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Solvent comparison for postcombustion CO_2 capture

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1. Introduction

Global warming is established as one of the most serious problems facing the earth at present. Anthropogenic CO_2 is one of the gases causing this problem, and large sources are traffic, fossil fuel based power production, iron and steel and cement production, and the metal and metal alloy production based on reduction with carbon. CO_2 absorption in aqueous amine solutions is the most widely used process in the industry, and the only viable one at present. However, capital and operating costs are high, and in particular the heat required for absorbent regeneration requires large quantities of energy, causing large drops in efficiency for the industry. One of the options to decrease the operational and investment cost is the usage of a highly effective amine solutions. The target in 2050 is to produce double amount of energy of the present level with half of the CO_2 emitted to the atmosphere. The rate of absorption should be as high as possible to reduce the height of the absorber, to save the investment and maintenance costs, and to obtain a close approch to equilibrium. A high solvent capacity and close equilibrium approach can reduce the heat demand significantly and open for stripper operation at elevated pressures.

2. Experimental

In this work, experimental data on the absorption of CO_2 into aqueous solutions of different single and mixed amine systems are reported. The focus was the effect of the amine ratio, comparison of different amines and the concentration level of amine. Semi-quantitative screening tests were done in order to estimate the capacity and the absorption rate of different solutions.

For the tests a laboratory scale bubble reactor (750 ml) was used, which was kept in a water bath to ensure constant temperature during the exothermic reaction (40 ^{0}C for the absorption, 80 ^{0}C for desorption). In some cases, mostly when the amine concentration was high, due to the viscosity of the solution during the absorption, the stripping was not possible to perform in the available glass equipment. The vapour was cooled down to 15 ^{0}C after

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leaving the bubble reactor, and the CO_2 concentration was measured by an IR detector. The CO_2 concentration was 10 vol% in the inlet N_2/CO_2 gas mixture and controlled by a flow controller. The IR analyzer was calibrated before every measurement.

The paper will report on the screening tests compared to a base case of 30 wt% ethanolamine (5 M MEA).

3. Results and Discussion

The total capacity and the reaction rate during absorption are shown in Figure 1. It is clear that far the highest total absorption capacity is shown by 5 M MAPA, and its reaction rate is also the highest. The three solutions with TRIZMA have the lowest absorption rates, but in these cases the activator concentration is just 1 mol/l. As activator MEA has the lowest performance (monoamine) whereas PZ performs a bit faster and the final loading with Pz is the same as with 5 M MAPA (both diamines). The 5M DEEA/2M MEA is slower and the capacity lower than the 3M DEEA/1M PZ which may be a bit surprising, considering that the DEEA is in higher concentration, and that PZ has two secondary amino groups. However, from the literature it is known that Pz is significantly faster than MEA. Also increasing viscosity of the concentrated amine solutions will influence negatively on the mass transfer. As seen DEEA and DMMEA with MEA have comparable kinetics at low loadings, but DMMEA maintains a higher total loading per kg solution. The situlation with DMMEA is the same as with DEEA, MEA is the weakest activator, and PZ is a slightly better activator then MAPA, but the difference between the latter is not significant. Decreasing the DMMEA concentration to 3M and keeping MAPA at 2M decreses the initial kinetics, but the total capacity is increased (probably also viscosity plays a role). AMP/PZ (3/1) system is slightly better than DMMEA/PZ (3/1). The 5 M MEA solution has an absorption rate in the middle of the tested solutions, and only the AMP/PZ 3/1 system has higher total capacity at lower amine concentration.

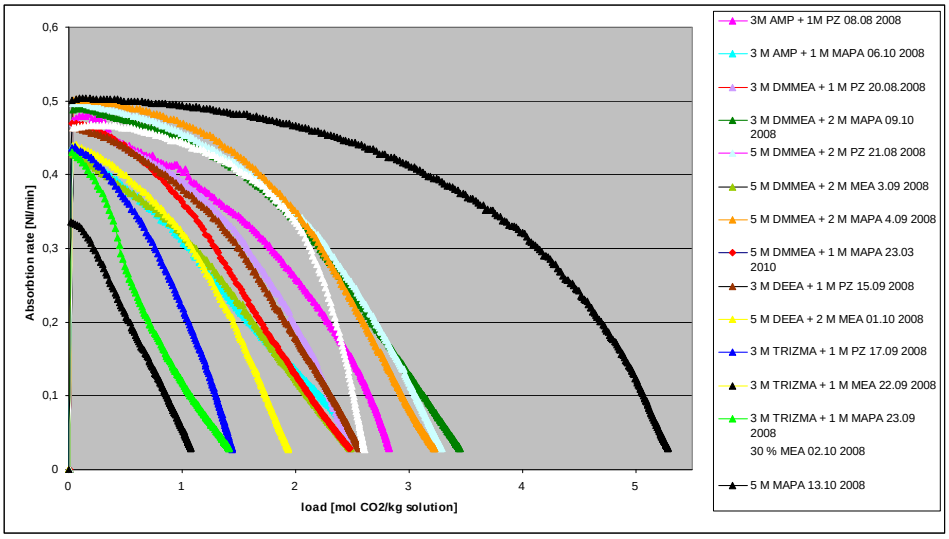

Figure 1. Comparison of the total capacity and reaction rate of tested solutions

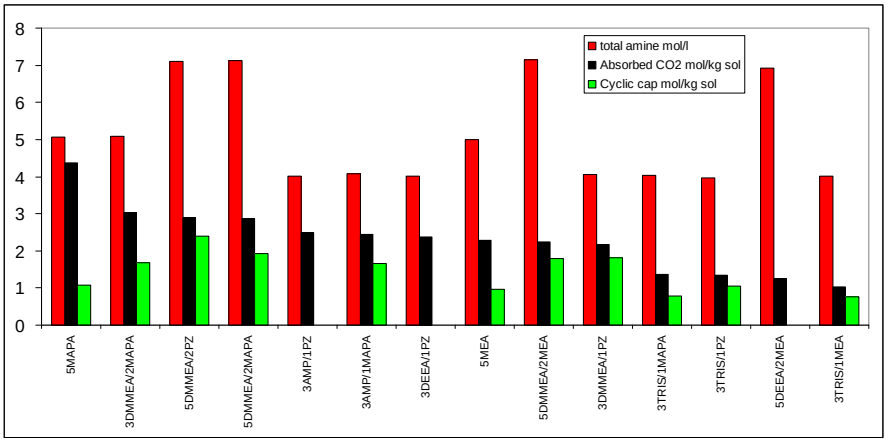

Figure 2. Total and cyclic capacity comparison of the measured systems

In Figure 2 it can be seen, that although 5 M MAPA has the highest total capacity, the cyclic capacity is relatively low, and so needs a higher flow rate to maintain the absorbtion capacity. The best ratio between the total and the cyclic capacity was found for the DMMEA/PZ 5/2 system, which is slightly better then DMMEA with MAPA.

4. Conclusion

From the measurements above it is clear that the selection of the right system is very important for the optimal operation and investment. It can be also seen that a high total capacity does not necessarily mean always high cyclic capacity. From the measured tertiary and sterically hinderned amines DMMEA and AMP perform the best, and from the activators MAPA and PZ are both better than MEA. High concentrations of amines theoretically means higher capacity, but in practice, the increasing viscosity can act against the kinetics, and the system performs below the expectations.

5. References

Brúder, P., 2009. CESAR WP 1.1 – Solvent selection. Presentation, Trondheim, Norway, February 18.