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A new sulfolane based solvent for CO₂ capture

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Abstract

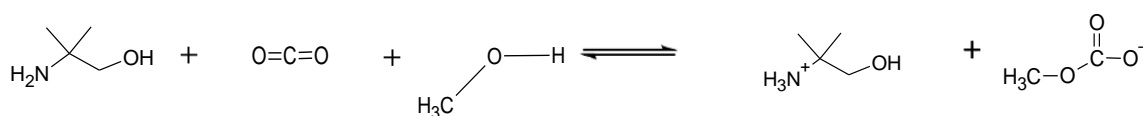
Chemical absorption using aqueous amine is considered as the established technique for post combustion CO₂ capture [1]. The most studied amine for this purpose is the aqueous monoethanolamine (MEA) and 30wt% MEA is the benchmark system and standard first-generation mixture for CO₂ capture. MEA is preferred as the solvent due to it being least expensive, highly reactive, water soluble and has a high absorption capacity with acid gases in gas mixtures [1, 2]. However, MEA is a highly corrosive chemical and has been shown to react with construction materials such as pipes and column walls [3]. Therefore, concentrated MEA solution should be avoided to minimize corrosion. Absorbing CO₂ using aqueous MEA also has other drawbacks such as high energy requirement and solvent degradation at high temperature [4].

Other amine-based solutions have also been investigated to optimize the process, and these solvents are usually classified as the second-generation CO₂ capture solvents. Aqueous piperazine is one of the these solutions, which can reduce operational expenditure (OPEX) by providing higher capture capacity and lower regeneration energy [5].

The regeneration energy can be reduced further by replacing aqueous amine systems with water-lean solvent systems [6]. For example, the K₂Sol solvent system is claimed to reduce the regeneration energy by 35% in comparison to MEA [7]. These organic solvents can also be good physical absorbents of CO₂ [4, 5, 8]. Furthermore, these solvents can be regenerated at low temperature since the absorption reaction leads to formation of less stable alkyl carbonate species [9]. Over the years, a number of water-lean systems utilizing different amines such as 2-amino-2-methyl-1-propanol (AMP), MEA, diethanolamine (DEA), 2-(2-aminoethoxy)ethanol (DGA) and methyl diethanolamine (MDEA) with different alcohols, polyethylene glycol (PEG), ethylene glycol (EG) or glycol ethers have been proposed [3, 9-16].

In this work, we evaluate five different amines in a new water-lean system containing sulfolane and methanol. Sulfolane and methanol are commercially available chemicals and sulfolane has been used as one of the components in the sulfinol process. Solutions were prepared by mixing a known amount of amine with sulfolane and methanol at a mole ratio of 1:0.3:1.1. In order to evaluate the effectiveness of the new solvent system, we have performed CO₂ absorption and desorption tests. The absorption was conducted at 20 °C whilst the desorption at 58 °C. Both of these reactions were monitored in-situ using a time-based ATR-FTIR spectrometer.

Figure 1 shows typical time-based ATR-FTIR spectra for AMP system during experiments. Upon introduction of CO₂, it can be seen that some chemical reactions took place as indicated by the formation of new peaks. These peaks were then reduced during desorption. In figure 2, selected ATR-FTIR scans of AMP system are shown. During experiments, changes in peak height were seen at wavenumbers of 1640, 1445, 1396, 1298, 1082, and so on. The peak at 1640 cm⁻¹ can be assigned to the C=O stretching bond of monomethyl carbonate species (MMC). The peak at 1290 cm⁻¹ is associated with the asymmetric stretching bond of O-C-O of MMC. No peak at 1575 cm⁻¹, which may indicate formation of carbamate, is observed during experiments suggesting that the reaction in the amine system proceeds through alkyl carbonate formation. Earlier investigation by Barzagli et. al. [8] also suggested the formation of alkyl carbonate, as shown in scheme 1. This may also explain the ability of our amine system to be regenerated at mild temperature of 58 °C.



Scheme 1. Suggested reaction for the formation of monomethyl carbonate by sulfolane based non-aqueous AMP solvent system.

We present further characterization of our new solvents in the full paper [17], and how they are compared to the existing solvents available. Details on the reaction mechanism will also be discussed.

Keywords: FTIR-ATR; Non-aqueous; Organic solvents; Sulfolane; Carbon dioxide capture

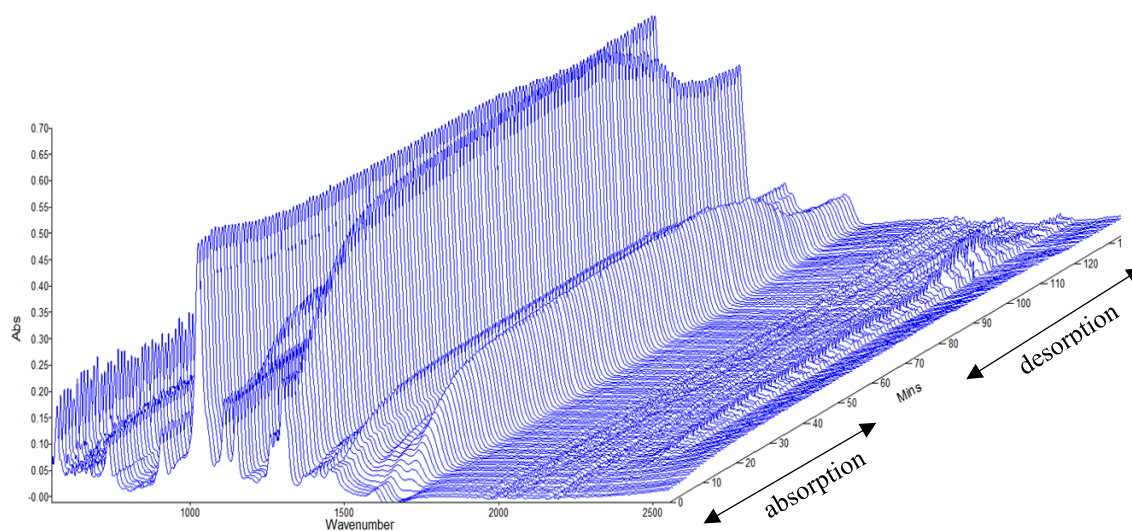


Figure1: Time-based ATR-FTIR scans of for the sulfolane based AMP non-aqueous solvent during CO₂ absorption and desorption

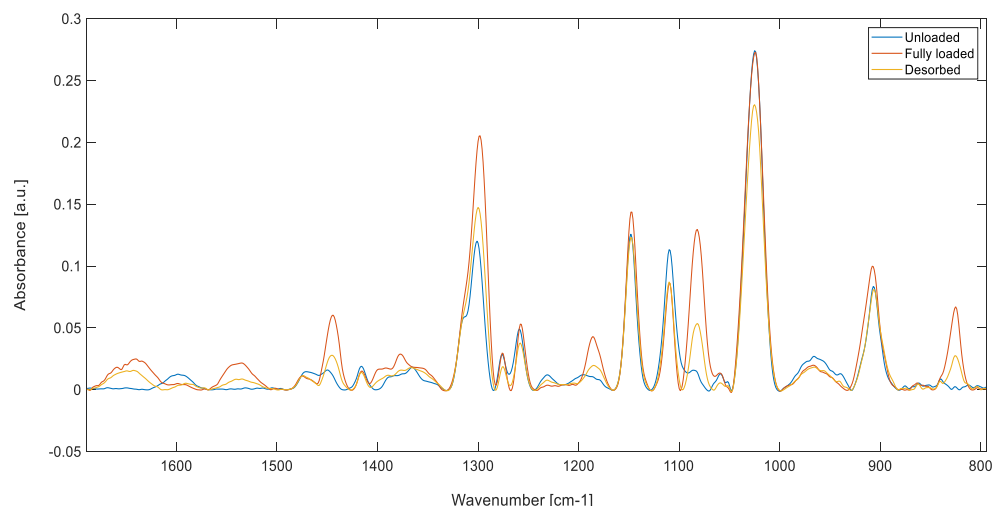


Figure 2: Spectra obtained by FTIR analysis for sulfolane based AMP non-aqueous solvent

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