experimentally selected. The soil types that were used in the second experiment were determined empirically. Our research has shown that soils that have been used in a hydroponic system can replace traditional soil in the extreme conditions of space. Then, in the second stage, the effectiveness of the selected soils was compared by growing certain plants in hydrogel, perlite and in a mixture of the two soils.

Keywords: microgreens, growing microgreens, perlite, hydrogel, hydroponic system.

Поступила в редакцию: 19.01.2024
Одобрена: 11.03.2024
Первая публикация на сайте: 05.01.2025

МРНТИ: 31.15.33

ELECTROCHEMICAL PRODUCTION OF METALS FROM ITS SALTS AQUEOUS SOLUTION

*[1]A.A.KANAFIN, [1]K.V.MANASHEVA
[1]Nazarbayev Intellectual School of Chemistry and Biology direction in Almaty
(Almaty, Kazakhstan)
*kanafin_a0611@hbalm.nis.edu.kz, manasheva_v@hbalm.nis.edu.kz

Abstract
The electrolyzer, at its core, involves applying an electric current through an aqueous solution containing ionic forms of metals. This intricate process orchestrates the oxidation of metal atoms at the anode and the concurrent reduction of identical metal atoms at the cathode. This controlled electrochemical interplay leads to the disintegration of solution components into their elemental constituents. The potential applications of metal production in aqueous solutions using electrolyzers extend to the realms of manufacturing metal materials, batteries, solar cells, and other technologies. Electrolyzers are a promising field of research for metal production in aqueous solutions, offering the efficient utilization of renewable energy sources and a reduced environmental footprint. This comprehensive article delves into the array of existing electrolyzer technologies designed to produce metals within a solution and its pivotal role within the contemporary landscape of metal material fabrication. This article provides an overview of the current state and future prospects of lead electrorefining in China, focusing on diaphragm and bipolar membrane technologies. Theoretical modeling, process simulation, and economic analysis Statistical analysis, cost-benefit analysis Investigated the research progress and application potential of electrolysis technology, including energy efficiency and environmental impact. Moreover, research endeavors pivot towards the development of efficient, eco-friendly electrolysis systems leveraging renewable energy resources like solar or wind power. The potential applications of metal production using electrolysis extend to the realms of manufacturing metal materials, batteries, solar cells, and other technologies. This research sheds light on the potential of BPMs for a more sustainable future.
Keywords: electrolysis; electrochemistry; chemical production; hydrometallurgy; ecology.

Introduction

The quest for more efficient methodologies in metal production has been a central focus for engineers and scientists in recent years. One of the promising methods that have garnered attention is the utilization of electrolyzers for synthesizing metals within aqueous solutions. This process relies on the fundamental principle of electrochemical water decomposition, aiming to separate diverse metallic elements.

The electrolyzer, at its core, involves applying an electric current through an aqueous solution containing ionic forms of metals. This intricate process orchestrates the oxidation of metal atoms at the anode and the concurrent reduction of identical metal atoms at the cathode. This controlled electrochemical interplay leads to the disintegration of solution components into their elemental constituents.

Initially confined to the realms of chemistry and alkali production, this technology has evolved to gain prominence as a viable avenue for the production of various metals, including esteemed elements such as gold, silver, and platinum. Moreover, electrolyzers functioning within aqueous environments champion environmental sustainability and energy efficiency, further augmenting their significance within the domain of metal fabrication.

This comprehensive article delves into the array of existing electrolyzer technologies designed for metal production within aqueous solutions. The discourse encompasses an analysis of the operational principles, merits, drawbacks, and prospective trajectories of this method. By engaging with this material, readers will attain a holistic comprehension of the electrolyzers potential in producing metals within aqueous solutions and its pivotal role within the contemporary landscape of metal material fabrication.

A Concise Survey of Key Approaches to Attain Metals from Aqueous Solutions

Recent years have witnessed a burgeoning emphasis on the exploration of efficacious pathways for metal extraction from aqueous solutions. Among these, the electrolyzer emerges as a preeminent and ecologically sound approach. The electrolyzer functions as a transformative device converting chemical energy into electrical energy through electrolytic reactions. In the pursuit of extracting metals within aqueous mediums, the principal process centers on electrolysis. Numerous electrolysis methods are employed for metal production within aqueous solutions. Foremost among them is the anodic deposition technique. Herein, metal ions are conveyed towards the anode and subsequently deposited onto its surface.

Another prevalent technique in metal extraction is the cathode deposition method, wherein the transference of metal ions occurs toward the cathode, facilitating their deposition and transformation into metallic form. Further worth acknowledging is the galvanic decomposition method, a process orchestrating the simultaneous deposition of two distinct metals onto separate electrodes. Each of these methodologies possesses its own set of advantages and drawbacks, dictating the methodological choice based on the desired characteristics of the resultant metal.

Grasping the Essence of Electrolysis

The foundational grasp of electrolysis serves as a pivotal gateway to comprehending the operational paradigm underlying the electrolyzer's role in metal production within aqueous solutions. Electrolysis stands as a process wherein the passage of an electric current induces the chemical disintegration of substances into positively charged ions (cations) and negatively charged ions. In the context of aqueous solutions, this process yields positive metal ions and negative hydroxide ions.

For the execution of electrolysis within an aqueous milieu, a specialized apparatus is indispensable - an electrolyzer. Comprising two electrodes, the anode and cathode submerged within the solution, the former serves as the positive pole while the latter functions as the negative pole. Upon application of a consistent voltage across these electrodes, the anode undergoes oxidation, leading to the migration of positively charged cation ions through the solution towards the cathode.

At the cathode, the inverse reaction transpires - positive ions metamorphose into deposited metal upon the cathode's surface, culminating in the extraction of metals from aqueous solutions through the process of electrolysis.

Environmental Implications and Future Trajectories of Electrolyzers

The current phase of electrolyzer advancement for metal production in aqueous solutions spotlights its environmental repercussions. This spotlight isn't solely a product of burgeoning metal production rates but also a response to heightened societal environmental consciousness.

One of the primary challenges confronting electrolyzers pertains to the generation of slag waste laden with heavy metals and hazardous substances, adversely affecting soil and water resources. To mitigate this issue, ongoing research focuses on novel anode coating materials and refining slag purification systems.

Another crucial facet involves the energy consumption inherent in electrolyzer operations. Traditional methodologies incur substantial electrical energy expenses, resulting in elevated operational costs and detrimental environmental effects. Consequently, research endeavors pivot towards the development of efficient, eco-friendly electrolysis systems leveraging renewable energy sources like solar or wind power.

Main body

Taxonomy of Electrolyzers and Foundational Operating Principles

The systematic categorization of electrolyzers and their core operational principles constitute pivotal elements in crafting efficient aqueous solution metal production systems. Diverse types of electrolyzers abound, encompassing portable, submersible, and centrifuge variants:

- Portable electrolyzers, engineered for use in confined volumes, offer ease of mobility owing to their compact design. Their intrinsic attribute of facilitating precise control over the electrolysis process enables the extraction of metals with elevated purity levels.
- Submersible Electrolyzers, expansive vessels teeming with metal solutions, operate by conducting a current through the solution, inducing metal separation at the electrode. Renowned for their heightened performance, these electrolyzers find extensive application across diverse industrial sectors.
- Centrifuge Electrolyzers, on the other hand, play a pivotal role in purifying metal powders by leveraging centrifugal separation forces to isolate pure metal from impurities.

Fundamental Electrolyzer Operations: Conducting Current Through Metal Solutions

At the crux of electrolyzer functionality lays the fundamental principle of channeling an electric current through a solution housing the target metal, leading to the desired metal's extraction at the electrode.

Global Deployment and Technology Landscape of Electrolyzers

The widespread application of electrolyzers for metal production in aqueous solutions extends across leading nations worldwide. The USA, China and Germany stand at the forefront, employing state-of-the-art electrolyzers known for their exceptional productivity and process efficiency.

Moreover, these global leaders actively invest in advancing electrolyzer technologies, with a particular focus on enhancing efficiency. Recent endeavors delve into the utilization of nanomaterial as anode materials, presenting the potential to escalate reaction rates and curtail energy consumption.

Electrolyzers, ubiquitous in their application across nations, share common traits—comprising a cathode and an anode delineated by a diaphragm or membrane. A paramount component within these systems is a direct current source pivotal for sustaining the electrolysis process.

Distinct Electrolyzer Approaches in Leading Nations

In the United States, a prevalence of electrolyzers grounded in solid oxides is noted, boasting elevated efficiency and longevity. In contrast, China spearheads the development of electrolyzers founded on polymer membranes, aiming to curtail equipment costs while simultaneously amplifying productivity.

Diaphragm cells are commonly used in USA. A diaphragm cell consists of two compartments separated by a porous membrane. Lead chloride solution is circulated through the anode compartment, while electrolyte flows through the cathode compartment. At the electrodes, the following reactions take place:
At anode: $PbCl_2 \rightarrow Pb + 2Cl^-$ (Cl gas is released)

Ar cathode: $2H^+ + 2e^- \rightarrow H_2$ (H gas is released)
Overall reaction: $PbCl_2 + H_2 \rightarrow Pb + 2HCl$ [Ciro E. et al, 2021].

So, let's look at the technical component of electrolyzer in United States of America. Technical Specifications and Performance Metrics:

1. Typical current density for diaphragm cells used in lead production ranges from 150 to 300 A/m² [Mondal A. et al., 2022].
2. Cell voltage typically falls between 2.1 and 2.4 V (ILA, 2022).
3. Energy consumption as for manganese, per ton of lead produced is around 2,500 kWh/t Pb [Tsurtaumia G. et al., 2019].

Diaphragm cells have been criticized for their chlorine gas emissions and wastewater generation. Research is ongoing into cleaner technologies, such as bipolar membranes, which can potentially reduce these environmental impacts. The capital cost of diaphragm cells is relatively low compared to newer technologies. However, their higher energy consumption can lead to increased operating costs. The US Department of Energy supports research and development of advanced electrolysis technologies for metals production, including lead. This could lead to the adoption of cleaner and more efficient electrolyzers in the future.

In China, the adoption of bipolar membrane (BPM) technology for lead production is increasing due to government initiatives and subsidies. Compared to diaphragm cells, BPMs offer energy savings of up to 20%, reducing operating costs and emissions. BPMs are more environmentally friendly as they reduce chlorine gas emissions and wastewater generation. Additionally, BPMs can potentially produce lead with higher purity, making them suitable for specific applications like electronics and batteries [Li W. et al., 2022]. This shift towards BPM technology signifies China's advancement in the chloro-alkali industry and highlights a move towards more efficient and sustainable lead production methods. Also to obtain a BPM that can support currents in a technologically relevant range (>100 mA cm–2) [Blommaert M.A. et al., 2021].

These are the primary choice for lead production in Germany, similar to the US and China. Their well-established technology, simple design, and cost-effectiveness make them attractive options. [ELIA, 2023; BGR, 2022].

Two compartments separated by a porous diaphragm membrane. Lead chloride solution circulates through the anode compartment, while electrolyte flows through the cathode compartment.

At the electrodes, these reactions occur:
Anode: $PbCl_2 \rightarrow Pb + 2Cl^-$ (chlorine gas evolution)
Cathode: $2H^+ + 2e^- \rightarrow H_2$ (hydrogen gas evolution)
Overall: $PbCl_2 + H_2 \rightarrow Pb + 2HCl$

Technical Specifications are the quite same as electrolyzer in United States of America. Bingjie Jin mentioned that suitable parameters of the electrorefining process for production of quite pure lead from MSA medium in this study have a acceptable range as follows: current density varies at 150 - 250 Amper per square metre, electrode spacing is around 3.0 - 6.0 cm, electrorefining temperature approximately 293.5 - 313.5 K degrees which is 19,85-39.85 C degrees, lead concentration 60 - 150 g/L and a free-MSA concentration of 100 g/L. The specific energy consumption was less than 110 kW.h/t-Pb, and the cathodic current efficiency was greater than 99%. The cathodic lead has a lead concentration higher than 99.99%" [Jin B. et al., 2016].

So in order to get acquainted with the methods of using electrolyzers, I suggest considering the following table 1. Undertaking a comprehensive assessment of the advantages and disadvantages inherent in electrolyzers for metals production in aqueous solutions assumes paramount significance. This scrutiny is instrumental in gauging the efficacy and economic viability of this technology for practical implementation.

Table 1

Usage by countries

Country	Dominant Electrolyzer Type	Advantages	Challenges and Future
USA	Diaphragm cells	- Simple and mature technology. - Well-established operation procedures. - Relatively low capital cost.	• Higher energy consumption leads to increased operating costs. • Environmental concerns: chlorine gas emissions and wastewater generation.
China	Diaphragm cells & Bipolar membranes (BPMs)	- Diaphragm cells: Similar to USA, affordable and simple. - BPMs: Energy efficiency (up to 20% savings), cleaner production, and higher lead purity.	• Higher upfront cost: While long-term savings are promising, BPMs have higher initial investment compared to diaphragm cells. • Technological maturity: Research and development efforts continue to optimize BPM performance and address operational challenges. • Market penetration: Despite rapid adoption, BPMs haven't fully replaced diaphragm cells yet, requiring further efforts to encourage widespread use.
Germany	Diaphragm cells	- Well-established technology, simple design, and cost-effective.	• Higher upfront cost compared to diaphragm cells. • Technological development in progress to optimize performance and address operational challenges.

Critical Evaluation of Electrolyzer Merits and Demerits

A pivotal advantage lies in the potential utilization of renewable energy sources, such as solar or wind, within electrolyzer processes, fostering environmental sustainability by diminishing greenhouse gas emissions and mitigating reliance on oil or gas.

Furthermore, electrolyzers operating within aqueous solutions exhibit heightened metal purity, circumventing contamination linked to slag formation or oxidation processes. This, in turn, augments product quality stability.

Conversely, challenges encompass the upfront expenditures associated with initial equipment acquisition and system maintenance. Rigorous control and upkeep of optimal conditions are imperative for ensuring peak efficiency, with potential hindrances posed by the need for a consistent power supply, potentially restricting widespread technology adoption.

Literature review

The literature review focuses on various aspects of lead production, recycling, and electrolysis processes as discussed in recent publications and reports.

The International Lead Association provides insights into the lead production process, highlighting the importance of understanding the various stages involved in lead production [ILA, 2022]. The report from the China Nonferrous Metals Industry Association discusses the development of the lead industry, shedding light on the current status and future prospects within the Chinese market [CNMIA, 2023]. The European Lead Industry Report by ELA offers valuable information on the lead industry in Europe, potentially covering market trends, challenges, and opportunities within the region [ELIA, 2023].

The Bundesanstalt für Geowissenschaften und Rohstoffe provides insights into lead-related data and information, focusing on the lead industry's status and trends in Germany [BGR, 2022].

Research articles by E.Ciro and A.Mondal explore novel processes for lead battery recycling and electrorefining from exhausted lead-acid batteries, showcasing advancements in sustainable lead production methods [Ciro E., 2021; Mondal A., 2022].

Hydro-Electrometallurgical Technology present a novel hydro-electrometallurgical technology for simultaneous production of manganese metal, electrolytic manganese dioxide, and manganese sulfate monohydrate, demonstrating innovative approaches in metal production [Tsurtsumia G. et al., 2019].

Bingjie Jin and David B. Dreisinger discuss a green electrorefining process for producing pure lead from methanesulfonic acid medium, emphasizing environmentally friendly methods in metal refining [Jin B. et al., 2016].

Marijn A. Blommaert et al. investigate bipolar membrane applications within advanced electrochemical energy systems, emphasizing the advantages and challenges associated with this technology [Blommaert M.A. et al., 2021].

Wei Li delve into low-temperature water electrolysis processes, highlighting fundamental principles, progress, and new strategies in sustainable energy conversion through water electrolysis [Li W. et al., 2022].

This literature review encapsulates recent developments and research findings in the field of lead production, recycling, and electrolysis processes from various perspectives across different regions and scientific studies.

Methodology and methods

The methodology used for this literature review involved a structured approach to gather and analyze information on lead production, recycling, and electrolysis processes. Here's a simplified breakdown of the steps followed:

1. Finding Relevant Sources. We searched academic databases and websites for recent (2019-2023) articles and reports on lead industry developments.
2. Choosing What to Include. We selected sources that offered insights into lead production, recycling, and new technologies in the industry.
3. Collecting Information. Key details were extracted from these sources, focusing on advancements in lead processes and sustainability.
4. Analyzing the Data. We looked for common themes and trends in the information to understand the current state of lead production methods.
5. Organizing the Information. The data was grouped based on different aspects like recycling methods, electrolysis techniques, and environmental impacts.
6. Bringing it All Together. The findings were combined to create a clear overview of the latest developments in the global lead industry.
7. Reviewing for Accuracy. We double-checked the methodology and information to ensure it accurately reflects the current state of lead production practices.

This straightforward methodology helped create a comprehensive literature review on lead production, making complex information more accessible and understandable.

Results

By the results of our research, electrolysis shines as a transformative force in metal production. It unlocks diverse metal extraction (gold, silver, platinum) in water, while boasting potential for enhanced energy efficiency and reduced environmental impact compared to traditional methods. This power lies in harnessing electricity to deconstruct substances and precisely extract/deposit metals.

We explored various methods like anodic/cathode deposition and galvanic decomposition, revealing their unique suitability for different metals.

We acknowledge environmental concerns with electrolyzers, like slag waste and energy consumption. Our research identifies promising areas for optimization through advancements in materials, waste purification, and renewable energy integration. To solidify these findings, we recognize the need for robust data on each method's performance, waste composition, and energy consumption.

Discussion

By the fruit of our research, we can summarize a transformative vision for metal production, centered around the potent force of electrolysis. This clean technology, fueled by electricity, dismantles the limitations of traditional methods, paving the way for a future where metal extraction embraces both efficiency and environmental responsibility.

Our discussions delved into the heart of electrolysis, revealing its ability to unlock diverse metals like gold, silver, and platinum from the embrace of aqueous solutions. The process employs various methods, such as anodic and cathode deposition, each wielding its own precision to cater to the unique properties of different metals. While this clean power holds immense promise, we acknowledged the lingering challenges of waste generation and energy consumption. Our discourse, however, ignited a path forward, highlighting promising avenues for optimization through advancements in materials, waste treatment, and the integration of renewable energy sources.

To fully grasp the potential of this revolution, we explored the tapestry of electrolyzer types - portable, submersible, and centrifuge, each possessing unique strengths for tailored applications. We emphasized the paramount importance of understanding the flow of electricity through the solution, for it is the lifeblood of efficient production. Our gaze then shifted to the global landscape, where the United States, China, and Germany stand as trailblazers in this new age of metal production. Diaphragm cells currently reign supreme in lead electrorefining, but the winds of change are blowing. Bipolar membranes (BPMs) are rapidly gaining traction, championed by research like Wei Li which illuminate their potential for cleaner, more efficient lead production with reduced emissions and potentially higher purity [Li W. et al., 2022]. This shift towards sustainability is further exemplified by China's growing embrace of BPMs alongside diaphragm cells, as documented by the China Nonferrous Metals Industry Association [CNMIA, 2023].

Conclusion

In conclusion, electrolyzers stand as a promising realm of research for metal production in aqueous solutions, offering the efficient utilization of renewable energy sources and a reduced environmental footprint. Continued research and development are imperative to enhance the technology's efficiency, economic viability, and industrial applicability. It remains crucial to delve deeper into optimizing electrolyzer operating conditions, catalyst selection, and the development of novel materials for anodes and cathodes.

The potential applications of metal production in aqueous solutions using electrolyzers extend to the realms of manufacturing metal materials, batteries, solar cells, and other technologies. This paves the way for sustainable industrial development and a diminished reliance on finite natural resources such as oil.

In essence, electrolyzers for metal production in aqueous solutions chart a promising trajectory within the ecological domain, with recent endeavors focusing on advancing technologies and ensuring a harmonious balance between efficiency and environmental impact.

References

Blommaert M.A., Aili D., Tufa R.A., Li Q., Smith W.A., Vermaas D.A. (2021) Insights and Challenges for Applying Bipolar Membranes in Advanced Electrochemical Energy Systems.

ACS Energy Letters, 6, 7, 2539-2548. DOI: https://doi.org/10.1021/acsenergylett.1c00618 (date of access: 13.02.2024).
Bundesanstalt für Geowissenschaften und Rohstoffe – BGR (2022) *Rohstoffwirtschaftliche Länderberichte – Blei* [Electronic resource]: URL: https://www.bgr.bund.de/DE/Home/homepage_node.html (date of access: 03.02.2024).
Jin B., Dreisinger D.B. (2016) A green electrorefining process for production of pure lead from methanesulfonic acid medium. *Separation and Purification Technology,* 170, October, 199-207. DOI: https://doi.org/10.1016/j.seppur.2016.06.050 (date of access: 13.02.2024).
China Nonferrous Metals Industry Association (2023) *Lead industry development report* [Electronic resource]: URL: http://www.cmra.cn/en/ (date of access: 11.01.2024).
Ciro E., Lupi C., Mondal A., Pilone D. (2021) Novel lead battery recycling process combining pyrometallurgical anode preparation and electrorefining. *Journal of Sustainable Metallurgy,* 7:1727-1735. DOI: https://doi.org/10.1007/s40831-021-00447-y (date of access: 04.02.2024).
European Lead Industry Association - ELA (2023) *Lead Industry Report* [Electronic resource]: URL: https://uia.org/s/or/en/1100068007 (date of access: 23.01.2024).
International Lead Association (2022) *Lead production process* [Electronic resource]: URL: https://ilac.org/ilac-mra-and-signatories/evaluation-process/ (date of access: 23.01.2024).
Mondal A., Ciro E., Lupi C., Pilone D. (2022) Lead Electrorefining Process from Exhausted Lead Acid Batteries by Using Acidic and Alkaline Electrolytes. *Journal of Sustainable Metallurgy,* 8(4):1-12. DOI:10.1007/s40831-022-00598-6 (date of access: 11.02.2024).
Li W., Tian H., Ma L., Wang Y., Liu X., Gao X. (2022) Low-temperature water electrolysis: fundamentals, progress, and new strategies/ Materials Advances, 14. DOI: https://doi.org/10.1039/D2MA00185C (date of access: 10.02.2024).
Tsurtsumia G., Shengelia D., Koiava N., Lezhava T., Gogoli D., Beriashvili L., Suladze S., Kakhniashvili I. (2019) Novel hydro-electrometallurgical technology for simultaneous production of manganese metal, electrolytic manganese dioxide, and manganese sulfate monohydrate. *Hydrometallurgy,* 186, June, 260-268. DOI: https://doi.org/10.1016/j.hydromet.2019.04.028 (date of access: 17.02.2024).

Сулы ертінді металл тұздарынын электрохимиялық өндірісі

*[1]*А.А.Канафин*, [1]*К.В.Манашева*
[1]*Назарбаев Зияткерлік Мектеб, химия-биология бағыты (Алматы, Қазақстан)*

Аңдатпа
Электролизер жұмысының негізінде металдардың иондық нысандары бар су ерітіндісі арқылы электр тогын өткізу жатыр. Бұл күрделі процесс анодтағы металл атомдарының тотығуына және катодтағы сол металл атомдарының бір мезгілде қалпына келуіне әкеледі. Бұл бақыланатын электрохимиялық өзара іс-қимыл ерітінді компоненттерінің олардың қарапайым құрауыштарына ыдырауына әкеледі. Электролизерлердің көмегімен су ерітінділерінде металдар алудың әлеуетті мүмкіндіктері металл материалдарының, аккумуляторлардың, күн батареяларының өндірісіне және басқа технологияларға қолданылады. Электролизерлер жаңартылатын энергия көздерін тиімді пайдалануды және қоршаған ортаға әсерді азайтуды ұсына отырып, су ерітінділерінде металдар алу үшін перспективалы зерттеу саласы болып табылады. Бұл мақалада ерітіндіде металдар алуға арналған электролизерлердің көптеген қолда бар технологиялары және олардың металл өндірісінің қазіргі заманғы ландшафтындағы негізгі рөлі қаралады. Мақалада мембраналық және биполярлық технологияларға баса назар аудара отырып, Қытайдағы қорғасынды электрорафиндаудың ағымдағы жай-күйі мен болашақ перспективаларына шолу ұсынылған. Теориялық модельдеу, процестерді имитациялау және экономикалық талдау Статистикалық талдау, шығындар мен пайданы талдау Энергия тиімділігі мен қоршаған ортаға әсерді қоса алғанда, электролиз технологиясын қолдану әлеуеті мен зерттеу барысын зерделеу. Бұдан басқа, зерттеу күш-жігері күн немесе жел энергиясы сияқты жаңартылатын энергия көздерін пайдаланатын тиімді, экологиялық таза электролиз жүйелерін әзірлеуге бағытталған. Электролиз көмегімен металдарды алудың әлеуетті мүмкіндіктері металл материалдарының,

аккумуляторлардың, күн батареяларының және басқа да технологиялардың өндірісіне қолданылады. Бұл зерттеу тұрақты болашақ үшін ВРМ әлеуетіне жарық түсіреді.
Түйін сөздер: электролиз; электрохимия; химия өндірісі; гидрометаллургия; экология.

Электрохимическое получение металлов из водного раствора их солей

*[1]*А.А.Канафин*, [1]*К.В.Манашева*
[1]*Назарбаевская Интеллектуальная Школа химико-биологического направления (Алматы, Казахстан)*

Аннотация
В основе работы электролизера лежит пропускание электрического тока через водный раствор, содержащий ионные формы металлов. Этот сложный процесс приводит к окислению атомов металла на аноде и одновременному восстановлению атомов того же металла на катоде. Это контролируемое электрохимическое взаимодействие приводит к распаду компонентов раствора на их элементарные составляющие. Потенциальные возможности получения металлов в водных растворах с помощью электролизеров распространяются на производство металлических материалов, аккумуляторов, солнечных батарей и другие технологии. Электролизеры являются перспективной областью исследований для получения металлов в водных растворах, предлагая эффективное использование возобновляемых источников энергии и уменьшение воздействия на окружающую среду. В данной статье рассматривается множество существующих технологий электролизеров, предназначенных для получения металлов в растворе, и их ключевая роль в современном ландшафте производства металлических материалов. В статье представлен обзор текущего состояния и будущих перспектив электрорафинирования свинца в Китае с акцентом на мембранные и биполярные технологии. Теоретическое моделирование, имитация процессов и экономический анализ Статистический анализ, анализ затрат и выгод Изучение хода исследований и потенциала применения технологии электролиза, включая энергоэффективность и воздействие на окружающую среду. Кроме того, исследовательские усилия направлены на разработку эффективных, экологически чистых систем электролиза, использующих возобновляемые источники энергии, такие как солнечная или ветровая энергия. Потенциальные возможности применения получения металлов с помощью электролиза распространяются на производство металлических материалов, аккумуляторов, солнечных батарей и других технологий. Это исследование проливает свет на потенциал ВРМ для более устойчивого будущего.
Ключевые слова: электролиз; электрохимия; химическое производство; гидрометаллургия; экология.

Поступила в редакцию: 10.02.2024
Одобрена: 11.03.2024
Первая публикация на сайте: 05.01.2025

МРНТИ: 81.93.29

INTEGRATED COMPUTER NETWORK SECURITY SYSTEM: SVM-BASED INTRUSION DETECTION AND THREAT PREDICTION USING MACHINE LEARNING ALGORITHMS

*[1]*M.S.UTARBAYEVA*, [1]*M.A.MUKANOVA*
[1]*Nazarbayev Intellectual School of Chemistry and Biology*
(Almaty, Kazakhstan)
utarbaeva_m0512@hbalm.nis.edu.kz, mukanova_m@hbalm.nis.edu.kz

Abstract
With the rapid growth in the use of computer networks and the significant expansion of related applications, cybersecurity issues are becoming increasingly relevant. This paper will provide an overview of solutions to growing network security problems, followed by developing a tool for detecting and preventing cyber threats by analyzing network traffic data from the Security Information and Event Management System (SIEM). Using