# BioMedical Admissions Test (BMAT)

## Section 2: Chemistry

### Chemistry 12: Electrolysis

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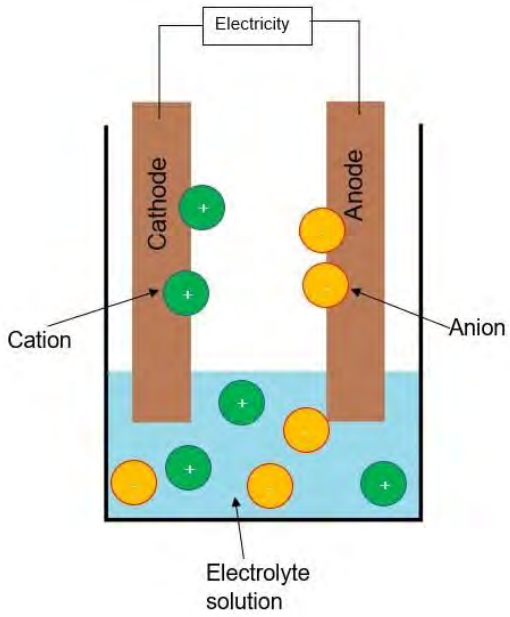
## Key Definitions for Electrolysis

- **Electrolyte:** Molten or aqueous solution containing the ionic compound.
    - The **electrolyte contains free ions,** and this is essential for electrolysis to be able to occur. Free ions **conduct the electricity,** and allow a current to flow; they 'complete the circuit'.
- **Electrode:** A solid electricity conductor which is in contact with the ionic solution. They can be positively or negatively charged and attract the oppositely charged ions.
- **Anode:** The **positively-charged** electrode.
- **Cathode:** The **negatively-charged** electrode.
- **Anion:** Negative ion.
- **Cation:** Positive ion.
- **Potential difference:** This is the difference in electrical charge between two points in a circuit.

## The Process of Electrolysis

The **anode** and **cathode** are connected to a source of electricity. Together, the anode, electrode and cathode **form a circuit** which allows **current** to flow. The current is simply a flow of electrons, and it sets up a **potential difference**.




- ➔ The potential difference in the circuit causes the **cathode to become negatively charged and the anode to become positively charged.**
- ➔ Ions in the **electrolyte** will be attracted to the electrode of the opposite charge: the **anode** or **cathode**. Anions in the solution will move towards the anode and cations will be attracted to the cathode.
- ➔ At the electrodes, the ions will lose or gain electrons to obtain a full outer hell and become more stable. **Anions lose electrons** at the **anode** to become **atoms** or **molecules**, with no overall charge. Loss of electrons is oxidation and so anions are oxidised. For example, $Cl^-$ ions move to the anode where they lose electrons to become Cl atoms or $Cl_2$ molecules.
    - **Cations gain electrons** at the **cathode** to become **atoms** or **molecules**, with no overall charge. Gain of electrons is reduction and so cations are reduced. For

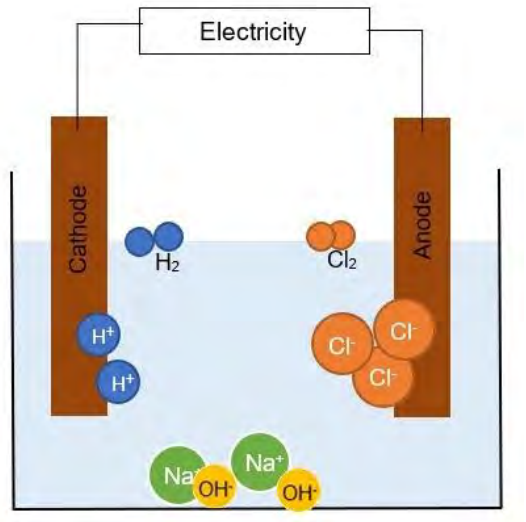
example, $H^+$ ions move to the cathode where they gain electrons to become H molecules.

- The atoms or molecules are often released as a gas or form a solid on the surface of the electrode, causing an increase in the weight and thickness of the electrode.

### Example 1: Electrolysis of Sodium Chloride

Electrolysis of aqueous sodium chloride yields hydrogen and chloride, with aqueous sodium hydroxide remaining in solution.

- The water releases $H^+$ ions.
- **Cations** are attracted to the **cathode**.
  - Cations are positive ions and therefore $H^+$ is a cation.
  - The **cathode is the negative electrode**.
- At the cathode, cations are **reduced**, which means that they **gain electrons**. This converts the $H^+$ ion which was released by the water into hydrogen, which leaves the NaCl solution as hydrogen gas.




Half equation for reactions occurring at the cathode:

$$2H^+ + 2e^- \rightarrow H_{2(g)}$$

- **Anions** are attracted to the **anode**.
  - Anions are negative ions and therefore $Cl^-$ is an anion.
  - The **anode is the positive electrode**.
- At the anode, anions are **oxidised**, which means that they **lose electrons**.
  - This converts the $Cl^-$ ion into chlorine, which leaves the NaCl solution as chlorine gas.

Half equation for reactions occurring at the anode:

$$2Cl^- \rightarrow Cl_2 + 2e^-$$

<u>What happens to the sodium ions?</u>

Sodium ions are positive ions. So why do they not move to the cathode with the hydrogen ions?

- ➔ The $Na^+$ ions will stay in the solution because it is **more reactive than hydrogen** and so the $Na^+$ ion will stay as an ion and the $H^+$ ions will move to the cathode to form hydrogen.
- ➔ However, if the metal ion was less reactive than hydrogen, it would move to the cathode and form the metal atom.

Whether hydrogen or a metal is produced at the cathode therefore depends on the **reactivity series**.

- ➔ If the metal is less reactive than hydrogen, then the metal will be produced at the cathode.
- ➔ If the metal is more reactive than hydrogen, then hydrogen will be produced at the cathode.

| | |
|---|---|
| Most Reactive | Potassium |
| | Sodium |
| | Lithium |
| | Calcium |
| | Magnesium |
| | Aluminium |
| | Carbon |
| | Zinc |
| | Iron |
| | Hydrogen |
| Least Reactive | Copper |
| | Silver |
| | Gold |

The hydroxide ions $OH^-$ released from the water also stay behind in solution and react with the $Na^+$ ions left behind, forming NaOH in solution.

### Example 2: Electrolysis of Hydrochloric acid

Similarly to the electrolysis of aqueous sodium chloride, the electrolysis of HCl also produces hydrogen and chlorine gas.

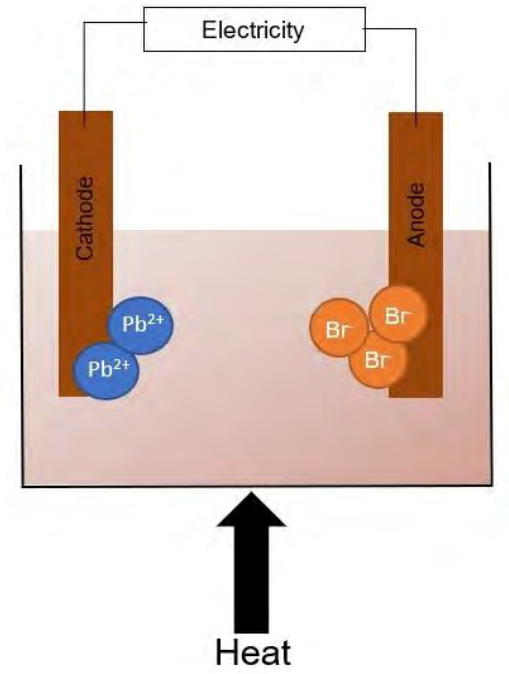
- $H^+$ ions from HCl are attracted to the cathode. Two $H^+$ ions accept 1 $e^-$ to become a $H_2$ molecule.
  - Half equation for reaction occurring at the cathode:
    **$2H^+ + 2e^- \rightarrow H_2$**

- $Cl^-$ ions from HCl are attracted to the anode. 2 $Cl^-$ ions lose $1e^-$ each to form a $Cl_2$ molecule.
  - Half equation for reaction occurring at the anode:
    **$2Cl^- \rightarrow Cl_2 + 2e^-$**

## Example 3: Electrolysis of Molten Lead Bromide

When salts such as lead bromide are **molten**, they will **conduct electricity**.

- ➔ The salt must be molten because the salt is the electrolyte and in order for the ions in the salt to move to the electrodes the ions in the electrolyte must be **free to move**.
- ➔ Ions are only free to move in **aqueous solutions** or in **molten liquids**.




In order to make such salts molten, heat must be applied to the salt which will turn the salt into a liquid form. The ions are now free to move and so can move to the electrodes.

- Lead ions, $Pb^{2+}$ are **positive ions** and so are attracted to the **cathode** (the negative electrode).
- Here, the $Pb^{2+}$ ions are **reduced**, which means they **gain electrons**.
  - Each $Pb^{2+}$ ion gains $2e^-$ to form a lead atom.

Half equation for the reaction occurring at the cathode:

$$\mathbf{Pb^{2+} + 2e^- \rightarrow Pb}$$

- Bromide ions, $Br^-$, are **negative ions** and so are **attracted to the anode** (the positive electrode).
- Here, the $Br^-$ ions are **oxidised**, which means they **lose electrons**.
  - Two bromide ions lose one electron each to become one $Br_2$ molecule.

Half equation for the reaction occurring at the cathode:

$$\mathbf{2Br^- \rightarrow Br_2 + 2e^-}$$

## Electroplating

**Electroplating** is the process of using **electrolysis** to put a thin layer of metal onto another metal. There are many benefits to electroplating, the main benefits being to improve the appearance of the metal and to make it more resistant to corrosion and so by electroplating, the metal can be protected.

When electroplating:

- The **metal ions of the plating metal** which are in the electrolyte solution will be **attracted to the cathode**.
    - This is because the **cathode is negatively charged** and so will **attract the positively charged metal ions**.
- As the metal ions move to the cathode, they will **gain electrons** and **lose their charge**, allowing them to be **deposited** onto the cathode.
- Because the cathode is the original metal you wish to plate, the plating metal is deposited on top of the original metal.
- As the plating metal ions leave the electrolyte solution, more enter the solution from the anode to replace those lost that were deposited onto the cathode.

This means:

- The **anode** should be the **plating metal**, i.e. the metal you wish to cover the other metal in.
- The **cathode** should be the **original metal**.
- The **electrolyte** needs to contain ions of the **plating metal**.

**For example**, if you wanted to **electroplate brass cutlery with silver**.

- The anode would need to be silver
- The cathode would be the brass
- A silver nitrate solution could be used for the electrolyte.

**Example: Electroplating Copper onto metals**

**Anode**: Copper (the electroplating metal)
**Cathode**: Metal to be electroplated
**Electrolyte**: Copper sulfate solution

- Copper ions from the electrolyte are attracted to the cathode. Here they gain electrons to become copper atoms, which are deposited on the cathode, causing this electrode to gain mass.
- Copper ions leave the anode to enter the electrolyte and replace the lost copper ions and therefore the anode decreases in mass.

**Half reactions**:

At the anode: $\mathbf{Cu_{(s)} \rightarrow Cu^{2+}_{(aq)} + 2e^-}$

At the cathode: $\mathbf{Cu^{2+}_{(aq)} + 2e^- \rightarrow Cu_{(s)}}$