An overview of hydrogen storage in aqueous formate solutions

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Hydrogen is widely recognized as a key energy vector in the impending energy transition, expected to contribute approximately 15% to total decarbonization by 2050. While green hydrogen production is expanding, storage and transportation remain critical bottlenecks preventing widespread adoption. Conventional hydrogen storage relies on physical methods, including high-pressure gas storage (up to 800–1000 bar) and cryogenic liquid storage (down to 20 K). Both approaches demand extreme conditions, leading to significant energy efficiency and safety concerns. Alternative material-based storage solutions—such as metal hydrides, metal-organic frameworks (MOFs), adsorbents, and liquid carriers—present their own challenges, including limited cycle stability, complex thermal management, and low technology readiness levels. Recently, aqueous formate solutions have emerged as a promising hydrogen storage system. Formate salts are inexpensive, non-toxic, non-flammable, stable, and as derivatives of formic acid, they can be sustainably sourced from biomass. In the presence of water and a suitable catalyst, formate undergoes conversion to bicarbonate, releasing hydrogen according to the following reaction (Fig. 1A)

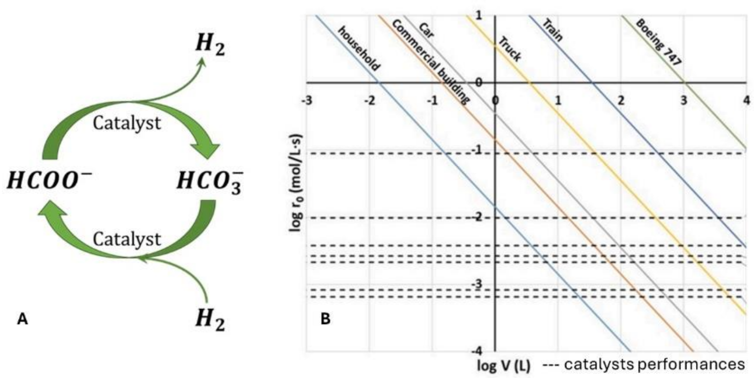

Fig. 1. A. Reaction scheme. B. Kinetics vs storage volume for different power applications.

This equilibrium reaction is easily reversible by pressurizing with hydrogen and adjusting the temperature. Notably, the Gibbs free energy of reaction reaches zero at approximately 50°C, enabling efficient hydrogen release and uptake under near-ambient conditions. Preliminary studies indicate that suitable catalytic systems can achieve hydrogen release kinetics compatible with mobile and stationary applications under mild conditions (Fig. 1B). Moreover, initial calculations suggest that formate-based hydrogen storage could achieve energy densities comparable to pressurized hydrogen systems, depending on operating conditions, while maintaining high energy efficiency. Furthermore, quantitative risk assessments demonstrate that this system is inherently safer than conventional hydrogen storage methods, both under normal operation and in the event of the most probable accidental scenarios. These advantages position aqueous formate solutions as a promising alternative for next-generation hydrogen storage and transportation technologies.