Kinetics of the Absorption of CO_2 into aqueous loaded solutions of AMP and AMP/PZ

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ABSTRACT

Amine-based absorption is currently the most advanced and cost-effective means of post-combustion CO_2 capture among the different technologies that can be used (Dutcher et al., 2015). Much work has been done to reduce energy consumption, which constitutes one of the major penalties to the absorption process. Therefore, when it comes the need to develop new energy-efficient solvents for the successful implementation of CO_2-capture worldwide. An alternative to the widely used ethanolamine (MEA) is an aqueous solution of 2-amino-2-methyl-1-propanol (AMP), promoted with piperazine (PZ). It has been demonstrated that an aqueous blend 3.0 M AMP/ 1.5 M PZ, known as CESAR1, exhibits lower energy consumption (Mangalapally and Hasse, 2011), lower degradation rates (Lepaumier et al., 2009), and higher loading capacity compared to MEA (Choi et al., 2007).

A reliable kinetics model must be developed for an accurate design of CO_2 absorption columns. Data for CO_2 absorption kinetics using initially unloaded PZ/H_2O, AMP/H_2O and AMP/PZ/H_2O are available in the open literature (Alper, 1990; Khan et al., 2019; Samanta and Bandyopadhyay, 2007; Seo and Hong, 2000; Sodiq et al., 2014; Xu et al., 1996; Yih and Shen, 1988). However, data for AMP and AMP/PZ CO_2-loaded-aqueous solutions are not available. This work wants to fill these experimental gaps to characterize better solvent kinetics at industrial conditions, since the CO_2-loading will change along the absorber.

For this work, a string of discs contactor (SDC) will be used to measure the absorption kinetics. The operating procedure of kinetics experiments with SDC is accurately described by Hartono et al. (Hartono et al., 2021). The overall mass transfer coefficient K_g (mol m^{-2} s^{-1} kPa^{-1}) will be calculated using Eq 1. It only involves the measured molar flux, N_{CO_2}, and the driving force, logarithm mean pressure difference ($LMPD$), that can be assessed according to Eq 2.

$$K_g = \frac{N_{CO_2}}{LMPD} \qquad Eq\ 1$$

$$LMPD = \frac{(P^{in}_{CO_2,bulk} - P^{*,in}_{CO_2}) - (P^{out}_{CO_2,bulk} - P^{*,out}_{CO_2})}{ln\left(\frac{P^{in}_{CO_2,bulk} - P^{*,in}_{CO_2}}{P^{out}_{CO_2,bulk} - P^{*,out}_{CO_2}}\right)} \qquad Eq\ 2$$

$P^{in}_{CO_2,bulk}$ and $P^{out}_{CO_2,bulk}$ represent respectively the inlet and outlet CO_2-partial pressure in the column while $P^{*,in}_{CO_2}$ and $P^{*,out}_{CO_2}$ represent the partial pressure at the interface that will be calculated using published e-NRTL model (Hartono et al., 2021).

Kinetics data will then be interpreted according to zwitterionic and termolecular mechanisms providing the kinetics constant and will be then compared to already available experimental data (Ali, 2005; Alper, 1990; Seo and Hong, 2000; Sodiq et al., 2014; Xu et al., 1996; Yih and Shen, 1988).

Validation of the setup was performed with the benchmark solvent for CO_2-capture, ethanolamine, for which kinetics data are largely available (Luo et al., 2012; Versteeg et al., 1996) and shown in Figure 1.

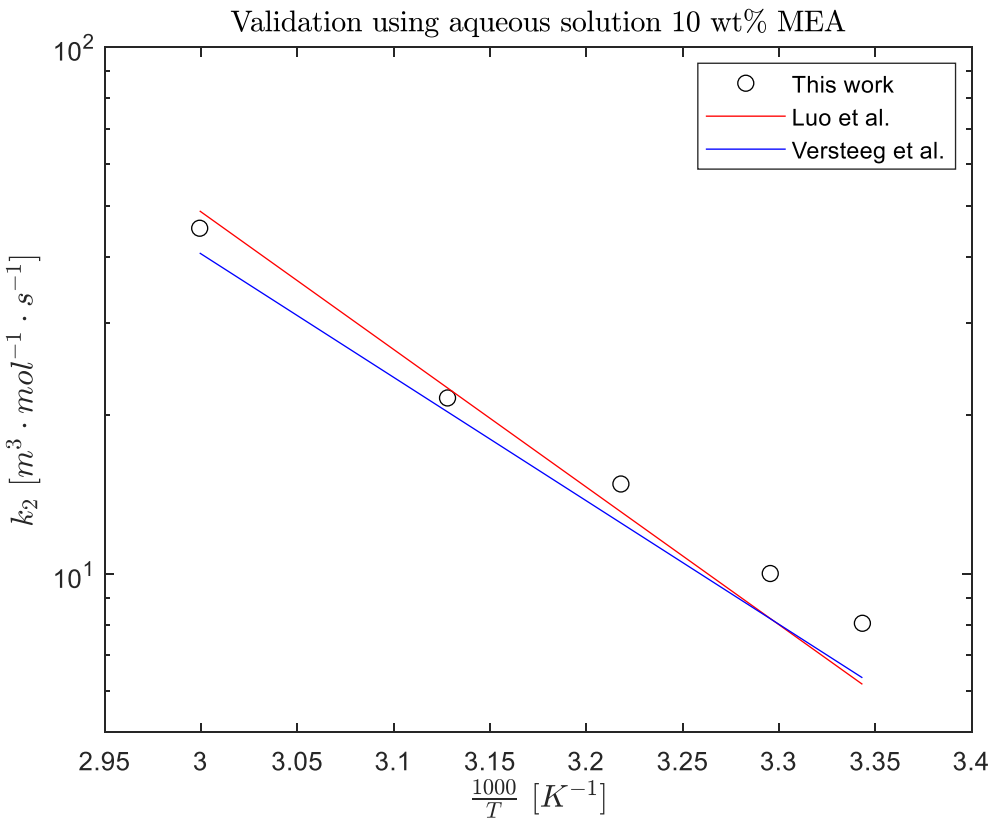

Figure 1: Arrhenius Plot: II order kinetics constant k_2 vs 1/T

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