

## **Low-Temperature Electrolysis for Green Hydrogen Production**

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The lecture introduces electrolysis as an enabling technology for the production of green hydrogen, emphasizing the role of energy materials in the development of efficient, durable, and sustainable systems. After a brief introduction to green hydrogen, the main applications of hydrogen are analyzed through the discussion of two emblematic cases: its use in the transportation sector as an energy carrier for zero-emission mobility, and its use as a chemical precursor for the production of molecules with high industrial impact.

The lecture then focuses on the production of green hydrogen via water electrolysis, introducing the four main families of electrolyzers: (i) alkaline electrolysis (AEL), (ii) proton exchange membrane electrolysis (PEMEL), (iii) anion exchange membrane electrolysis (AEMEL), and (iv) solid oxide electrolysis cells (SOEL). While providing a general comparative framework, the course focuses on low-temperature systems (AEL, PEMEL, and AEMEL), which are currently central to industrial applications and to integration with intermittent renewable energy sources.

The fundamental aspects of thermodynamics and electrochemical kinetics are then examined, along with their relationship to process intensity and energy efficiency. Reversible voltage, the main overpotentials, and the mechanisms governing the hydrogen evolution reaction (HER) and the oxygen evolution reaction (OER) at the electrode/electrolyte interfaces are discussed. The study of catalysts and membranes is then addressed, with particular reference to their impact on chemical and toxic resource use, catalytic efficiency, ion transport mechanisms, chemical and mechanical stability, and degradation processes. The lecture concludes by outlining the main research challenges in materials for low-temperature electrolysis, highlighting future directions to enable the sustainable large-scale production of green hydrogen for both sustainable mobility and the chemical industry.