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Results of RITE's novel water-lean solvent for energy efficient CO_2 capture

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Abstract

The present study was aimed at developing novel water-lean a solvent system for the recovery of CO_2 generated from steel making industries. More specifically, the developed water-lean a solvent system must show high CO_2 solubility and low viscosity at the whole range of CO_2 loading. At the same time, sufficient amine regeneration must occur at a low temperature of 80–90 ºC compared to bench-mark monoethanolamine (MEA). To achieve this target, we have investigated a vast number of synthetic and commercial amines as absorbents and alcohols/no-alcohols as solvents. Several experiments mixing amine(s) with alcohol/non-alcohol were performed to identify high performer water-lean a solvent(s). The developed water-lean solvent system showed high CO_2 solubility and low viscosity homogeneous mixture (single phase) at the whole range of CO_2 loading with the advantages of higher absorption and regeneration rates, higher cyclic CO_2 capacities, higher regeneration efficiencies, lower specific heats, and lower heats of reaction compared to reference MEA. Some promising water-lean solvents were tested at a bench-scale test plants with capacities of 5 kg-CO_2/day and showed promising results in terms of reducing absorbent regeneration energy. Another critical issue in the use of water-lean a solvent system is how to control the water, because water is omnipresent in the process, as it is introduced via the flue gas. The water tolerance of the water-lean solvent system will also briefly be discussed.

.*Keywords:* Non-aqueous solvent, CO_2 absorption capacity, absorption and regeneration rate, cyclic capacity, regeneration efficiency

The latest efforts in aqueous amine solvents are exciting and promising, there are still several

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drawbacks to amine-based CO_2 capture solvents including high volatility and corrosiveness of the amine solutions as well as the high parasitic energy penalty during the solvent regeneration step. Therefore, the development of new alternative non-aqueous/water-lean solvents (3rd generation CO_2 capture solvents) that can overcome above mentioned drawbacks and can capable of processing larger quantities of CO_2 with lower energy demand will be a high demand for practical application.

To identify cost-effective approaches for CO_2 capture, the past decade has witnessed the development of various new solvents, including concentrated non-aqueous/water-lean solvents. Non-aqueous amine solvents have potential advantages over aqueous amines, specifically lower heat capacity (approximately one-half), lower heat of vaporization of organic solvents, and higher boiling temperature compared to that of water. Many formulations of non-aqueous CO_2 selective solvents have been tested, including amine-based non-aqueous solvents, CO_2-binding organic liquids, aminosilicones, alkylimidazole blended with amine, room temperature ionic liquids (RTILs), amino-functionalized task-specific ionic liquids (TSILs) and mixed RTILs with alkanolamines. All these non-aqueous/water-lean solvents possess several advantages over the aqueous solvents namely, high-boiling-point, low vapor pressure, thermally stability with a lower heat capacity than that of water. Despite their potential for CO_2 capture, non-aqueous solvents possess some challenges: the non-linear increase in viscosity once CO_2 is absorbed, precipitate formation, or solvent gelation leading to a highly viscous gel or waxy solid.

To overcome the aforementioned drawbacks, this work focuses on the development of a water-lean a solvent system that will increase CO_2 solubility and reduce the viscosity of the CO_2 loaded solution and will not form any precipitate, viscous gel, or waxy solid upon exposure to CO_2. More specifically, the non-aqueous absorbent system must be a homogeneous mixture (single phase) within the whole CO_2 loading range. At the same time, sufficient amine regeneration at a low temperature range of 80–90 ^oC is desired. This makes it possible to use waste low temperature heat for regeneration at a low cost, resulting in a more cost-effective CO_2 absorption process. Another critical issue in the use of water-lean a solvent system is how to control the water, because water is omnipresent in the process, as it is introduced via the flue gas. The water tolerance of the water-lean solvent system will also briefly be discussed.

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