Evaluation of solvent blends for post combustion CO\textsubscript{2} capture

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Introduction

Chemical absorption using aqueous amine solvents is considered as a suitable technology for post combustion CO\textsubscript{2} capture. It has already reached commercial stage, but efforts are still focused on reducing the cost and energy demand of the process. In the search for energy efficient solvents, an important quantity to consider is the reboiler heat duty. The reboiler heat duty represent the largest fraction of the operating cost and is the sum of three terms:

\[ Q_{\text{Reg}} = Q_{\text{Des}} + Q_{\text{Strip}} + Q_{\text{Sens}} \]  

\( Q_{\text{Des}} \) is the energy needed to release CO\textsubscript{2} from the solution (heat of absorption), \( Q_{\text{Strip}} \) the energy needed to produce stripping steam and \( Q_{\text{Sens}} \) is the energy needed to heat the solvent to the desorption temperature. Out of the three terms, a large contributor to the total energy is the heat of absorption. However, focusing only on heat of absorption is misleading as the three energy terms are correlated [1].

Primary and secondary amines form a fairly stable carbamate requiring more energy to reverse the reaction compared to tertiary amines that react with CO\textsubscript{2} through base catalysis of CO\textsubscript{2} hydration. However, tertiary amines, with low heat of absorption also have slower reaction rate compared to primary and secondary amines. Thus, in several publications, blends of tertiary amines and primary amines have been studied to identify systems that would have operating window with smaller heat of absorption of CO\textsubscript{2} combined with relatively high absorption rate. In our previous work, eight blended MAPA systems in the molar ratio 3:1 (3M Tertiary amine + 1M MAPA) were studied using the fast solvent screening method [2]. Results indicated that the optimum pKa range of the tertiary amine, giving the highest absorption capacity and cyclic capacity, was between pKa 9.48 and 10.13. As a continuation of that work, the reboiler heat duty of three of the well-performing amine solvent blends will be evaluated using a short cut method proposed by Kim et al. [3]. Further, published VLE data for amine blends will be used to estimate cyclic capacities and reboiler duties. Collecting all literature data, will allow discussion of the effect of tertiary amine pKa, amine concentration and cyclic capacity on reboiler duty

Method

Reboiler heat duty will be estimated using a shortcut method suggested by Kim et al.[3]. The method was derived from energy balance around the regenerator and estimates the three energy terms compromising the reboiler heat duty using vapour-liquid equilibrium (VLE) data at various CO\textsubscript{2} loadings in the temperature range 40-120 °C. In the present work, rich loading correspond to a CO\textsubscript{2} partial pressure of 9.5kPa at 40 °C, while the lean loading correspond to a CO\textsubscript{2} partial pressure of 20kPa at reboiler temperature. For estimation of \( Q_{\text{rx}} \), experimental calorimetric data will be used or
VLE data followed by integration of the Gibbs-Helmholtz equation. The total reboiler pressure will be fixed at 1.9 bar and the reboiler temperature will be found by iteration.

**Results**

Fig. 1 shows reboiler duties of blended amine systems reported in the literature or estimated with available VLE data. Among the blended amine systems, the reboiler heat duty varies from 2.5-2.9 GJ/tCO$_2$. Thus, all blended systems obtain a lower reboiler heat duty than 30wt% MEA, but compared to each other, the reboiler heat duties are very similar. Additionally, it seems that increase of total amine concentration does not decrease the reboiler duty.

In the final work we will carefully discuss reboiler duties of published amine blends focusing on the effect of the three energy terms in Equation 1 and the cyclic capacity. Finally, the effect of pKa of the tertiary amine will also be evaluated.

![Reboiler duties graph](image-url)

**Fig. 1** Estimated reboiler duties

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**References**