

Electrochemical nitrogen fixation in metal-N₂ batteries: A paradigm for simultaneous NH₃ synthesis and energy generation

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Abstract

Electrochemical N₂ reduction reaction (NRR) has emerged as the most effective alternative to the conventional Haber-Bosch process for N₂ fixation. Although NRR is only used in the synthesis of NH₃, researchers have recently exploited it in Metal-N₂ batteries (hereafter, M-N₂ batteries) to kill two birds with one stone by fixing N₂ and generating electricity at the same time. There are three types of electrochemical energy storage approaches, namely rechargeable with irreversible electrochemical reaction (under aqueous or non-aqueous conditions), non-rechargeable with irreversible electrochemical reaction (under aqueous conditions), and rechargeable with reversible electrochemical reaction (under non-aqueous conditions). However, the hydrogen evolution reaction (HER) in an aqueous medium takes precedence over the NRR, resulting in a poor Faradic efficiency (FE) for the NRR selectivity. This obvious but unwanted HER causes the low conversion efficiency in aqueous M-N₂ batteries. Furthermore, the instability of cathode electrocatalysts causes a significant drop in the overall performance of M-N₂ batteries. Despite these flaws, M-N₂ batteries represent the first step toward simultaneous N₂ fixation and energy storage. Herein, we comprehensively review the NRR mechanism, electrochemistry, and performances of M-N₂ batteries. With an emphasis on the strategies to design highly efficient cathode catalysts and electrolytes for future M-N₂ batteries, we also chronicle the strategies to suppress the undesired HER in M-N₂ batteries. Furthermore, based on the photoelectrochemical NRR and solar-powered metal-gas batteries, a future outlook on photo-assisted M-N₂ batteries is also provided.