: disinfectant and bleach; sodium hydroxide: soap making; hydrogen: fuel. 3. H<sup>+</sup> ions are removed as hydrogen gas, leaving OH<sup>-</sup> and Na<sup>+</sup> in solution. **H<sub>2</sub> fuel, Cl<sub>2</sub> disinfectant, NaOH soap.**

**Problem 11 Copper plating**

1.  $\text{Cu}^{2+} + 2\text{e}^- \rightarrow \text{Cu}$ . 2. Two electrons per atom:  $0.20 \div 2 = 0.10$  mol. 3.  $0.10 \times 64 = 6.4$  g. **6.4 g of copper.**

**Problem 12 Refining copper**

1. Anode:  $\text{Cu} \rightarrow \text{Cu}^{2+} + 2\text{e}^-$ . Cathode:  $\text{Cu}^{2+} + 2\text{e}^- \rightarrow \text{Cu}$ . 2.  $12.8 - 0.8 = 12.0$  g. 3.  $12.0 \div 12.8 \times 100 = 93.75\%$ . **12.0 g dissolves; the anode is 93.8% pure.**

**Problem 13 Silver-plated spoon**

1. The cathode, so positive silver ions reach it. 2. A bar of pure silver, which replaces the ions used. 3.  $\text{Ag}^+ + \text{e}^- \rightarrow \text{Ag}$ . **Spoon = cathode;  $\text{Ag}^+ + \text{e}^- \rightarrow \text{Ag}$ .**

**Problem 14 Balance the half equations**

1.  $\text{Al}^{3+} + 3\text{e}^- \rightarrow \text{Al}$ . 2.  $2\text{O}^{2-} \rightarrow \text{O}_2 + 4\text{e}^-$ . 3.  $2\text{Br}^- \rightarrow \text{Br}_2 + 2\text{e}^-$ . **3e<sup>-</sup>; 2 and 4e<sup>-</sup>; 2 and 2e<sup>-</sup>.**

**Problem 15 Cost of an aluminium plant**

1. It dissolves the oxide so the mixture melts near 950 °C, saving energy. 2. Oxygen formed at the anodes reacts with the hot carbon and burns it away. 3.  $C + O_2 \rightarrow CO_2$ . **C + O<sub>2</sub> → CO<sub>2</sub>.**

**Problem 16 Current and mass**

1. 0.40 g. 2. 1.0 A:  $0.60 \div 30 = 0.020$  g/min; 0.5 A:  $0.30 \div 30 = 0.010$  g/min. 3.  $0.15 \div 0.010 = 15$  min. 4. Current is the charge flowing per second, and each  $Cu^{2+}$  needs two electrons, so double the electrons per second deposits double the copper. **0.020 and 0.010 g/min; 15 min.**

**Problem 17 Masses in aluminium extraction**

1.  $54\,000 \div 27 = 2000$  mol. 2.  $Al_2O_3$  gives 2Al, so 1000 mol  $Al_2O_3$ ;  $M = 102$ , so  $1000 \times 102 = 102\,000$  g. 3.  $2Al_2O_3 \rightarrow 4Al + 3O_2$  gives 1500 mol  $O_2$  and each  $O_2$  burns one C:  $1500 \times 12 = 18\,000$  g. **102 kg of  $Al_2O_3$  and 18 kg of carbon.**

**Problem 18 Brine plant output**

1.  $M = 58.5$ ;  $11\,700 \div 58.5 = 200$  mol. 2.  $200 \text{ mol NaOH} \times 40 = 8000$  g. 3.  $100 \text{ mol } Cl_2 \times 24 = 2400 \text{ dm}^3$ . **8.0 kg NaOH and 2400 dm<sup>3</sup> Cl<sub>2</sub>.**

**Problem 19 Carbon or copper electrodes?**

1. Oxygen from hydroxide ions. 2. The copper anode is oxidised and dissolves; the same amount of copper is deposited on the cathode, so the changes are equal. 3. Anode:  $Cu \rightarrow Cu^{2+} + 2e^-$ ; cathode:  $Cu^{2+} + 2e^- \rightarrow Cu$ . 4. With copper electrodes each  $Cu^{2+}$  removed is replaced, but with carbon the  $Cu^{2+}$  is used up. **Copper dissolves at the anode and plates at the cathode.**

**Problem 20 Spot the errors**

1. The anode is positive. 2. Hydrogen forms at the cathode because sodium is more reactive than hydrogen. 3. At the anode chloride ions lose electrons:  $2Cl^- \rightarrow Cl_2 + 2e^-$ . 4. In a solid the ions cannot move, so the salt must be molten or dissolved. **Four errors corrected.**