Hydrogen has become a pillar of international decarbonization energy system plans because it has high energy density and lacks the carbon profile in combustion if it is generated by non-renewable resources. Some approaches to producing green hydrogen include electrochemical water splitting, or the dissociation of H2O into hydrogen (H2) and oxygen (O2), using electric power; this approach is particularly promising when combined with renewable electric power, such as solar or wind power (Oni, 2025). In comparison with steam methane reforming, electrolysis has virtually no carbon emissions with low-carbon electricity, which corresponds to net-zero goals. Earth-abundant materials, nanostructuring, and computational design are central to the realization of scalable, efficient, and sustainable electrochemical water splitting in the preparation of industrial green hydrogen. The electrolysis of water is directly dependent on the electrocatalysts, which can support the two important half-reactions: oxygen evolution reaction at the anode (OER) and hydrogen evolution reaction at the cathode (HER) (Oni, 2025). The two reactions use several electron transfers, and the overpotentials are high; thus, the use of catalysts is indispensable to minimize energy barriers and enhance the rate of reaction. Previously, the benchmark was precious metals, including platinum (Pt) in the case of HER, and iridium (Ir) or ruthenium (Ru) oxides in the case of OER, with remarkable activity and stability. The drawback, however, is that they are rare and expensive to scale. To address these limitations, there has been a growing emphasis on research using earth-abundant catalysts, transition metal compounds, nanostructure architecture, and composite materials. Perovskite oxides have demonstrated high OER activity under alkaline conditions because of their tunable electronic structures and flexibility in their compositions that can be engineered to sacrifice adsorption energies and catalytic turnover (Beall et al., 2021). These catalysts are also

Clear Text

Scan

No AI Content Found

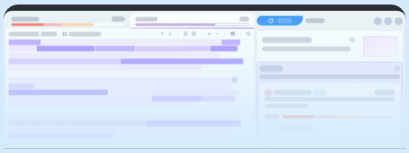
Percentage of text that may be AI-generated.

0%

All Clear — Nothing Flagged

Zero concerns this time, but our detection logic is ready for what comes next. Explore how it works when content is flagged.

See AI Logic In Action



Try Another Text

adsorption energies and reaction wash cycles, enabling the rational design of low-overpotential, high-catalytic stability materials (Cho et al., 2025). These theoretical apprehensions and experimental confirmations have significantly reduced development time in the next generation of electrocatalysts. Another important novelty is the production of bifunctional catalysts that can achieve both HER and OER in a single substance, reducing both electrolyzer design and complexity. This tendency is typified by ternary chalcogenides and mixed metal compounds, which perform competitively in both half-reactions with reasonable durability. Their multifunctional catalysts do not require individual anode and cathode materials but may lower the manufacturing and operating expenses. Further improved catalyst performance in the water electrolysis process is achieved by combining with better electrolyzer designs and long-lasting ion-conductive membranes. It has been demonstrated that optimized membrane-electrode assemblies and scalable cell architectures minimize gas-crossover, thermal losses, and component decay, as well as enhancing performance and service-life. The results facilitate the creation of photo-electrocatalytic systems in which light capture is combined with catalytic breakdown of water to reduce exogenous energy requirements (Ha et al., 2025). Nevertheless, long-term stability, cost-effective production, and maintenance of nanoscale features are important issues despite positive results in laboratories. The focus on catalyst recyclability and the need to decrease the use of limited minerals adds to the demand behind sustainable, scalable design of industrial hydrogen production. To sum up, the development of advanced catalysts lies at the heart of converting electrochemical water splitting into one of the sources of green hydrogen production. Researchers are also working toward scalable, affordable, and performance-enhancing catalysts through materials chemistry, nanostructuring, computational design, and system

Clear Text

Scan

No AI Content Found

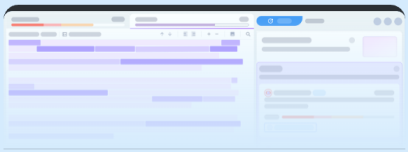
Percentage of text that may be AI-generated.

0%

All Clear — Nothing Flagged

Zero concerns this time, but our detection logic is ready for what comes next. Explore how it works when content is flagged.

See AI Logic In Action



Try Another Text