Comparison of the kinetic promoters piperazine and carbonic anhydrase for CO₂ absorption

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Abstract

Carbon capture technology to large greenhouse gas emitter like fossil fuel burning power plants can be applied in near future and retrofitted when post combustion carbon capture (PCC) technology is used. The principles of the chemical absorption, the most mature technology in post combustion carbon capture [1], are well understood and are applied in gas treating since the early 1930s [2]. Selectively capturing carbon dioxide from flue gas streams poses though challenges to the process as the treated gas streams are very large and the driving force for the process, i.e. the partial pressure of CO₂, is very low[3]. As no valuable product is formed in this process are the costs of applying this technology based on the capital costs and operating costs. The capital costs can be reduced if the mass transfer rates are high as smaller equipment can be used for the separation. The energy requirement for the solvent regeneration is the main contributor to the overall operating costs [4], changing to a solvent with lower heat of reaction could reduce the energy input for regeneration [5]. The reaction kinetics of a solvent are linked to the heat of reaction though, higher reaction kinetics comes generally with higher heat of reaction [4].

Solvents with low heat of reaction like tertiary amine or carbonate salt solutions have such low reaction kinetics and mass transfer rates that they are practically infeasible for PCC. The use of kinetic promoters that speed up the solvent reaction rates can help overcome the kinetic limitation of slow reacting solvents. These kinetic rate promoters can either be small amounts of fast reacting amines, like Piperazine (PZ), or a biocatalyst like the enzyme carbonic anhydrase (CA) that catalyzes the reversible reaction between water and CO₂. Piperazine as a chemical compound changes the chemical and physical equilibrium of the solvent whereas the addition of carbonic anhydrase showed no effect on the thermodynamic properties of the solvent [6][7]. Based on their nature and reaction mechanism different temperature and loading dependency of the absorption can be expected.

In this study the application of two different kinetic promoters, piperazine and carbonic anhydrase, were compared in a tertiary amine and a carbonate salt solution. The experiments were conducted in a wetted wall column apparatus that allows for mass transfer measurements at very precisely defined process conditions. N-methyldiethanolamine (MDEA) and K₂CO₃ in aqueous solutions were tested with either small amounts of carbonic anhydrase or additional 5 wt% piperazine. The process temperature was varied between 298 K and 328 K and the loading of the solvent was varied in a range to present a typical lean solvent and a rich solvent. Absorption enhancement was determined as change in liquid side mass transfer coefficient compared to the solvent without...
promoter. Both promoters could significantly increase the mass transfer. They showed different temperature and loading dependency that could be explained by their different nature and reaction mechanism. Based on these findings process conditions could be identified where either the one or the other promoter performed better.

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1. References


