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Experimental screening of high-performance water lean solvents for carbon capture

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Abstract

Reducing the energy penalty associated with CO_2 absorption using aqueous chemical solvents remains a significant challenge in post-combustion CO_2 capture (PCC). Aqueous amine-based solvents are widely used in industrial PCC due to their rapid CO_2 uptake and high absorption capacity [1]. However, the energy demand associated with solvent regeneration presents a critical challenge, accounting for approximately 50-80% of the total operational costs. Extensive research has been directed toward developing new solvents that offer improved efficiency with lower energy requirements. Such development requires careful evaluation of solvent properties under working conditions, such as solvent capacity, phase behavior and viscosity. To address this issue, water-lean solvents, composed of amines combined with organic diluents, offer an alternative approach by lowering the energy demand during solvent stripping.

Water lean solvents (mixed with little water) or non-aqueous solvents (without water) have gained attention as promising alternatives [2,3]. These systems utilize high boiling point organic solvents in place of water, avoiding the strong hydrogen bonding network characteristic of aqueous systems and instead relying on the weaker dipole-dipole interactions that demand less thermal input during regeneration. Earlier research on water lean solvents often combined active amines with organic compounds such as methanol or ethanol where they harvest the physical solubility properties of the diluents to aid the absorption capacity of the mixture. These mixtures however suffered from limited absorption capacity and their volatility [4].

This study presents an experimental screening of potential water lean solvent formulations for CO_2 absorption. The diluents composed of water lean solvents were selected for their favorable physical properties, including low viscosity, high dielectric constant, and vapor pressures comparable to water. Solvents were evaluated according to criteria relevant to industrial applications, including phase stability and CO_2 absorption capacity. The influence of amine structure and diluent on solvent performance revealed distinct structure-property relationships. In particular, an increase in the alkyl chain length between the amine group and adjacent functional moieties was found to significantly affect phase behavior upon CO_2 absorption. Preliminary results showed that several water-lean solvents achieved CO_2 absorption capacities comparable to those of the industrial benchmark, monoethanolamine (MEA), while exhibiting improved tolerance to water-induced phase separation. These results demonstrate that water-lean formulations can deliver both effective CO_2 capture performance and reduced energy demand. The insights gained into the relationship between molecular structure and solvent behavior provide a basis for the rational design of amine-diluent systems, supporting the development of energy-efficient solvents for post-combustion CO_2 capture.

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[1] D. Loachamin, J. Casierra, V. Calva, A. Palma-Cando, E.E. Ávila, M. Ricaurte, Amine-Based Solvents and Additives to Improve the CO_2 Capture Processes: A Review, ChemEngineering 8 (2024).
[2] R.R. Wanderley, D.D.D. Pinto, H.K. Knuutila, From hybrid solvents to water-lean solvents – A critical and historical review, Sep. Purif. Technol. 260 (2021) 118193.
[3] I.I.I. Alkhatib, A. Galindo, L.F. Vega, Systematic study of the effect of the co-solvent on the performance of amine-based solvents for CO_2 capture, Sep. Purif. Technol. 282 (2022) 120093.
[4] Y.J. Heintz, L. Sehabiague, B.I. Morsi, K.L. Jones, H.W. Pennline, Novel physical solvents for selective CO_2 capture from fuel gas streams at elevated pressures and temperatures, Energy and Fuels 22 (2008) 3824–3837.