Sorption Performance and Hydrothermal Stability of Ionic Liquids for Biogenic CO_2-to-Methanol Conversion at Wastewater Treatment Plants

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Closing industrial carbon loops requires technologies that convert dispersed biogenic CO_2 into transportable and storable products. The Horizon Europe ILIMITED project is developing a sorption-enhanced process for decentralized CO_2 conversion to methanol, with wastewater treatment plants envisioned as prospective biorefineries. The process targets methanol yields above 80% through the in-situ removal of methanol and water using a selective liquid sorbent. Continuous product removal shifts the reaction equilibrium, potentially increasing CO_2 conversion while reducing downstream separation requirements and enabling lower-pressure operation. A metal additively manufactured, fluid-guiding reactor will support process intensification through improved flow distribution and heat and mass transfer.

A major challenge is identifying a liquid sorbent that retains affinity for methanol and water at temperatures up to 513 K while exhibiting low volatility, manageable viscosity, and sufficient thermal, chemical, and hydrothermal stability. Temperature-programmed thermogravimetric analysis was used to screen phosphonium- and ammonium-based ionic liquids with different cations, anions, functional groups, and additives. Molecular sieve 3A, TEGDME, and Santovac 5 were included as reference materials.

The preliminary results identify $[NTf_2]^-$-based ionic liquids as the most thermally robust platform. $LiNTf_2$-containing $[P_{1444}][NTf_2]$ additionally exhibited low-temperature sorption, whereas dicyanamide- and dimethyl-phosphate-based liquids showed reduced stability. TEGDME reference was limited by its high volatility.
These findings guide the selection of stable liquid sorbents for the ILIMITED process and support CO_2 utilization through decentralized renewable-methanol production and long-term chemical energy storage.

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