Issues related to Electrolysis

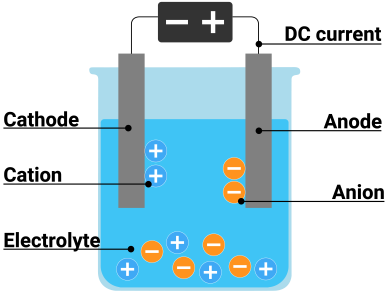
The term electrolysis was first popularized in the 19th century by Michael Faraday. It was a process that helped in the study of chemical reactions in obtaining pure elements. Today, electrolysis is commercially important as it is used widely in separating or obtaining pure elements from naturally occurring sources such as ores. The use of electric current to stimulate a non-spontaneous reaction. Electrolysis can be used to separate a substance into its original components/elements and it was through this process that a number of elements have been discovered and are still produced in today's industry.

# **What is Electrolysis?**

Electrolysis is defined as a process of decomposing ionic compounds into their elements by passing a direct electric current through the compound in a fluid form. The cations are reduced at cathode and anions are oxidized at the anode. The main components that are required for conducting electrolysis are an electrolyte, electrodes, and some form of external power source is also needed. Additionally, a partition such as an ion-exchange membrane or a salt bridge is also used but this is optional. These are used mainly to keep the products from diffusing near the opposite electrode. In Electrolysis, an electric current it sent through an electrolyte and into solution in order to stimulate the flow of ions necessary to run an otherwise non-spontaneous reaction.

An acidified or salt-containing water can be decomposed by passing electric current to their original elements hydrogen and oxygen. Molten sodium chloride can be decomposed to sodium and chlorine atoms.

Electrolysis is usually done in a vessel named ‘electrolytic cell’ containing two electrodes (cathode and anode) connected to a direct current source and an electrolyte which is an ionic compound undergoing decomposition, in either molten form or in a dissolves state in a suitable solvent. Generally, electrodes that are made from metal, graphite and semiconductor materials are used. However, the choice of a suitable electrode is done based on chemical reactivity between the electrode and electrolyte as well as the manufacturing cost.



# **Factors Affecting Electrolysis**

The factors that may affect the electrolysis are;

i) The nature of the electrode

ii) Nature and state of the electrolyte

iii) Nature and electrode potential of ions present in the electrolyte and

iv) Overvoltage at the electrodes.

## **Nature and State of the Electrolyte**

Electrolysis involves the movement of ions towards the oppositely charged electrodes. Naturally, the electrolyte should have mobile ions. In solids, ions are in specific positions and cannot move at ordinary temperatures. Hence, solids are unsuitable for electrolysis.

For electrolysis, electrolyte should be in the liquid form- molten or in solution with a suitable polar solvent. Sodium chloride will undergo electrolysis in the molten state or in aqueous solution.

## **Nature and Electrode Potential of Ions Present in the Electrolyte**

* Electrolysis of electrolytes of two elemental ions is straight forward giving the two elements on electrolysis. Molten sodium chloride gives sodium atoms and chlorine molecule.
* Electrolysis of radical ions does not give the elemental atoms.
* Electrolytes containing more than one ionic compound depends on the relative redox potentials.
* Electrolysis of aqueous solutions of electrolytes. Water molecules also can undergo redox reactions and will compete with redox reactions of the electrolyte ions.
* Electrolysis of molten sodium chloride gives sodium and chlorine. But electrolysis of aqueous sodium chloride gives hydrogen and chlorine and not sodium.

## **Nature of the Electrode**

For the same electrolyte, the nature of the electrolyte may give different products. When aqueous copper sulphate solution is, electrolyzed, the following redox reactions are possible.

At cathode: Reduction at pH =7

**Cu2+ (aq) + 2e– →Cu (s) E° = 0.34V and 2H2O + 2e–→H2 + 2OH– E° = -1.02V**

**At anode: Oxidation at pH = 7**

**Cu(s) →Cu2+ (aq) + 2e– E° = – 0.34V and 2H2O → O2(g) + 4H+ + 4e– E° = +1.4 V**

At the cathode, out of the two electrodes reduction potential of copper ions is more positive than the reduction of water. So, irrespective of electrode, copper ions from the electrolyte will be reduced and deposited on the cathode, increasing its mass. But the reaction at anode depends on the electrode.

Electrolysis with inert electrodes like platinum, graphite, etc. Inert electrodes do not react with the electrolyte or the products and so does not undergo any changes. Since oxidation of water has more positive potential, oxygen will be evolved at the anode.

But, if the copper is used as an anode, it will react with the sulphate ion to retain the electrolyte concentration. So, there will not be any gas evolution. Instead, the anode mass slowly decreases going into the solution.

## **Overvoltage at the Electrodes**.

The redox potential of electrolyte ions decides the electrolysis reactions and products. Sometimes, redox potentials of some half-reactions during the electrolysis is more than the thermodynamic potentials. This excess voltage (over-voltage) of the half-reaction may make the reaction unfavourable and change the product of electrolysis.

In the hydrolysis of aqueous sodium chloride, at the anode, two oxidation reactions can take place. The reduction potential of water and chloride is +0.82V and 0.1.36V respectively.

**2H2O→O2(g) + 4H+ + 4e– E° = -0.82 V**

**2Cl–→ Cl2 + 2e–E = – 1.36V**

Oxidation of water being more positive is more feasible and so, the evolution of oxygen gas should happen at the anode. But, the evolution of oxygen from water has an overvoltage of -0.6V making the voltage for the oxidation of water as -1.42V. Chloride oxidation is more positive than the net voltage of water oxidation. Chloride is oxidized to chlorine at the anode.

# **Magdeburg Research**

Renewable energies such as solar, hydro or wind power are in principal abundant but subjected to strong fluctuations. Therefore, development of new technologies for storage of these renewable energies is of special interest. Electrochemical technologies are ideal candidates for the use of excess current, and consequently an increased electrification of chemical processes is expected. In this respect, there are different pathways to utilize excess current electrochemically. Intermediate energy storages in (a) chemical energy carriers like hydrogen via water electrolysis or (b) electrochemical energy storage devices like batteries are perhaps most accepted and discussed solutions. Additionally, excess current can be used with the main goal not to be stored for later use, but to solve some environmental issue or for construction purposes. Possible applications are waste water treatment and electromachining. The article collection in this special issue consists of one review paper and nine original research papers and discusses these topics in more detail. As a Guest Editor of this special issue, I thank all authors for their contributions and wish all readers interesting insights and new inspirations for their works.

**Electrolysis Processes for Intermediate Energy Storage in Chemical Energy Carriers Like Hydrogen–Water Electrolysis**

There are three main technologies for water electrolysis: alkaline water electrolysis (AEL), proton exchange membrane (or polymer electrolyte membrane) electrolysis (PEMEL), and solid oxide electrolysis (SOEL), with two of them (AEL and PEMEL) at high technical readiness level. Despite these facts and intensive discussions on water electrolysis as a key technology for generation of pure hydrogen using renewable electricity, currently less than 4% of hydrogen originates from electrolysis, with the main part originating not from water but from from chlor-alkali electrolysis where hydrogen is a by-product of chlorine production . Broad introduction of cost competitive and preferably zero carbon routes for hydrogen production is urgently required. In the review paper of Brauns and Turek , some of the main challenges hindering broader penetration of water electrolysis are discussed with a focus on AEL. As the authors write, AEL is a key technology for large-scale hydrogen production powered by renewable energy. However, conventional electrolyzers are designed for operation at fixed process conditions, therefore, the implementation of fluctuating and highly intermittent renewable energy is challenging. Their system analysis enabled important insights and a roadmap for more energy efficient systems. According to these authors, in order to be competitive with the conventional path based on fossil energy sources, each component of a hydrogen energy system needs to be optimized to increase the operation time and system efficiency. They stress that by combining AEL with hydrogen storage tanks and fuel cells, power grid stabilization can be achieved. As a consequence, the conventional spinning reserve can be reduced, which additionally lowers the carbon dioxide emissions.

**Electrolysis Processes for Intermediate Energy Storage in Electrochemical Energy Storage Devices**

Diagram

Description automatically generatedDue to the high power fluctuations that are inherent to renewable energy sources, the dynamics of the storage media is of great importance when designing storage concepts for renewable energy. Electrochemical storage systems showing even better dynamics than batteries are so-called supercapacitors. These devices can be quickly charged and discharged, but have lower energy density than batteries. Still, due to their favorable dynamics, they can be a valuable addition to batteries in the framework of intermediate energy storage from renewables. The storage capacity of these devices depends largely on employed materials. In this special issue, development of novel electrode material for supercapacitor application based on pseudocapacitance is discussed. Guragain et al.developed a large-surface-area MCO2O4 material in which a tubular microstructure leads to a noticeable pseudocapacitive property with the excellent specific capacitance value exceeding 407.2 F/g at 2 mV/s scan rate. In addition, a Coulombic efficiency ~100% and excellent cycling stability with 100% capacitance retention was noted even after 5000 cycles. These tubular MCO2O4 microstructures display peak power density exceeding 7000 W/kg. Based on these authors, the superior performance of the tubular MCO2O4 microstructure electrode is attributed to their high surface area, adequate pore volume distribution, and active carbon matrix, which allows effective redox reaction and diffusion of hydrated ions.

ACKNOWLEDGEMENTS

<https://byjus.com/jee/electrolysis/>

<https://chem.libretexts.org/Bookshelves/Analytical_Chemistry/Supplemental_Modules_(Analytical_Chemistry)/Electrochemistry/Electrolytic_Cells/Electrolysis>

<https://byjus.com/questions/what-are-the-factors-affecting-the-product-of-electrolysis/>

<https://socratic.org/questions/how-does-temperature-affect-electrolysis>

[Electrochemical Energy Conversion, Max Planck Institute for Dynamics of Complex Technical Systems, D-39106 Magdeburg, Germany; vidakovic@mpi-magdeburg.mpg.de](Electrochemical%20Energy%20Conversion,%20Max%20Planck%20Institute%20for%20Dynamics%20of%20Complex%20Technical%20Systems,%20D-39106%20Magdeburg,%20Germany%3B%20vidakovic@mpi-magdeburg.mpg.de)

[rauns, J.; Turek, T. Alkaline water electrolysis powered by renewable energy: A review.](https://www.google.com/search?q=issues+related+to+Electrolysis&rlz=1C5CHFA_enPK943PK943&oq=issues+related+to+Electrolysis&aqs=chrome..69i57j0i512l9.12262j0j7&sourceid=chrome&ie=UTF-8" \l ":~:text=Editorial%20on%20Special,mdpi.com%20%E2%80%BA%20pdf) *[Processes](https://www.google.com/search?q=issues+related+to+Electrolysis&rlz=1C5CHFA_enPK943PK943&oq=issues+related+to+Electrolysis&aqs=chrome..69i57j0i512l9.12262j0j7&sourceid=chrome&ie=UTF-8" \l ":~:text=Editorial%20on%20Special,mdpi.com%20%E2%80%BA%20pdf)* **[2020](https://www.google.com/search?q=issues+related+to+Electrolysis&rlz=1C5CHFA_enPK943PK943&oq=issues+related+to+Electrolysis&aqs=chrome..69i57j0i512l9.12262j0j7&sourceid=chrome&ie=UTF-8" \l ":~:text=Editorial%20on%20Special,mdpi.com%20%E2%80%BA%20pdf)**[,](https://www.google.com/search?q=issues+related+to+Electrolysis&rlz=1C5CHFA_enPK943PK943&oq=issues+related+to+Electrolysis&aqs=chrome..69i57j0i512l9.12262j0j7&sourceid=chrome&ie=UTF-8" \l ":~:text=Editorial%20on%20Special,mdpi.com%20%E2%80%BA%20pdf) *[8](https://www.google.com/search?q=issues+related+to+Electrolysis&rlz=1C5CHFA_enPK943PK943&oq=issues+related+to+Electrolysis&aqs=chrome..69i57j0i512l9.12262j0j7&sourceid=chrome&ie=UTF-8" \l ":~:text=Editorial%20on%20Special,mdpi.com%20%E2%80%BA%20pdf)*[, 248. [CrossRef]](https://www.google.com/search?q=issues+related+to+Electrolysis&rlz=1C5CHFA_enPK943PK943&oq=issues+related+to+Electrolysis&aqs=chrome..69i57j0i512l9.12262j0j7&sourceid=chrome&ie=UTF-8" \l ":~:text=Editorial%20on%20Special,mdpi.com%20%E2%80%BA%20pdf)

[Vorhauer, N.; Altaf, H.; Tsotsas, E.; Vidakovic-Koch, T. Pore network simulation of gas-liquid distribution in porous transport layers.](https://www.google.com/search?q=issues+related+to+Electrolysis&rlz=1C5CHFA_enPK943PK943&oq=issues+related+to+Electrolysis&aqs=chrome..69i57j0i512l9.12262j0j7&sourceid=chrome&ie=UTF-8" \l ":~:text=Editorial%20on%20Special,mdpi.com%20%E2%80%BA%20pdf) *[Processes](https://www.google.com/search?q=issues+related+to+Electrolysis&rlz=1C5CHFA_enPK943PK943&oq=issues+related+to+Electrolysis&aqs=chrome..69i57j0i512l9.12262j0j7&sourceid=chrome&ie=UTF-8" \l ":~:text=Editorial%20on%20Special,mdpi.com%20%E2%80%BA%20pdf)* **[2019](https://www.google.com/search?q=issues+related+to+Electrolysis&rlz=1C5CHFA_enPK943PK943&oq=issues+related+to+Electrolysis&aqs=chrome..69i57j0i512l9.12262j0j7&sourceid=chrome&ie=UTF-8" \l ":~:text=Editorial%20on%20Special,mdpi.com%20%E2%80%BA%20pdf)**[,](https://www.google.com/search?q=issues+related+to+Electrolysis&rlz=1C5CHFA_enPK943PK943&oq=issues+related+to+Electrolysis&aqs=chrome..69i57j0i512l9.12262j0j7&sourceid=chrome&ie=UTF-8" \l ":~:text=Editorial%20on%20Special,mdpi.com%20%E2%80%BA%20pdf) *[7](https://www.google.com/search?q=issues+related+to+Electrolysis&rlz=1C5CHFA_enPK943PK943&oq=issues+related+to+Electrolysis&aqs=chrome..69i57j0i512l9.12262j0j7&sourceid=chrome&ie=UTF-8" \l ":~:text=Editorial%20on%20Special,mdpi.com%20%E2%80%BA%20pdf)*[, 558. [CrossRef]](https://www.google.com/search?q=issues+related+to+Electrolysis&rlz=1C5CHFA_enPK943PK943&oq=issues+related+to+Electrolysis&aqs=chrome..69i57j0i512l9.12262j0j7&sourceid=chrome&ie=UTF-8" \l ":~:text=Editorial%20on%20Special,mdpi.com%20%E2%80%BA%20pdf)