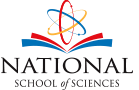
# National School of Science(NSS)



**Electrolysis And Its Application**

**Submitted To Submited By**

**Rashika Khadka John Timalsina**

**758**

**CERTIFICATE OF APPROVAL**

This project work entitled, “**Electrolysis Its Application**” by Mr. John Timalsina under the supervision of, is here submitted for the partial fulfillment of project work of chemistry of grade 11 has been accepted.

Date:

Supervisor

……………………..

Rashika Khadka

Department of chemistry

National School of Sciences

Kathmandu, Nepal

**ACKNOWLEDGEMENT**

It is my greatest fortune to get a very cooperative teacher Rashika Khadka during the work in progress, her support, helpfulness, and constant encouragement kept me motivated in project work. She provided invaluable interest, guidance during the course of work. I am very much grateful towards her.

I would like to express my special thanks of gratitude to all the teachers of department of chemistry of NSS for their constant guidance, encouragement and advice. I would also like to express my gratitude to all the teaching and non-teaching staffs of the National School of Science (NSS).

**Abstract**

This paper looks at the future of electrolysis, a process that’s key to many industries, including hydrogen production, metal refining, and making chemicals. It highlights areas where more research could make electrolysis more efficient and sustainable. For example, developing better electrode materials could improve performance by making them more durable and reducing energy waste. Optimizing electrolytes and exploring eco-friendly options like ionic liquids could also make the process more effective. Additionally, reducing energy losses from overvoltage and using renewable energy sources for electrolysis could help make these processes more sustainable. The paper also looks into how electrolysis could be used for new chemical production and better metal recovery, offering opportunities to create greener solutions. Finally, scaling up electrolysis systems for large industrial applications, while improving their cost-effectiveness and automation, could open the door to even more widespread use. Overall, the paper shows how advancing electrolysis technology could play a key role in building a more sustainable future.

**Table of content**

Introduction---------------------------------------------------- 1-2

Literature review----------------------------------------------- 3-8

Applications----------------------------------------------------- 9-11

Conclusion------------------------------------------------------- 12

Recommendations----------------------------------------------- 13

Reference--------------------------------------------------------- 14

Introduction

Electrolysis may be defined as a chemical process in which electricity is applied to force a chemical reaction to occur. The terminology might be complex for laymen, but it simply means that an electric current is passed through an electrolyte to transform it into a chemically changed substance which usually cannot take place automatically without the application of some energy. Electrolytes which are the substances used in this process are usually dissolved in a solution or are molten compounds containing ions capable of conducting current. The process is crucial in different industries for various purposes including metal recovery and production of chemicals and is also important in research and industrial operations.

Electrolysis has two electrodes: an anode which is a positively charged electrode, and a cathode which is a negatively charged electrode. With application of voltage, ions in the electrolyte will migrate to the electrodes – the cat ions to the cathode and the anions to the anode. The ions reach the cathode and undergo a reduction reaction, which means that electrons are gained by the ions and this process leads to solid or gas products. On the other hand, the anode undergoes oxidation reactions where electrons get lost from ions and different types of chemical compounds or gas are formed. This movement and interaction of ions at the electrodes is the basis of the process of electrolysis.

The best-known use of electrolysis is the extraction of metals from their ores. aluminum, for example, is extracted from its ore called bauxite through the platinum of the electrolyte. During this electrolytic process, aluminum oxide Al₂O₃ is dissolved in molten cryolite, and the electric current is directed through the solution. The aluminum ions' movement to the cathode is then caused by the electric current and the gaining of electrons, they form into aluminum metal on the cathode whereas the oxygen ions move to the anode and release oxygen gas. This is the preferred method because aluminum is a highly reactive metal and cannot be extracted by the traditional methods, such as heating with carbon.

Another important way in which this method is used is in electroplating which is a process where a thin layer of metal is coated onto a surface. One of the most common reasons is that the objects look better but if one is applying a metal with high corrosion resistance, it can protect the part below it from being corroded or improved. A few metals that are mostly used for electroplating are gold, silver, chrome, and copper. The use of electroplating is extremely extensive in industries like jewelry, electronics, and automobile manufacturing, where both the aesthetics and durability of the surface of the products are the vitally needed qualities.

Republic of Electrolysis also makes it possible in the treatment of metal extraction and electroplating though the art of chemistry is very much centered around the electrolysis processes. For instance, the chlor-alkali process is a process that involves the use of electrolyzing salt water to produce chlorine gas, sodium hydroxide, and hydrogen gas. As chlorine is a key industrial chemical which is used for the production of plastics, disinfectants, solvents, while sodium hydroxide is used in soap making and the paper industry In the electrolysis of water, a potential other application, water is broken down to form hydrogen gas and oxygen gas Hydrogen is produced through this is fast becoming an important factor as a fuel for the cars as a pollution-free power plant and in the synthesis of ammonia for the production of fertilizers.

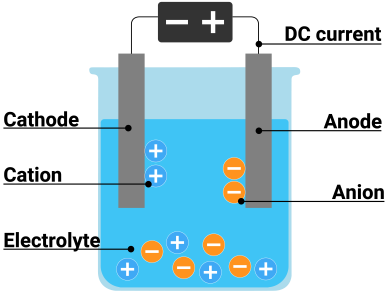
Electrolysis has become an important contributor to the rising hydrogen production as well. Electrolysis in water breaks down the water into hydrogen and oxygen, representing a likely tool for green hydrogen fuel generation according to the most recent studies. Hydrogen can be the power source for fuel cells working in an entirely eco-friendly manner i.e. the only byproduct emitted is water vapor. In light of the growing need for renewable energy solutions, electrolysis has been in the spotlight for its capability to produce hydrogen, an eco-friendly electricity source, thus, giving room to efforts reducing carbon emissions and transforming our energy infrastructure into a more sustainable system.

To sum up, electrolysis has become a crucial process that is used in various industries. The benefits range, among others, from extracting metals like aluminum to the production of chemicals, and even hydrogen which are indispensable to the modern world. The industries are extending their boundaries with the constant search for sustainable methods to be less energy-hungry. Thus the role of electrolysis is expected to become more important, mainly in green technologies, such as hydrogen production and renewable energy storage.

Literature review

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 the cathode, and anions are oxidized at the anode. The main components that are required to conduct 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. They are used mainly to keep the products from diffusing near the opposite electrode.

An acidified or salt-containing water can be decomposed by passing an electric current to its original elements, hydrogen and oxygen. Molten sodium chloride can be decomposed into 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 the chemical reactivity between the electrode and electrolyte as well as the manufacturing cost.

## Electrolytic Process

In the process of electrolysis, there is an interchange of ions and atoms due to the addition or removal of electrons from the external circuit. Basically, on passing current, cations move to the cathode, take electrons from the cathode (given by the supply source battery), and are discharged into the neutral atom. The neutral atom, if solid, is deposited on the cathode and, if gas, moves upwards. This is a reduction process, and the cation is reduced at the cathode.

At the same time, anions give up their extra electrons to the anode and are oxidized to neutral atoms at the anode. Electrons released by the anions travel across the electrical circuit and reach the cathode completing the circuit. Electrolysis involves a simultaneous oxidation reaction at the anode and a reduction reaction at the cathode.

For example, when an electric current is passed through molten sodium chloride, the sodium ion is attracted by the cathode, from which it takes an electrode and becomes a sodium atom.

Chloride ion reaches the anode, gives its electron, and becomes chlorine atoms to form chlorine molecules.

Na+(in electrolyte) + e–(from cathode) → Na …. At Cathode

Cl–(from electrolyte) → e– + Cl → Cl2…. At Anode

The electrolysis process, while useful to get elemental forms from compounds directly, can also be used indirectly in the metallurgy of alkali and alkaline earth metals, purification of metals, deposition of metals, preparation of compounds, etc.

## Cell Potential or Voltage

The minimum potential needed for the electrolysis process depends on the ability of the individual ions to absorb or release electrons. It is also sometimes described as decomposition potential or decomposition voltage which is the minimum voltage (difference in electrode potential) between the anode and cathode of an electrolytic cell that enables electrolysis to occur.

The voltage at which electrolysis is thermodynamically preferred is the difference of the electrode potentials, as calculated using the Nernst equation. Applying additional voltage, referred to as overpotential, can increase the rate of reaction and is often needed above the thermodynamic value. It is especially necessary for electrolysis reactions involving gases such as oxygen, hydrogen or chlorine.

This ability is measured as an electrode potential of the ions present in the electrolytic cell. The cell potential is the sum of the potential required for the reduction and oxidation reaction. The potential involved in various redox reactions is available in literature as standard reduction potential.

Reaction with positive redox cell potentials will only be feasible as per thermodynamic [Gibbs free energy](https://byjus.com/jee/gibbs-free-energy/) (or standard potential). Generally, the electrolysis is thermodynamically controlled.

In electrolysis, a potential equal to or slightly more than that is applied externally. The ions, which are stable and not reacting, are made to undergo reaction in the presence of externally applied potential. External potential, hence, causes an unfavourable reaction to take place. In electrolysis, chemical bonds connecting atoms are either made or broken; hence, electrolysis involves the conversion of electrical energy into chemical energy.

## Faraday’s Law of Electrolysis

The amount of the redox reaction depends on the quantity of electricity flowing through the cell. The amount of reaction or the number of ions discharged is given by Faraday’s law of electrolysis. There are two laws: Faraday’s first law and second law.

Faraday’s first law can be summarised as follows:

. Here, m is the mass of the substance that has undergone change, E is the equivalent mass of the substance, ‘I’ is the current and ”t is the time in seconds of the passing of current.

Faraday’s second law compares the mass of different substances undergoing a change for the same current.

According to the second law,

Here, M and E are the changed mass and equivalent mass of the substances, respectively.

## Product of Electrolysis

The products of electrolysis reactions depend on the oxidising and reducing species present in the electrolytic cell. Electrolysis will produce products present in the compound. When more than one cation and anions are present, each ion will compete for reduction and oxidations. Reactions with more positive redox potentials will be reduced or oxidized in preference to others.

So, in spite of multiple redox couples present, only one can be reduced or oxidized. Sometimes, the ions that are reduced or oxidized may depend on their relative amount. In other words, the redox reaction and electrolysis may become kinetically controlled. In such cases, the product of analysis may differ on the relative concentration of the various ions present in the electrolyte.

For example, electrolysis of aqueous sodium chloride may give different products:

1. Hydrogen and chlorine
2. Hydrogen and oxygen
3. Hydrogen, oxygen and chlorine.

## Factors Affecting Electrolysis

The factors that may affect electrolysis are listed below:

i) The nature of the electrode

ii) Nature and state of the electrolyte

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

iv) Overvoltage at the electrodes.

**i) 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, electrolytes 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 an aqueous solution.

**ii) Nature and Electrode Potential of Ions Present in the Electrolyte**

* Electrolysis of electrolytes of two elemental ions is straightforward, giving the two elements on electrolysis. Molten sodium chloride gives sodium atoms and chlorine molecules.
* Electrolysis of radical ions does not give the elemental atoms.
* Electrolytes containing more than one ionic compound depend 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.

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

Electrolysis with inert electrodes like platinum, graphite, etc. – Inert electrodes do not react with the electrolyte or the products, so does not undergo any changes. Since the 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.

**iv) Overvoltage at the Electrodes**

The redox potential of electrolyte ions decides the electrolysis reactions and products. Sometimes, the redox potentials of some half-reactions during the electrolysis are 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, 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. Chlorine is liberated, and not oxygen, because of overvoltage.

## Electrolysis Applications

Electrolysis, as stated above, is a process of converting the ions of a compound in a liquid state into their reduced or oxidized state by passing an electric current through the compound. Thus, electrolysis finds many applications, both in experimental and industrial products. Some of the important ones are given below:

1) Determination of equivalent weight of substances.  
2) Metallurgy of alkali and alkaline earth metals.  
3) Purification of metals.  
4) Manufacture of pure gases.  
5) Manufacture of compounds like sodium hydroxide, sodium carbonate, potassium chlorate

We will discuss the different applications of electrolysis in detail below.

### Determination of Equivalent Weight of Substances

We know Faraday’s second law states that the mass of substances deposited is proportional to their equivalent weight. The mass of any deposited substance can be, mathematically related as:

M1E2=M2E1

The equivalent mass of an unknown metal or substance can be calculated by passing a known current through the solutions and determining the mass of substances (M1 and M2) deposited in their respective cells. If the equivalent mass of one substance is known, the equivalent mass of the unknown substance can be calculated from the above equation.

### Electrolysis of Molten Salts

Metallurgy of alkali and alkaline earth and third group metals ores of metal is concentrated and converted mostly to oxides. Oxides are reduced with reducing agents such as carbon, aluminium etc. Since alkali and alkali earth metals have the largest reduction potentials, any other metals or their compounds cannot reduce them.

The only way of isolation of alkali and alkali earth metals is to directly electrolyze their molten chlorides. Mixing with other halides, like calcium chlorides, reduces the melting point of pure halides.

### Electrorefining – Purification of Metals

Metals obtained after concentration and reduction of ores have a purity of about 90-99%. An aqueous solution of the metal salt with the impure metal as the anode and the pure metal as the cathode is electrolyzed. The pure metal of more than 99% purity deposits on the cathode, and the impurities are collected at the bottom as mud. Copper and nickel are some examples of the metal purified by electrorefining.

### Electroplating

An object can be coated to the required thickness with a select metal by electrolysis. The object to be coated is made of the cathode. An aqueous solution of the metal salt to be coated is the electrolyte. The same metal or any inert metal can be the anode. In electrolysis, metal ion from the electrolyte deposit on the object. The loss of metal ions in the solution will be compensated if the same metal made the anode.

The deposition can be used to protect the metal from [corrosion](https://byjus.com/jee/corrosion/) for making ornaments, etc. Coating iron with metals like zinc, lead, chromium, and nickel improves the corrosion resistance of iron. Gold and silver coating on cheaper metals is used for making ornaments.

It is also used in electrochemical machining (ECM). Here, an electrolytic cathode is used as a shaped tool for removing material by anodic oxidation from a work piece. ECM technique is often used for deburring or for putting a permanent mark or logo on metal surfaces like tools or knives.

### Electro-forming

Electroforming is a process of making a replica of objects using electrolysis. The object to be replicated is pressed in wax to make a mould. Graphite powder is coated uniformly to make it conductive. This is used as a cathode, and the salt of the metal to be deposited is taken as the electrolyte. After getting the required coating by electrolysis, the wax and the graphite are melted away.

### Manufacture of Pure Gases

Aqueous salts on hydrolysis yield different products depending on the relative concentrations of salt and water. Electrolysis of concentrated brine (sodium chloride) forms pure hydrogen and chlorine gases. Pure chlorine gas is collected in the Chlor-alkali industries by the electrolysis of brine aqueous solution.

Pure hydrogen and oxygen are obtained by hydrolysis of water in the presence of acid or base or inert salt of alkali and alkaline earth metals. The percentage of hydrogen for commercial use is manufactured by the electrolysis of water worldwide.

Continuous electrolysis of water removes all the normal hydrogen isotopes leaving the deuterium ions. The deuterium oxide leftover after electrolysis of normal water is ‘heavy water’. Heavy water is used as a moderator in nuclear reactors producing electrical energy from nuclear reactions.

### Manufacture of Compounds

Compounds like sodium hydroxide, sodium hydrosulphite, potassium permanganate, potassium chlorate, ammonium per-sulphate, heavy water etc., are manufactured by electrolysis. Sodium hydroxide is a side product in the chloralkali industries, preparing chlorine gas by the electrolysis of brine.

Potassium permanganate is obtained by the electrolysis of potassium manganite solution. Ammonium sulphate or ammonium bisulphate on electrolysis forms ammonium persulphate.

### Electro crystallization

This is a specialized application of electrolysis. In this process, conductive crystals are grown on one of the electrodes from oxidized or reduced species that are generated in situ. This technique is popularly used to manufacture single crystals of low-dimensional electrical conductors, such as linear chain compounds or charge-transfer salts.

Conclusion

Electrolysis is a process that decomposes ionic compounds into their elements using an electric current. In this process, cations are reduced at the cathode, while anions are oxidized at the anode. Electrolysis requires an electrolyte (ionic compound in molten or dissolved form), electrodes, and an external power source. Factors such as electrode material, electrolyte composition, and overvoltage significantly influence the products formed. For instance, in the electrolysis of molten sodium chloride, sodium is reduced at the cathode, and chlorine is oxidized at the anode, while in aqueous solutions, water can also undergo oxidation or reduction.

Faraday’s laws describe the relationship between the amount of substance altered and the quantity of electricity passed through the electrolyte. The laws help predict the amount of material deposited or dissolved during electrolysis, depending on the equivalent weight of the substances involved. The electrolysis process is influenced by factors such as the nature of the electrolyte, the electrode material, the electrode potential of ions, and overvoltage. Overvoltage can cause unfavorable reactions, like the oxidation of chloride ions instead of water, which can shift the expected products.

Electrolysis has several important industrial and experimental applications. It is used in metal purification (electrorefining), electroplating, and electroforming, where it deposits metals onto objects. Electrolysis is also crucial for producing pure gases like hydrogen and chlorine and for synthesizing chemicals such as sodium hydroxide and potassium chlorate. The technique plays a key role in manufacturing heavy water for nuclear reactors and in producing valuable chemical compounds. By controlling various factors in electrolysis, industries can optimize production, improve product quality, and reduce costs.

Electrolysis is a fundamental process with a wide range of applications in industry and science. Understanding the principles of electrolysis, including the influence of electrode materials, electrolyte properties, and overvoltage, allows for more efficient and targeted use of the process in diverse fields such as metallurgy, chemical manufacturing, and energy production.

Recommendations

1. **Better Electrode Materials**: One area that could benefit from research is the development of new electrode materials. By finding materials that conduct electricity more efficiently, resist corrosion, and reduce overvoltage, we can make the electrolysis process more energy-efficient. This could be especially useful for industries that rely on electrolysis to produce chemicals like hydrogen and chlorine.
2. **Optimizing Electrolytes**: The type of electrolyte used plays a major role in how effectively electrolysis works. Research could focus on creating new electrolytes or improving existing ones to increase the movement of ions, boost reaction speeds, and cut down energy use. Exploring more eco-friendly alternatives, such as using ionic liquids, could also make electrolysis greener.
3. **Reducing Overvoltage**: Overvoltage, or the extra energy needed to drive certain reactions, can waste a lot of energy in electrolysis. Finding ways to reduce overvoltage—maybe by developing better catalysts or modifying the electrode surfaces—could make electrolysis more efficient and predictable. This would be particularly helpful in processes that involve the production of gases like hydrogen and oxygen.
4. **Making Electrolysis More Energy-Efficient**: With the growing demand for sustainable energy solutions, it's important to explore how electrolysis can be powered by renewable energy sources like solar or wind. This could make processes like hydrogen production more eco-friendly and cost-effective. Research on improving the energy efficiency of electrolysis systems, including ways to recover and reuse heat, could help reduce both costs and environmental impact.
5. **New Applications for Electrolysis**: Electrolysis has the potential to be used for more than just producing basic chemicals. Future research could explore how electrolysis can be used to create new chemicals for industries like pharmaceuticals, agriculture, and even green chemistry. Developing more precise and efficient methods could open up exciting possibilities for sustainable chemical production.
6. **Improving Metal Recovery**: Electrorefining is an important process in recovering valuable metals, and there’s still room to improve it. Research into more efficient methods for recovering metals, especially from complex ores and recycling waste materials, could help reduce the need for mining and support a more sustainable, circular economy.
7. **Scaling Up for Industry**: Lastly, research should focus on making electrolysis systems more practical for large-scale industrial use. By improving the design, durability, and automation of electrolysis cells, we can make them more cost-effective and reliable for producing essential chemicals and gases in large quantities.

Reference

* Faraday, M. (1834). *The Chemical Effects of the Electric Current*. Philosophical Transactions of the Royal Society of London, 124, 77–122.
* Gaddy, J. L., & Huggins, R. A. (1982). *Electrolysis and its Application to Hydrogen Production*. Journal of Electrochemical Society, 129(11), 2530–2536.
* Cherepanov, L. (2010). *Electrochemical Process Engineering*. John Wiley & Sons.
* "Electrolysis of Water: From Science to Technology." (2019). International Journal of Hydrogen Energy, 44(6), 3234–3246.
* Lide, D. R. (2005). *Handbook of Chemistry and Physics*. CRC Press.
* Dutta, A., & Ghosh, S. (2020). *Electrolysis: Industrial and Emerging Applications*. Springer.
* "Hydrogen Production and Storage: The Electrolysis Advantage." (2021). Journal of Energy Storage, 29, 101–110.