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Development of amine-based non-aqueous absorbent for post-combustion CO₂ capture

Firoz Alam Chowdhury^{a*}, Kazuya Goto^a, Hidetaka Yamada^a, Shin Yamamoto, and Yoichi Matsuzaki^b

^aChemical Research Group, Research Institute of Innovative Technology for the Earth, 9-2 Kizugawadai, Kizugawa-shi, Kyoto 619-0292, Japan

^bAdvanced Technology Research Laboratories, Nippon Steel & Sumitomo Metal Corporation, 2-6-1 Marunouchi, Chiyoda-ku, Tokyo 100-8071, Japan

Abstract

In the present paper, we have planned to develop a cost saving non-aqueous absorbent system that will not form any precipitate/solid upon exposure to CO₂ at the whole range of its CO₂ loading. At the same time sufficient regeneration of the amine at low temperature (90 °C) compared to reference monoethanolamine (MEA) based non-aqueous absorbents. To achieve our target we have investigated 18 alcohols, 3 non-alcohols as solvents and 5 alkyl linked alkanolamines as absorbents. Several fundamental experiments by mixing alkanolamines with alcohols/non-alcohols were performed in our laboratory to evaluate their CO₂ capture performance. Based on our experimental results, we succeeded to develop high-performance non-aqueous liquid absorbents (without solid/precipitate formation) with the advantages of higher absorption rates, higher cyclic capacities, higher regeneration efficiencies, lower specific heats, and lower heats of reaction compared to MEA.

Keywords: non-aqueous solvent; CO₂ capture; amine absorbent; absorption-regeneration; reaction rate; heats of reaction; cyclic capacity

Research Institute of Innovative Technology for the Earth (RITE) under the umbrella of Cost-saving CO₂ Capture System (COCS) and CO₂ Ultimate Reduction System for Cool Earth 50 (COURSE50) projects, have developed highly efficient single and mixed aqueous amine based absorbents for targeting CO₂ generated from steel making industries.¹⁻³ All of these CO₂ absorbents are capable of reducing the energy consumption associated with CO₂ separation, which is the primary concern associated with chemical absorption systems. These absorbents regeneration energy for CO₂ capture was achieved approximately 2.0 GJ/t-CO₂.²

Recently, specific organic liquids have been designed and tested for CO₂ capture including CO₂ binding organic liquids, amine based non-aqueous solvents, room temperature ionic liquids (RTILs), amino-functionalized task specific ionic liquids (TSILs), and mixing RTILs with alkanolamines. All these absorbents have several advantages over the aqueous alkanolamines being high-boiling, thermally stable liquids with lower heat capacity than water. However, the expensive synthesis of the starting compounds (for example, amidine, guanidine, amine functionalized imidazole) with respect to alkanolamines and the high viscosity of the carbonated derivatives, and the formation of solid/precipitated products upon reaction with CO₂, which, represent a neat drawback for any industrial application irrespectively of the improved CO₂ capture efficiency.

* Corresponding author. Tel.: +81-774-75-2360; fax: +81-774-75-2355.

E-mail address: firoz@rite.or.jp

In order to overcome above mentioned drawbacks, this work we have planned to develop a cost savings non-aqueous absorbent system that will not form any precipitate/solid upon exposure to CO₂. More specifically, the non-aqueous absorbent system must be a homogeneous mixture (single phase) at the whole range of CO₂ loading. At the same time sufficient regeneration of the amine at low temperature 90 °C compared to aqueous amine solution 120 °C. This provides the possibility to use waste low temperature heat at low cost for the regeneration, which makes the CO₂ absorption process more cost effective.

Initially we have done gas scrubbing tests of all 18 alcohols and three non-alcohol solvents with AMP in order to select the best alcohol/non-alcohol solvent in terms of absorption rate and cyclic CO₂ capacity. This time the absorption experiments were conducted at 40 °C and the absorbed CO₂ was regenerated at 90 °C. Most of the (AMP+alcohol)/(AMP+non-alcohol) solutions precipitated with increased CO₂ loading, except ethylene glycol (EGL), 1, 3-propanediol (1,3-PD), 1, 4-propanediol (1,4-BD), and triethylene glycol (TEG) showed single phase. We selected EGL and TEG as organic solvents due to their higher absorption rate and higher cyclic capacity compared with other tested alcohols and non-alcohol solvents. Next we screened all alkanolamine [1-amino-2-propanol (1A2P), 2-amino-1-propanol (2A1P), 2-amino-2-methyl-1-propanol (AMP), 2-(ethylamino)ethanol (EAE), and 2-(isopropylamino)ethanol (IPAE)] absorbents with mixing EGL and TEG by varying their concentration in order to select the best alkanolamine absorbent. We found only (EAE+TEG) solution that will not formed any precipitate/solid up to ~ 80 wt% absorbent concentrations with maximum CO₂ loading. Then we optimized (EAE+TEG) based solutions and the preferred solutions performances were compared with (MEA+TEG) solution in terms of absorption rate, cyclic capacity and heats of reaction shown in Fig. 1. Particularly, absorbents 3 and 4 would be the most suitable solutions for the absorption/recovery of CO₂ from PCC gas streams using less energy.

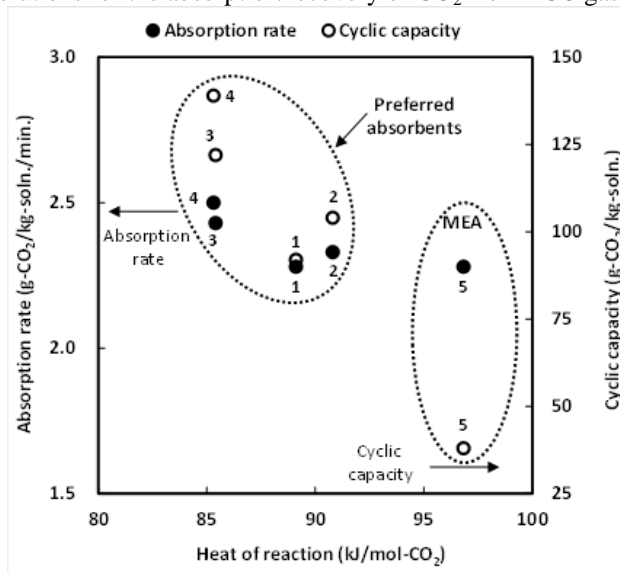


Fig. 1. Comparison of CO₂ capture performances (EAE+TEG) based absorbents with reference (MEA+TEG) absorbents.

We succeeded to develop high-performance non-aqueous liquid absorbents (without solid/precipitate formation) with the advantages of higher absorption rates, higher cyclic capacities, higher regeneration efficiencies, lower specific heats, and lower heats of reaction compared to bench-mark MEA absorbent. The new absorbents can easily releases CO₂ at a lower temperature (90 °C). This provides the possibility to use waste low temperature heat at low cost for the regeneration, which makes the CO₂ absorption process more cost effective.

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