# C10-12: Electrolysis, metals and reversible reactions

Kettering Science Academy

## 1. Electrolysis

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| **Electrolysis** | Using energy from **direct current** to break compounds down into their **elements**. |
| **Electrolyte** | Electrolytes are **ionic compounds** in the **molten state** or **dissolved in water**. Used for electrolysis because ions can move. |
| **Electrolysis of solids** | Does not work as ions can't move. |
| **Electrodes** | Conducting rods placed in electrolyte, connected to power supply. |
| **Cathode** | Negative electrode where cations (+) are discharged. |
| **Anode** | Positive electrode where anions (-) are discharged. |
| ***PANIC*** | **P**ositive **A**node **N**egative **I**s **C**athode |
| **Cation** | The cation is attracted to the cathode. As cathodes are negative, cations are **positive**. |
| **Anion** | The anion is attracted to the anode. As anodes are positive, anions are **negative**. |
| ***OIL RIG*** | **O**xidation **i**s **L**oss (of electrons)<br>**R**eduction **i**s **G**ain (of electrons) |
| ***AnOx*** | **An**ode is for ***ox***idation |
| ***CaRe*** | **Ca**thode is for **re**duction |
| **oxidAtion** | Oxidation occurs at the **Anode** |
| **reduCtion** | Reduction happens at the **Cathode** |
| **Half-equations** | An equation that shows what happens to just one of the ions during chemical reaction. |
| **Half-equations in electrolysis** | Show electron transfer:<br>Cathode (reduction):<br>$M^+ + e^- \rightarrow M$<br>Anode (oxidation):<br>$X^- \rightarrow X + e^-$ |

## 2. Products of electrolysis

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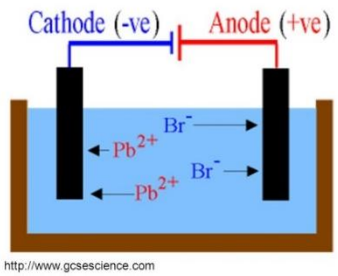
| **Discharged** | When an ion loses its charge to become an atom |
| **Electrolysis of molten salts** | Cathode: metal<br>Anode: non-metal |
| **Ions in salt solutions** | Metal, non-metal and $H^+$ and $OH^-$ because water partially ionises. |
| **Hydrogen half-equation** | $2H^+(g) + 2e^- \rightarrow H_2(g)$ |
| **Electrolysis of salt solutions - cathode** | Metal, unless reactive metal such as K, Na, Li, Mg, Ca in which case hydrogen. |
| **Electrolysis of salt solutions - anode** | Non-metal, unless sulphate salt in which case oxygen. |
| **Electrolysis of sulfuric acid** | Cathode: hydrogen<br>Anode: oxygen |
| **Purifying copper - setup** | Anode: impure copper<br>Cathode: pure copper<br>Electrolyte: copper sulphate solution |
| **Purifying copper - explanation** | Copper atoms leave the anode ($Cu \rightarrow Cu^{2+} + 2e^-$), travel through solution and go to cathode ($Cu^{2+} + 2e^- \rightarrow Cu$). Impure atoms on the anode fall to the bottom as sludge. |

Electrolysis of molten lead bromide




## 3-4. Core practical – electrolysis of copper sulfate solution

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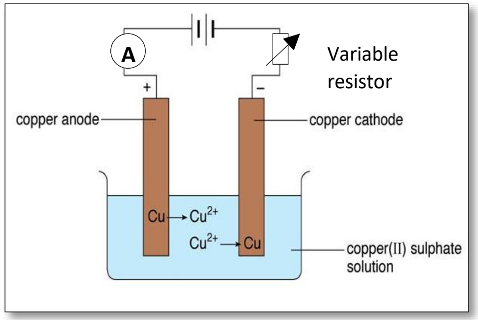
| **Aim** | To see how the changing the current affects the rate of electrolysis. |
| **Prepare electrodes** | Clean two copper electrodes, label one anode and one cathode, weigh each and record mass. |
| **Setup** |  |
| **Run the experiment** | Switch the power supply on, adjust the variable resistor so the ammeter reads 0.2 A and leave for 20 minutes. |
| **Record results** | Carefully remove each electrode, rinse them with propanone. Re-weigh each and record. |
| **Range of results** | Repeat the experiment with a current of 0.3 A, 0.4 A and 0.5 A. |
| **Results** | The anode loses mass whilst the cathode gains mass. The higher the current the greater the mass change. |
| **Common Errors** | The deposited copper on the cathode gets knocked off so you cannot measure it easily |
| **Different ways it can be asked** | Different metals (e.g. silver).<br>Could show a graph.<br>*Triple students* – could link to **electroplating**. |

## 5. Reactivity

**Reactivity series (most to least)**

| | | |
|---|---|---|
| **potassium** | most reactive | **K** |
| **sodium** | | **Na** |
| **calcium** | | **Ca** |
| **magnesium** | | **Mg** |
| **aluminium** | | **Al** |
| **carbon** | | **C** |
| **zinc** | | **Zn** |
| **iron** | | **Fe** |
| **tin** | | **Sn** |
| **lead** | | **Pb** |
| **hydrogen** | | **H** |
| **copper** | | **Cu** |
| **silver** | | **Ag** |
| **gold** | | **Au** |
| **platinum** | least reactive | **Pt** |

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| **Forming cations** | The more reactive metals more easily lose electrons to form cations. |
| **Reaction with cold water ($H_2O(l)$)** | Metal + water → metal hydroxide + hydrogen<br><br>- Potassium – violently<br>- Sodium – very quickly<br>- Calcium – slowly |
| **Reaction only with steam ($H_2O(g)$)** | Metal + water → metal oxide + hydrogen<br><br>Magnesium, zinc, iron |
| **No reaction with water or steam** | Copper, silver, gold |
| **Reaction with acid** | Metal + acid → salt + hydrogen<br><br>- Sodium, potassium – violent<br>- Calcium, magnesium, zinc, iron – steady<br>- Copper, silver, gold – no reaction |

| 6. Displacement reactions | |
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| **Displacement reactions** | Reactions in which a more reactive metal displaces a less reactive metal from a salt eg: *copper sulfate + zinc → zinc sulfate + copper* Does not work backwards as copper is less reactive than zinc. |
| **Redox reactions** | Reactions in which an oxidation and reduction happen at the same time, such as displacement reactions. |
| **Redox during displacement** | The more reactive metal gets oxidised, eg: $Zn \rightarrow Zn^{2+} + 2e^-$ The less reactive metal gets reduced, eg: $Cu^{2+} + 2e^- \rightarrow Cu$ |
| **Spectator ion** | An ion that does not change during a chemical reaction. |

| 7. Extracting metals from their ores | |
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| **Native state** | When metals are found naturally in their pure form, such as silver and gold. |
| **Ore** | Rock containing enough of a metal compound to extract for profit. Normally oxides or sulphides of the metal. |
| **Extracting metals by heating with carbon** | For extracting less reactive metals such as zinc, iron, copper. Works because carbon is more reactive, eg: iron oxide + carbon → carbon dioxide + iron |
| **Extracting metals by electrolysis** | Done with metals more reactive than carbon such as potassium, sodium, calcium, magnesium, aluminium, eg: Aluminium oxide → aluminium + oxygen |
| **Bioextraction** | Using living organisms to extract metals. |
| **Bioleaching** | Growing bacteria on poor quality copper ore. The bacteria produce a solution of copper sulfate from which copper can be extracted by electrolysis. |
| **Phytoextraction** | Plants are grown that absorb metal compounds as they grow. The plants are then burnt to produce ash that is rich in metal compounds. |

| 8. Oxidation and reduction | |
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| **Oxidation** | Gaining oxygen |
| **Reduction** | Losing oxygen |
| **Redox** | Reduction and oxidation reactions always happen together. |
| **Reduction of iron** | Iron produced from iron oxide by heating with carbon: *iron oxide + carbon → carbon dioxide + iron* Iron is reduced, carbon is oxidised. |
| **Reduction of aluminium ore** | Aluminium is produced from aluminium oxide by electrolysis: *Aluminium oxide → aluminium + oxygen* Aluminium is reduced, oxygen is oxidised |
| **Rust** | Is hydrated iron oxide. Only iron *rusts*. |
| **Corrosion** | When metals slowly react with oxygen and/or water, making them weaker. |
| **Rates of corrosion** | More reactive metals corrode more quickly. |
| **Tarnish** | A protective layer of oxide that stops the layers below from corroding. |

| 9. Life-cycle assessment and recycling | |
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| **Recycling** | Converting old waste metal into new metal that can be reused |
| **Advantages of recycling** | - Natural reserves last longer<br>- Less pollution from mining<br>- Less pollution from processing<br>- Less waste in landfill<br>- Often less energy used |
| **Disadvantages of recycling** | - Can be expensive<br>- Can use a lot of energy in transporting, collecting and sorting |
| **Life-cycle assessment (LCA)** | Looks at environmental impact of all stages of a product's lifecycle. We should aim to reduce all damage. |
| **LCA stages** | - Obtaining and processing raw materials<br>- Making and packaging the product<br>- Using the product<br>- Disposal or recycling of the product |

| 10. Dynamic equilibrium | |
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| **Reversible reaction** | Reactions that can go forwards as well as backwards (with products turning back into reactants) |
| $\rightleftharpoons$ | The arrow used for reversible reactions. |
| **Dynamic equilibrium** | The point at which the rate of the forwards reaction and backwards reaction are equal, so the concentrations of reactants and products stops changing. |
| **Closed systems** | Nothing can escape, so dynamic equilibrium can be reached. |
| **Open systems** | Gases can escape so dynamic equilibrium can't be reached. |
| **Equation for making ammonia** | Nitrogen + hydrogen $\rightleftharpoons$ ammonia $N_2 + 3H_2 \rightleftharpoons 2NH_3$ (exothermic) |
| **Haber process** | For making ammonia in factories:<br>- 200 atm pressure – equilibrium shifts right, yield increases<br>- 450°C – equilibrium shifts left, lower yield but MUCH faster reaction<br>- Catalyst – increases reaction rate |

| 11. Changes to equilibrium systems | |
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| **General Rule (Le Chatelier's Principle)** | The equilibrium position shifts to **reduce the effects** of any changes to the system |
| **Effect on equilibrium of increasing temperature** | Exothermic reaction – eqm. shifts left, yield decreases Endothermic reaction – eqm. shifts right, yield increases |
| **Effect on equilibrium of decreasing temperature** | Exothermic reaction – eqm. shifts right, yield increases Endothermic reaction – eqm. shifts left, yield decreases |
| **Effect on equilibrium of increasing gas pressure** | Eqm. shifts to side with fewer gas molecules |
| **Effect on equilibrium of decreasing gas pressure** | Eqm. shifts to side with more gas molecules |
| **Effect on equilibrium of increasing concentration…** | …of products – eqm. shifts left, yield decreases …of reactants – eqm. shifts right, yield increases |
| **Effect on equilibrium of decreasing concentration** | …of products – eqm. shifts right, yield increases …of products – eqm. shifts left, yield decreases |

| Lesson | Memorised? |
|---|---|
| 1. Electrolysis | |
| 2. Products of electrolysis | |
| 3-4. Core prac - electrolysis of copper sulfate | |
| 5. Reactivity | |
| 6. Displacement reactions | |
| 7. Extracting metals from their ores | |
| 8. Oxidation and reduction | |
| 9. Life-cycle assessment and recycling | |
| 10. Dynamic equilibrium | |
| 11. Changes to equilibrium systems (HT) | |