Electrolyte for High Efficiency Hydrogen Reactors Version 2.0 from 2024

General Summary

This paper presents the development and analysis of an innovative electrolyte based on titanium dioxide (TiO_2), combined with sodium carbonate (Na_2CO_3), potassium carbonate (K_2CO_3) and calcium oxide (CaO). The focus is to explore the interactions between these compounds and demonstrate how their synergy increases the catalytic efficiency of electrolysis processes, with applications in hydrogen generation and internal combustion engines. The experimental results show a significant increase in energy efficiency and system stability, hydrogen productivity was increased and foaming did not occur during use even after increasing the temperature.

Keywords:

Electrolysis, TiO_2, Sodium Carbonate, Potassium Carbonate, Calcium Oxide, Green Hydrogen, Titanium Dioxide and Catalysts.

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How did it all start?

As already described in my e-book (The Essential Guide to Vehicle Hydrogen), in 2014, after a merger in the company where I worked, I invested a severance package and created a renewable energy company. I had then started to “sniff” HHO and pop bubbles, just like my mentored students did. I was focused on hydrogen production and very motivated by the progress of the tests. After experimenting with several types of hydrogen reactors, there was one gap that was missing to be completely successful in my goal of helping the Hydrogen community in Brazil to achieve fuel economy. To have consistent results, I needed an efficient electrolyte that was environmentally friendly and disposable, while at the same time not posing a risk to the vehicle in which the system was installed. In 2017, I had already used KOH (Potassium Hydroxide) and NaOH (Sodium Hydroxide) separately, and I knew the drawbacks of these two chemical elements. I needed a product that combined the efficiency of these two chemicals, but that did not foam, was not corrosive, did not burn the skin, did not cause damage in the event of an accident, helped maintain the reactor temperature, the ingredients were easy to find, and could be safely disposed of in nature.

Mechanism of the “Sodium-Potassium Pump”

When I began my studies on the best electrolytes known to science, I came across medical articles that described how the Sodium-Potassium Pump (Na^+/K^+-ATPase) works. Nature, over millions of years of evolution, has created incredibly perfect beings, where each essential function uses sodium and potassium masterfully to sustain life. These two elements are fundamental to the functioning of human organs, playing crucial roles in maintaining the electrical potential of cells and regulating vital processes, such as muscle contraction, nerve conduction and water balance. Proper control of these electrolytes is essential for the health and efficient functioning of the body.

I understood that I needed to create a solution based on these two elements, not to reinvent something, but to replicate the perfection of nature that had already developed this ideal system. I then began to study the essential characteristics to achieve efficiency in the process I was developing. I discovered that the working temperature, the ideal proportion between the elements, the concentration of salts in the water and the interaction between them were determining factors in ensuring the efficiency of the electrolysis.

During the tests, I realized that stabilizing the temperature of the liquid was essential to achieve the desired performance, just as occurs in the cells of the human body, whose ideal temperature varies between 37 and 42 degrees Celsius. In addition, I faced challenges such as foam formation, which caused discomfort to users of vehicle hydrogen systems. It was at this point that I began to experiment with chemical elements that could interact with the Sodium Potassium Pump mechanism, helping to eliminate foam and stabilize the process.

Temperature stabilization and optimized interaction of key chemicals proved crucial to ensure the efficiency and reliability of the electrolysis system I was developing. Thus, inspiration from nature guided the project towards results that respect its perfect and functional logic.

With the temperature stabilized and a deeper understanding of chemical interactions, I moved on to choosing the ideal compounds that could reproduce the balance between sodium and potassium, optimizing electrolysis for vehicle hydrogen systems. After extensive research and practical testing, I identified the following elements as pillars for the development of an efficient and safe solution:

- Potassium Carbonate (K_2CO_3)
- Sodium Carbonate (Na_2CO_3)
- Titanium Dioxide (TiO_2)
- Calcium Carbonate ($CaCO_3$)

These compounds were selected due to their ability to promote a stable and effective environment for hydrogen generation, while minimizing the risk of damage to electrodes and system components, preserving the safety of the vehicle and users.

Proportions and Interactions

1. Potassium Carbonate (K_2CO_3)

   - Ideal proportion: 60% of the total electrolyte solution.

   - Function: Potassium carbonate acts as the main conductor of electricity in the solution, allowing efficient electrolysis. Its presence increases the mobility of potassium ions, which have low electrical resistance, optimizing the system's energy consumption. In addition, it helps stabilize the pH of the solution, reducing electrode corrosion.

Another critical benefit of K_2CO_3 is its contribution to increasing the density of the liquid, which reduces the temperature required for efficient electrolysis. This characteristic improves overall performance and reduces the risk of overheating, making the system more reliable and safe.

2. Sodium Carbonate (Na_2CO_3)

- Ideal proportion: 30% of the total electrolyte solution.

- Function: Sodium carbonate complements potassium carbonate by providing sodium ions that balance the electrochemical interaction. It improves system stability and prevents conductivity spikes that could cause overheating.

Furthermore, Na_2CO_3 plays an important role in reducing foam formation during electrolysis. Its regulating action on the surface tension of the liquid prevents the formation of excessive bubbles, which increases the efficiency of gas separation and avoids operational problems.

3. Titanium Dioxide (TiO_2)

- Ideal proportion: 5% of the total electrolyte solution.

- Function: Titanium dioxide acts as a physical and chemical stabilizer, playing an essential role in eliminating foam formation during electrolysis. It drastically reduces the surface tension of the liquid, preventing the accumulation of bubbles that could interfere with the efficient separation of hydrogen and oxygen.

Furthermore, TiO_2 protects the electrodes, creating a protective layer that reduces wear caused by the passage of electric current, significantly increasing the durability of the reactor.

4. Calcium Carbonate ($CaCO_3$)

- Ideal proportion: 5% of the total electrolyte solution.

- Function: Calcium carbonate neutralizes impurities in the solution, preventing the build-up of deposits on the electrodes and other parts of the reactor. It also acts as a buffer, ensuring that the pH remains at ideal levels (close to 8-9), preserving both the efficiency of the reaction and the integrity of the system.

In addition, $CaCO_3$ indirectly contributes to maintaining the density of the liquid, which helps to reduce the operating temperature of the system. As a result, the reactor operates more efficiently and stably, even over long periods of use.

Benefits and Contributions

1. Elimination of Foam Formation:

- The combination of titanium dioxide and sodium carbonate was essential to solve the problem of foam, which used to interfere with the efficiency of electrolysis. These compounds adjust the surface tension of the liquid, preventing the accumulation of bubbles and improving the separation of the gases generated.

2. Reduction of Working Temperature:

- The presence of potassium carbonate as the major component, combined with calcium carbonate, increases the density of the electrolytic liquid. This lowers the temperature required for efficient electrolysis, protecting the system from overheating and extending its service life.

3. Hydrogen Production Efficiency:

- The optimized solution generates hydrogen evenly and continuously, with lower energy consumption, thanks to the ideal ratio of potassium and sodium carbonate.

4. Safety in Use:

- The developed system is stable and does not present significant risks of toxicity or unwanted chemical reactivity, even in the event of leaks or accidents. The absence of aggressive corrosive compounds protects both users and vehicle components.

5. Preservation of Electrodes and System:

- The protective layer formed by titanium dioxide, combined with the neutralizing action of calcium carbonate, reduces electrode wear, minimizing maintenance costs and increasing the durability of the system.

6. Minimizing Damage in Case of Accidents:

- In the event of leaks, the compounds used are safe to handle and do not generate gases or dangerous reactions when in contact with the environment. This protects both the vehicle occupants and the environment.

Conclusion

The development of this solution was guided by the search for efficiency and safety, inspired by the functioning of the Sodium Potassium Pump in the human body. The balanced mixture of potassium carbonate, sodium carbonate, titanium dioxide and calcium carbonate not only ensures efficient hydrogen generation, but also eliminates problems such as foaming, reduces the system's operating temperature and protects critical components. With these advances, it was possible to create a vehicle hydrogen system that combines efficiency, safety and durability, respecting the perfection of nature and integrating cutting-edge technology for the future of sustainable mobility.

Summary

The paper describes the formulation of an electrolyte for water electrolysis, focusing on the synergistic combination of titanium dioxide (TiO_2), sodium carbonate (Na_2CO_3), potassium carbonate (K_2CO_3) and calcium oxide (CaO). TiO_2 acts as the main catalyst, while the carbonates increase the ionic conductivity and CaO controls the pH and stability of the system. The text details the individual properties and interactions between the components, providing instructions for the preparation of the electrolyte, including optimized proportions and monitoring procedures (pH, conductivity, precipitation). The main application is the efficient generation of hydrogen, but applications in vehicle systems are also mentioned.

When developing the HHO Experts electrolyte formula, I sought to meet the needs of an inexpensive electrolyte, whose formula components were easily accessible, and at the same time that would not generate a large environmental impact. Safety in use and handling was also an important factor to consider. The combination of titanium dioxide (TiO_2) with sodium carbonate (Na_2CO_3), potassium carbonate (K_2CO_3) and calcium oxide (CaO) creates a highly efficient synergistic system to act as a catalyst in electrolysis. Each component contributes in a specific way to improving the catalytic properties and efficiency of the electrolysis process. Below is a detailed explanation of how this interaction occurs: 1. Titanium Dioxide (TiO_2):

- **Semiconductor Properties:**TiO_2 acts as a photocatalyst or electrocatalyst due to its ability to absorb light and create electron-hole pairs (e^-/h^+), which promote oxidation and reduction reactions.
- **Active Surface:**TiO_2 has a large surface area, ideal for adsorbing water molecules and increasing the chances of interaction with auxiliary catalysts.
- **Chemical Stability:**It is resistant to corrosion in alkaline environments, ensuring system durability.
- **Synergy with Ions:**TiO_2 interacts with the ions released by carbonates and CaO, helping in the conduction and transfer of charge in the electrolyte.

2. Sodium Carbonate (Na_2CO_3) and Potassium Carbonate (K_2CO_3):

- **Ionic Conductivity:**
  - Both release Na+Na^+Na+, K+K^+K+, and CO32−CO_3^{2-}CO32− ions, increasing the electrical conductivity of the electrolyte.
  - The ions K+K^+K+ and Na+Na^+Na+ facilitate the migration of electrical charge, reducing the resistance of the electrolyte.
- **Catalytic Effect:**
  - The CO32−CO_3^{2-}CO32− ion can form transient complexes with water molecules, facilitating its dissociation into OH−OH^-OH− and H+H^+H+, which accelerates the generation of hydrogen and oxygen gas.
  - The presence of K+K^+K+ and Na+Na^+Na+ ions also influences the stability of the electrode-electrolyte interface, favoring the reactions.

3. Calcium Oxide (CaO):

- **pH control:**
  - CaO reacts with water to form calcium hydroxide Ca(OH)2$Ca(OH)_2$Ca(OH)2, an alkaline compound that increases the pH of the electrolyte, creating a more conducive environment for electrolysis.
  - High pH improves water dissociation and reduces the overpotential required for electrochemical reactions.
- **Surface Activation:**
  - CaO can act as an activator on the TiO_2 surface, creating additional catalytic sites.

    - It forms complexes with CO32−CO_3^{2-}CO32− ions, stabilizing the electrolyte structure and preventing unwanted precipitation.
- **Interaction with Carbonates:**
    - CaO reacts with carbonates under controlled conditions, creating intermediate phases that can improve the dispersion of active materials in the electrolyte.

Component Synergy:

1. **Increased Electrical Conductivity:**
    - The ions released by carbonates and the alkaline environment promoted by CaO reduce the resistance of the electrolyte, increasing the energy efficiency of the system.
2. **Stabilization of the Electrode-Electrolyte Interface:**
    - The interaction between ions and TiO_2 improves the adhesion of water molecules to the catalytic surface, accelerating electrolysis reactions.
3. **Overvoltage Reduction:**
    - The alkaline environment and active sites provided by the materials reduce the energy required to initiate oxidation and reduction reactions.
4. **Increased Catalytic Efficiency:**
    - The combination of TiO_2 with ionic compounds creates heterostructures that favor the separation of electrical charges, increasing conversion efficiency.

Considerations About the Formula:

The combination of these materials creates a multifunctional electrolyte that combines high conductivity, chemical stability and enhanced catalytic properties. TiO_2 acts as the main catalyst, while Na_2CO_3, K_2CO_3 and CaO adjust the physical and chemical properties of the system, creating an ideal environment for electrolysis.

To further optimize the understanding and application of your composite electrolyte, we will detail some additional important aspects:

4. Optimization of Component Proportions:

The efficiency of the electrolyte depends on the correct proportion between the components. Here are some practical guidelines:

1. **Titanium Dioxide (TiO_2):**
    - It should be used in sufficient quantity to maximize the active surface area without forming clumps.
    - Typically, a concentration in the range of 5% to 20% by weight in the electrolyte is effective in ensuring catalytic activity.
2. **Sodium Carbonate (Na_2CO_3) and Potassium Carbonate (K_2CO_3):**
    - A combined carbonate ratio in the range of 1:1 is common, but can be varied to adjust ionic conductivity.
    - The total carbonate concentration is generally between 0.5 M and 1 M to ensure high electrical conductivity and stability.
3. **Calcium Oxide (CaO):**
    - It should be added in small amounts (typically 1% to 5% by weight) to avoid excessive saturation of Ca(OH)2$Ca(OH)_2$Ca(OH)2 in the electrolyte.
    - Its main function is to stabilize the pH, therefore, the quantity must be adjusted according to the desired pH (generally above 12).

5. Detailed Chemical and Structural Interactions:

1. **Primary Reactions in the Electrolyte:**
    - **Carbonates:**Na2CO3+H2O↔2Na++CO32−+H2ONa_2CO_3 + H_2O <--> 2Na^+ + CO_3^{2-} + H_2ONa2CO3+H2O↔2Na++CO32−+H2O K2CO3+H2O ↔2K++CO32−+H2OK_2CO_3 + H_2O <--> 2K^+ + CO_3^{2-} + H_2OK2CO3+H2

O↔2K++CO32−+H2O Carbonates stabilize the electrolyte while providing conductive ions.
    - **Calcium Oxide:**CaO+H2O→Ca(OH)2CaO + H_2O <-- Ca(OH)_2CaO+H2O→Ca(OH)2 Ca(OH)2+CO2→CaCO3(s)Ca(OH)_2 + CO_2 <-- CaCO_3 (s)Ca(OH)2+CO2→CaCO3 (s) (system equilibrium control)
2. **Synergy of TiO_2 with Released Ions:**
    - Titanium dioxide adsorbs water molecules on the surface and, under electrochemical conditions, facilitates the separation of the molecules into OH−OH^-OH− and H+H^+H+.
    - The ions Na+Na^+Na+, K+K^+K+ and CO32−CO_3^{2-}CO32− help to stabilize the reaction intermediates on the TiO_2 surface.

6. pH Control and Electrolyte Stability:

1. **pH maintenance:**
    - A consistently high pH is necessary to maximize electrolysis efficiency.
    - The use of Ca(OH)2Ca(OH)_2Ca(OH)2 from CaO helps maintain a pH above 12, which favors the dissociation of water and reduces the overpotential for hydrogen gas production.
2. **Avoid Unwanted Precipitation:**
    - Add the components slowly and monitor the pH and temperature to avoid excessive formation of precipitates such as CaCO3CaCO_3CaCO3.

7. Ideal Operating Conditions:

1. **Temperature:**
    - A range between 30°C and 80°C is recommended to improve ionic conductivity and catalytic efficiency, without compromising the stability of the materials.
2. **Current Density:**
    - Current density must be optimized to avoid overheating or system degradation. Typical values are between 10 and 50 mA/cm^2.
3. **Continuous Monitoring:**
    - Monitor the pH, temperature and conductivity of the electrolyte periodically to ensure constant performance.

8. Practical Applications and Benefits:

1. **Water Electrolysis:**
    - Excellent for hydrogen gas generation systems in clean energy applications.
    - High efficiency in hydrogen production due to low overpotential.
2. **Vehicle Systems:**
    - It can be used in hydrogen injection systems for internal combustion engines, like the ones you develop.
    - Provides long-term stability and low degradation over extended operating cycles.
3. **Maintenance and Reuse:**
    - The electrolyte can be regenerated, minimizing operating costs.
    - Periodic additions of carbonates or CaO help to extend shelf life.

Below I detail the specific equations, ratios for different applications, and quality control suggestions related to the electrolyte: 1. Specific Equations

The reactions that occur in the system can be divided into stages:

1.1 Dissociation Reactions in the Electrolyte

1. **Sodium Carbonate (Na_2CO_3):** Na2CO3→H2O2Na++CO32−Na_2CO_3 --->{H_2O} 2Na^+ + CO_3^{2-}Na2CO3H2O 2Na++CO32−
2. **Potassium Carbonate (K_2CO_3):** K2CO3→H2O2K++CO32−K_2CO_3 --->{H_2O} 2K^+ + CO_3^{2-}K2CO3H2O2K+ +CO32−
3. **Calcium Oxide (CaO):** CaO+H2O→Ca(OH)2CaO + H_2O <-- Ca(OH)_2CaO+H2O→Ca(OH)2
4. **Formation of Calcium Carbonate:** Ca(OH)2+CO2→CaCO3(s)+H2OCa(OH)_2 + CO_2 <-- CaCO3(s) + H_2OCa(OH)2+CO2 →CaCO3(s)+H2O

1.2 Electrochemical Reactions at the Cathode and Anode

1. **At the Cathode (Reduction):** Hydrogen gas production:2H2O+2e−→H2(g)+2OH−2H_2O + 2e^- <-- H_2(g) + 2OH^-2H2O+2e−→H2(g)+2OH−

2. **At the Anode (Oxidation):** Oxygen gas production:4OH−→O2(g)+2H2O+4e−4OH^- <-- O_2(g) + 2H_2O + 4e^-4OH−→O2(g)+2H2O+4e−

3. **Catalytic Interaction of TiO_2:** TiO_2 accelerates the splitting of water molecules:H2O+(TiO_2 surface)→OH−+H+H_2O + \text{(TiO_2 surface)} <-- OH^- + H^+H2O+(TiO_2 surface)→OH−+H+

2. Proportions for Different Applications

2.1 Application: Water Electrolysis for Green Hydrogen

- **TiO_2:** 10% to 15% by weight in the electrolyte to provide a wide catalytic area.
- **Sodium Carbonate (Na_2CO_3):** 0.5M to 1M.
- **Potassium Carbonate (K_2CO_3):** 0.5M to 1M.
- **Calcium Oxide (CaO):** 2% to 5% by weight.
- **Target pH:** > 12.
- **Operating temperature:** 60°C to 80°C.

2.2 Application: Hydrogen Injection in Combustion Engines

- **TiO_2:** 5% to 10% by weight, to reduce the formation of by-products.
- **Sodium Carbonate (Na_2CO_3):** 0.2M to 0.5M.
- **Potassium Carbonate (K_2CO_3):** 0.2M to 0.5M.
- **Calcium Oxide (CaO):** 1% to 3% by weight.
- **Target pH:** 11 to 12.
- **Operating temperature:** 40°C to 70°C.

3. Quality Control Suggestions

3.1 pH monitoring

- Use a pH meter to maintain the value in the desired range (≥ 12 for efficient electrolysis).
- Add small amounts of CaOCaOCaO or carbonates if the pH drops due to consumption of the components.

3.2 Electrical Conductivity

- Use a conductivity meter to check the conductivity of the electrolyte.
- Typical values: 10-30 mS/cm (milliSiemens per centimeter).
- Adjust carbonate concentrations to correct low conductivity.

3.3 Visual Inspection

- Check for the formation of precipitates (CaCO3CaCO_3CaCO3) in the electrolyte.
    - **Correction:**Remove excess precipitate and filter the electrolyte if necessary.
    - Maintain an adequate concentration of CO32−CO_3^{2-}CO32− to avoid saturation.

3.4 Purity of Components

- Use high purity reagents to avoid contamination and loss of efficiency.
- Recommended minimum purity:
    - **TiO_2:**≥ 99% (preferably anatase).
    - **Na_2CO_3 and K_2CO_3:**≥ 98%.
    - **Dog:**≥ 95%.

3.5 Operating Cycles

- Record system efficiency over time.
- **Reduced efficiency:**Indicates the need for electrolyte regeneration.
    - Add components or partially change the electrolyte.

To calculate the ideal weight of the components that result in 200 g of final mixture, consider the indicated proportions and the total sum of the components. Below, I detail the individual quantities for each component before mixing them with distilled water: Proportions and Calculated Weight

Basis:

- Assuming that the solid components represent a fraction of 20% of the final solution and the remainder is distilled water (80%).
- This means that the solid components will have a combined weight of 40 g (20% of 200 g), and the water will be 160 g (80% of 200 g).

Distribution of Solid Components: Based on recommended proportions:

1. **TiO_2 (10% a 15%):**
   - Para 12% (valor médio):

$$\text{Peso de } TiO_2 = 40\,\text{g} \times 0,12 = 4,8\,\text{g}$$

2. **Carbonato de Sódio (Na_2CO_3, 30%):**
   - Para 30%:

$$\text{Peso de } Na_2CO_3 = 40\,\text{g} \times 0,30 = 12,0\,\text{g}$$

3. **Carbonato de Potássio (K_2CO_3, 30%):**
   - Para 30%:

$$\text{Peso de } K_2CO_3 = 40\,\text{g} \times 0,30 = 12,0\,\text{g}$$

4. **Óxido de Cálcio (CaO, 25%):**
   - Para 25%:

$$\text{Peso de CaO} = 40\,\text{g} \times 0,25 = 10,0\,\text{g}$$

Components for concentrated solution	Total weight (g) 200 grams
Titanium Dioxide (TiO_2)	4.8 g
Sodium Carbonate (Na_2CO_3)	12.0 g
Potassium Carbonate (K_2CO_3)	12.0 g
Calcium Oxide (CaO)	10.0 g
Total Solids	40.0 g
Distilled water	160.0 g
Final Total	200.0 g

Final Composition Before Mixing for a highly concentrated final solution of the electrolyte to be mixed with distilled water (800 ml). Preparation Instructions

1. **Mixing of Solid Components:**
   - Weigh the solids individually on a precision balance.
   - Carefully mix the solid components to ensure even distribution.
2. **Adding Water:**
   - Add 160 g of distilled water to the solids gradually, mixing continuously to avoid lumps.
3. **Homogenization:**
   - Use a mechanical or manual stirrer to ensure a homogeneous solution.
   - Check the pH and adjust if necessary by adding small amounts of CaOCaOCaO or carbonates.
4. **Storage:**

- Store the solution in a closed container to prevent contamination or loss of water through evaporation.

If the goal is to calculate the final weight of the solids only (not including water) in the mixture before adding it, the total will be 200 g of solid components. Below, I present the ideal distribution based on the recommended proportions for storing the preparation without adding water:Weight Distribution (Solid Components Only)

1. **Dióxido de Titânio (TiO_2 - 12%):**
   - 12% de 200 g:
   $$\text{Peso de TiO}_2 = 200\,\text{g} \times 0,12 = 24,0\,\text{g}$$
2. **Carbonato de Sódio (Na_2CO_3 - 30%):**
   - 30% de 200 g:
   $$\text{Peso de Na}_2\text{CO}_3 = 200\,\text{g} \times 0,30 = 60,0\,\text{g}$$
3. **Carbonato de Potássio (K_2CO_3 - 30%):**
   - 30% de 200 g:
   $$\text{Peso de K}_2\text{CO}_3 = 200\,\text{g} \times 0,30 = 60,0\,\text{g}$$
4. **Óxido de Cálcio (CaO - 25%):**
   - 25% de 200 g:
   $$\text{Peso de CaO} = 200\,\text{g} \times 0,25 = 50,0\,\text{g}$$

Summary: Total Solid Weight

Formula component	Weight (g) for storage
Titanium Dioxide (TiO_2)	30.0 g
Sodium Carbonate (Na_2CO_3)	60.0 g
Potassium Carbonate (K_2CO_3)	60.0 g
Calcium Oxide (CaO)	50.0 g
Total Solids	**200.0 g**

Preparation of Solid Components

1. Weigh each component accurately using a suitable scale.
2. Mix the solids carefully to ensure homogeneity, cover the container tightly as the formula is highly hygroscopic (absorbs a lot of moisture)

ELECTROLYTE FOR HIGH EFFICIENCY HYDROGEN REACTORS

Summary

✈This work presents the development and analysis of an innovative electrolyte based on titanium dioxide (TiO_2), combined with sodium carbonate (Na_2CO_3), potassium carbonate (K_2CO_3) and calcium oxide (CaO).☛ ✈The research explores the interactions between these compounds and demonstrates how their synergy increases the catalytic efficiency in electrolysis processes, with applications in hydrogen generation and internal combustion engines.☛ ✈The experimental results indicate a significant increase in energy efficiency and system stability, in addition to improvements in hydrogen productivity, without foaming even at high temperatures.☛✍

Keywords

✈Electrolysis; TiO_2; Sodium carbonate; Potassium carbonate; Calcium oxide; Green hydrogen; Titanium dioxide; Catalysts.☛✍

1. INTRODUCTION

✈The development of clean energy sources is essential to address environmental challenges and meet global demands for sustainability.☛ ✈In this context, hydrogen generation by water electrolysis stands out as a promising alternative, especially when associated with vehicle systems.☛ ✈This work proposes an efficient, safe and sustainable electrolyte formulation, using accessible chemical compounds with low environmental impact.☛✍

2. DEVELOPMENT

2.1 Electrolyte Composition

✈The proposed electrolyte uses a balanced mixture of titanium dioxide (TiO_2), sodium carbonate (Na_2CO_3), potassium carbonate (K_2CO_3) and calcium oxide (CaO), each playing specific roles:☛✍

- **TiO_2:**✈main catalyst, promotes stability and reduces foam formation.☛✍
- **Na_2CO_3 and K_2CO_3:**✈increase ionic conductivity and optimize electrolysis efficiency.☛✍
- **Dog:**✈controls pH and prevents harmful deposits in the system.☛✍

2.2 Proportions and Mechanisms of Action

✈The ideal proportions have been defined to maximize system efficiency:☛✍

- **K_2CO_3:**✈60% of the solution, with conductive and pH stabilizing function.☛✍
- **Na_2CO_3:**✈30%, acting to reduce foam and stabilize the electrochemical interaction.☛✍
- **TiO_2:**✈5%, providing protection to the electrodes and increasing catalytic efficiency.☛✍
- **Dog:**✈5%, essential for neutralizing impurities and controlling pH.☛✍

✈The compounds were chosen to minimize corrosion, reduce the working temperature and prevent premature wear of the system.☛✍

2.3 Benefits of the Developed Solution

- **Foam reduction:**✈improved gas separation.☛✍
- **Thermal stability:**✈safe operation at elevated temperatures.☛✍
- **Greater energy efficiency:**✈continuous hydrogen production with lower energy consumption.☛✍
- **Safety and sustainability:**✈safe, recyclable and low environmental impact components.☛✍

3. CONCLUSION

✈Inspired by the biological mechanism of the sodium-potassium pump, this work presented an innovative and efficient electrolyte for vehicle hydrogen generation systems.☛ ✈The proposed formulation combines high catalytic efficiency, safety and durability, representing a significant advance in the application of hydrogen as a sustainable energy source.☛✍

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