Abstract

There has been significant effort toward enhancing the mass transfer of CO₂ in the absorber by developing high efficiency packing, intensifying gas/liquid mixing and modifying solvent properties to improve the effectiveness of the gas-liquid contact surface. One key yet overlooked component of solvent development is how the physical properties of solvent and impact CO₂ mass transfer and wettability of packing surfaces. Developing a better understanding of certain physical properties including viscosity, surface tensions and contact angle and how these can be manipulated to increase CO₂ mass transfer will be important to further optimize the performance of aqueous amine solvents. Additionally, understanding the changes as a result of the additive can also be used to increase CO₂ adsorption rate and mass transfer. The measurement of amine solvent physical properties and how these can be manipulated using additives to increase CO₂ mass transfer will be examined.

Keywords: CO₂ capture; amine solvents; solvent properties; CO₂ mass transfer

Full scale implementation of 2nd-Gen carbon capture systems is estimated to significantly increase the overall cost of electricity, with a significant contributing factor being the capital cost to build the absorber tower and its auxiliaries, such as flue gas booster fan(s) and amine pumps, determined by the height of absorber. Absorber height is directly related to the CO₂ absorption rate and is influenced by reaction kinetics, active gas-liquid contact surface, and CO₂ driving force. One of the major barriers to enabling mass transfer in amine solvent systems is the formation of a stable layer, or film, at the gas/liquid interface where CO₂ adsorption occurs, in terms of the gas side and liquid side resistances. For many 2nd-gen advanced solvents with fast CO₂ absorption kinetics, it has been reported that overall mass transfer is limited by the diffusion of CO₂ from the liquid film into the bulk liquid, and/or diffusion of the unreacted amine from bulk liquid to the interface liquid film. As the amine solvent loads with CO₂, the solvent viscosity increases 2x-3x relative to the lean solution, further slowing diffusion.

There has been significant effort toward enhancing the mass transfer of CO₂ in the absorber by developing high efficiency packing, intensifying gas/liquid mixing and modifying solvent properties to improve the effectiveness of the gas-liquid contact surface. Solvent physical properties can play an important role in many aspects of solvent performance. Higher viscosities can impact how the solvent flows down the packing and increase CO₂ diffusion resistance, while also increasing the energy required to pump the solvent throughout the system. The contact angle

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of the solvent on the packing material can be used to assess the wettability or surface coating of the solvent. This information can also be an indication of CO₂ mass transfer, and can be especially important when considering the use of alternative packing materials beyond stainless steel such as ceramics, polymers or even 3-D printed packing material.

Water is well-known for its high surface tension resulting from strong intermolecular hydrogen bonding. Other compounds, particularly organic and/or hydrophobic materials such as amines, will exhibit far less intermolecular attraction, resulting in a lower surface tension (compared to water). To maximize this effect, an additive (surface-active agent, surfactant) can be used containing a hydrophilic portion such that it can be dissolved in water, while at the same time containing a hydrophobic functional group that it is forced to the surface of the water to disrupt the hydrogen-bonding network (Figure 1a). In this way, the surface characterization of solvent can be modified even when used at low concentrations. When the surface tension and surface elasticity are modified to a certain range, small bubbles can form at the edge of the bulk solution, thereby increasing the liquid surface area and mass transfer (Figure 1b). The investigation into the impact of the different classes of additives (corrosion inhibitors, oxidation inhibitor, anti-foam, mass transfer/bubble enhancement compounds) on the physical properties, and subsequent performance, of amine solvents can be applied to all commercial available amine solvents.

A commercial aqueous amine solvent is typically composed of the main amine compound(s), inhibitors for corrosion, solvent oxidation, and/or foaming and water (as balance). The overwhelming majority of research and development in CO₂ capture solvents has focused on the amine chemistry, with little thought to the impact of the additives. Understanding the impact of additives on key solvent properties, including surface tension and elasticity, wettability, and whether these changes as a result of the additive may play a significant role in the CO₂ capture such as adsorption rate, degradation and aerosol formation. In this study, we will report the measurement of amine solvent physical properties and discuss how these can be manipulated using additives to increase CO₂ mass transfer.