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Intensification of low temperature thermomorphic biphasic amine solvent regeneration for CO₂ capture

Jiafei Zhang*, Yu Qiao, David W. Agar

Institute of Reaction Engineering (TCB), Department of Biochemical and Chemical Engineering, Technische Universität Dortmund, Emil-Figge-Straße 66, D-44227 Dortmund, Germany

ABSTRACT

High-energy requirements for solvent regeneration represent one of the main challenges in the conventional post-combustion capture (PCC) process. Thermomorphic biphasic solvent (TBS), comprising lipophilic amines as the active components, exhibit a liquid–liquid phase separation (LLPS) upon heating, giving rise to extractive behaviour, and thus enhancing desorption at temperatures well below the solvent boiling point. The low regeneration temperature of less than 90 °C together with the high cyclic CO₂ loading capacity, 3–4 mol/kg, of such TBS system permits the use of low temperature and even waste heat for desorption purposes. In order to improve the solvent regeneration process and reduce the commensurate energy demand still further, desorption experiments with various techniques for enhancing CO₂ release in place of gas stripping, such as nucleation, agitation, ultrasonic method, etc., were studied at temperatures in the range of 75–85 °C. Nucleation and agitation both accelerate CO₂ desorption, but regenerability by nucleation only achieves 70–85%, while by agitation attains 80–95%. Ultrasonic desorption also intensifies the solvent regeneration and superior to conventional stripping process. The energy consumption for TBS system with those intensification techniques is only half of that for alkanolamine-based process with steam stripping. Extractive regeneration is another potential method to substitute for stripping and reduce the exergy demands. An extraction process using inert solvent was developed for improving the regeneration efficiency and elevated pressures were applied for reducing the significant volatile solvent loss.

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Keywords: CO₂ capture; Amine absorbent; Solvent regeneration; Process intensification; Hybrid technology

1. Introduction

Solvent regeneration with its high energy consumption at temperatures of 120–150 °C represents one of the most significant weaknesses in alkanolamine-based CO₂ capture, contributing to more than half of the total processing costs. Development of new solvents and the integration of process heat are the most promising means of reducing the energy consumption (Wang et al., 2011). Many researchers have devoted a lot of work to identify new absorbents and techniques for reducing the energy requirement and thus increasing the capture efficiency (Chowdhury et al., 2009, 2011) have screened various aqueous tertiary amine solvents to mitigate the energy requirements by lowering the heat of absorption, with only modest deterioration in CO₂ loading capacity and reactivity. Some undisclosed solvents, which can

allegedly cut the regeneration energy by ≈30% compared to the benchmark monoethanolamine (MEA), have been investigated in the CASTOR project (Knudsen et al., 2007) and also by other researchers (Puxty et al., 2009; Goto et al., 2009; Kim et al., 2011), but the desorption still needs to be carried out with steam stripping at 120 °C or above.

A novel TBS system has been proposed by Agar et al. (2008) to ameliorate this problem, since they offer excellent reactivities and high loading capacities but also very deep regenerabilities at temperatures of only 80–90 °C, due to the partially miscible properties and thermally induced LLPS behaviour (Zhang et al., 2011a). Initial development work focussed on the miscibility of organic and aqueous phases and their temperature dependent phase transition behaviour. The concept of the phase transition CO₂ capture process is primarily determined by two processes:

* Corresponding author. Tel.: +49 231 755 2582.

E-mail address: jiafei.zhang@udo.edu (J. Zhang).

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