

Kinetic Evaluation of Sterically Hindered Amines under Partial Oxy-Combustion Conditions

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Abstract : Carbon capture and storage (CCS) technologies should play a relevant role towards low-carbon systems in the European Union by 2030. Partial oxy-combustion emerges as a promising CCS approach to mitigate anthropogenic CO₂ emissions. Its advantages respect to other CCS technologies rely on the production of a higher CO₂ concentrated flue gas than these provided by conventional air-firing processes. The presence of more CO₂ in the flue gas increases the driving force in the separation process and hence it might lead to further reductions of the energy requirements of the overall CO₂ capture process. A higher CO₂ concentrated flue gas should enhance the CO₂ capture by chemical absorption in solvent kinetic and CO₂ cyclic capacity. They have impact on the performance of the overall CO₂ absorption process by reducing the solvent flow-rate required for a specific CO₂ removal efficiency. Lower solvent flow-rates decreases the reboiler duty during the regeneration stage and also reduces the equipment size and pumping costs. Moreover, R&D activities in this field are focused on novel solvents and blends that provide lower CO₂ absorption enthalpies and therefore lower energy penalties associated to the solvent regeneration. In this respect, sterically hindered amines are considered potential solvents for CO₂ capture. They provide a low energy requirement during the regeneration process due to its molecular structure. However, its absorption kinetics are slow and they must be promoted by blending with faster solvents such as monoethanolamine (MEA) and piperazine (PZ). In this work, the kinetic behavior of two sterically hindered amines were studied under partial oxy-combustion conditions and compared with MEA. A lab-scale semi-batch reactor was used. The CO₂ composition of the synthetic flue gas varied from 15%v/v - conventional coal combustion - to 60%v/v - maximum CO₂ concentration allowable for an optimal partial oxy-combustion operation. Firstly, 2-amino-2-methyl-1-propanol (AMP) showed a hybrid behavior with fast kinetics and a low enthalpy of CO₂ absorption. The second solvent was Isophrondiamine (IF), which has a steric hindrance in one of the amino groups. Its free amino group increases its cyclic capacity. In general, the presence of higher CO₂ concentration in the flue gas accelerated the CO₂ absorption phenomena, producing higher CO₂ absorption rates. In addition, the evolution of the CO₂ loading also exhibited higher values in the experiments using higher CO₂ concentrated flue gas. The steric hindrance causes a hybrid behavior in this solvent, between both fast and slow kinetic solvents. The kinetics rates observed in all the experiments carried out using AMP were higher than MEA, but lower than the IF. The kinetic enhancement experienced by AMP at a high CO₂ concentration is slightly over 60%, instead of 70% - 80% for IF. AMP also improved its CO₂ absorption capacity by 24.7%, from 15%v/v to 60%v/v, almost double the improvements achieved by MEA. In IF experiments, the CO₂ loading increased around 10% from 15%v/v to 60%v/v CO₂ and it changed from 1.10 to 1.34 mole CO₂ per mole solvent, more than 20% of increase. This hybrid kinetic behavior makes AMP and IF promising solvents for partial oxy-combustion applications.

Keywords : absorption, carbon capture, partial oxy-combustion, solvent

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