Mass transfer performance of a catalyst-aided CO_2 capture in aqueous solutions of mono ethanolamine (MEA), and blends of monoethanolamine (MEA) with methyl diethanolamine (MDEA), and 2-(butylamino) ethanol (BEA) with 2-amino-2-methyl-1-propanol (AMP)

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1. Introduction

Carbon dioxide is noted to be the most important and detrimental of all greenhouse gases. These greenhouse gases cause a rapid climate change with global warming. One method well adopted for reducing CO_2 emissions is post combustion capture from power plant flue gases. Gas absorption by chemical solvents such as aqueous solutions of alkanol amines is one of the most effective methods for CO_2 removal. The mass transfer performance for CO_2 absorption into aqueous solutions of 5M mono ethanolamine (MEA), 7M blend MEA (mono ethanolamine) with MDEA (methyl diethanolamine) (5:2) and 4M blend of a novel solvent, BEA (2-(butylamino) ethanol) with AMP (2-amino-2-methyl-1-propanol) (2:2) were studied experimentally in a lab scale packed absorption and desorption column and their mass transfer performance was evaluated also by introducing an HZSM-5 catalyst (si/al 19) in the desorption column. The 4M blend of BEA and AMP was selected and its performance evaluated with a new HZSM-5 catalyst (si/al 11.5) in the desorption column. The experiments were conducted at atmospheric pressure, feed gas containing 15% CO_2 in N_2 gas to the absorption column. The mass transfer performances were evaluated in terms of the overall volumetric mass transfer coefficient (K_Ga_v and K_La_v). The results reveal that BEA/AMP blend has a high overall mass transfer coefficient. The K_Ga_v is an important design parameter used to calculate the height requirement of the different amines system. A high K_Ga_v value means a shorter absorption column height required. Same for desorption column with K_La_v

2, Experimental section

The experiment was conducted in a bench-scale full cycle unit shown in figure 2. The dimensions of the absorber and desorber column unit is 1.07m x 0.051m. The absorption column was packed with a 5.08cm diameter Sulzer LDX structured packing. The desorption column internals consist of different layers of packing to easily inculpate the catalyst whilst reducing the pressure drop in the column. A 0.18 m height of a 5.08 cm diameter Sulzer LDX structured packing placed at the topmost and bottom of the column. A 0.051m height 10mm marble and a 0.51m height 6mm diameter marble, randomly mixed with 150g of HZSM-5 catalyst which was the optimum catalyst weight reported by Osei et al, 2016. An amine solution of known concentration is supplied via an amine tank as shown in figure 1, into the absorption column of a lab scale pilot plant where it contacts feed gas supplied by 100%CO_2 and 100% N_2. The lean gas exits at the top of the column whiles the CO_2 rich amine leaves the bottom of the absorption column to the desorption column through a heat exchanger to heat the rich amine solution. For a fair comparison, hot water was used to heat the amine to 87°C before entering the desorber. Mass transfer data is collected and analysed for the different systems.
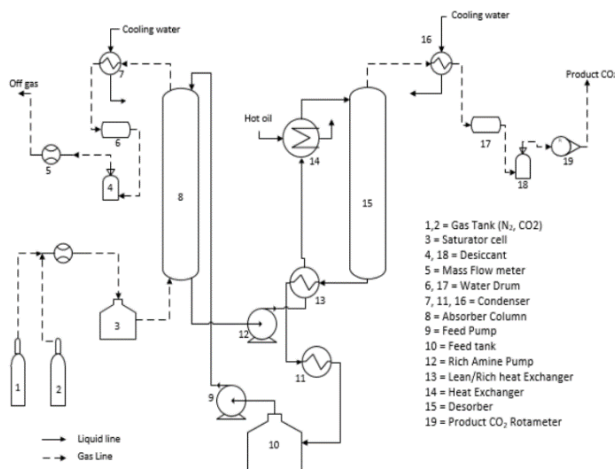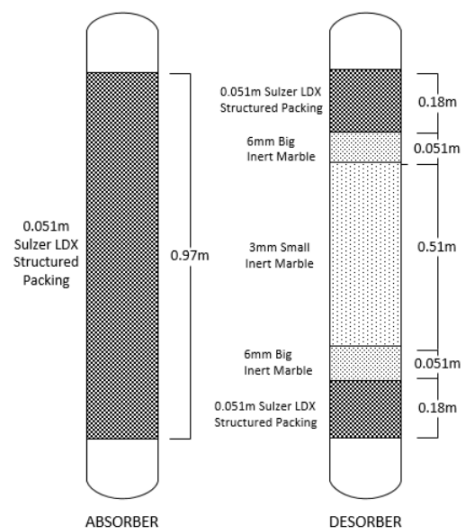
Fig 1: pilot plant setup (Osei, 2016)

Fig 2: Columns Configuration (Osei, 2016)

3. Results and discussions

From the results, figure 3- 5, we obtain the effect of catalyst and solvent on the overall mass transfer coefficients. It can be deduced from the graph that the 4M BEA/AMP (2:2) has the highest overall mass transfer coefficient among the no catalyst solvent system due to the reactive nature of that solvent blend reported by Narku Tetteh J et al, 2017. All solvents showed an increase in the overall mass transfer coefficients with catalyst, revealing the positive effect of the HZSM-5 catalyst. This catalyst, a bronsted acid catalyst, donates proton to the desorption reaction which tends to accelerate the rate of the desorption reaction. Finally, the effect of catalyst with a higher bronsted strength, HZSM-5 (si/al=11.5), was investigated with 4M BEA/AMP (2:2) blend solvent. The change from the initial HZSM-5 catalyst to the new catalyst increased the overall mass transfer coefficient but the difference wasn't so significant. This showed that the increase in the catalyst bronsted strength has very little effect on the 4M BEA/AMP (2:2) amine blend. Table 1 shows the log mean average overall mass transfer coefficients considering mass transfer along the column and mass transfer at the top and bottom of both columns. The log mean average was used due to the non-linearity of K_{Ga_v} along the column as seen from figures 3-5. Same trend as described above is observed.
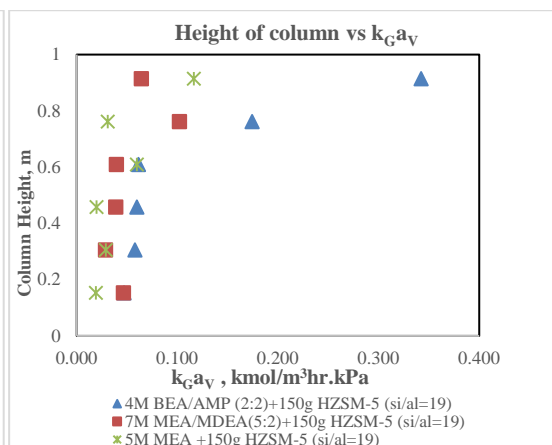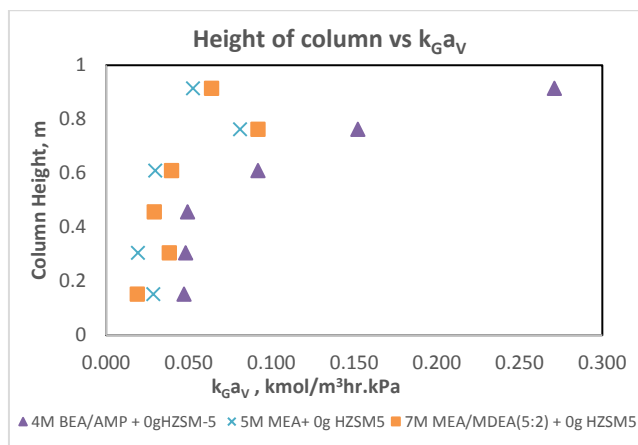
Fig 3: Effect of solvent (0g HZSM-5) on K_{Ga_v} of absorber

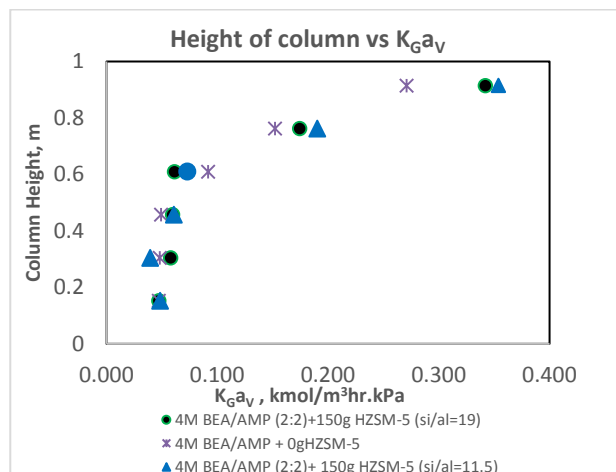Fig 4:Effect of catalyst on K_{Ga_v} of absorber

Height of column vs K_Ga_V

- 4M BEA/AMP (2:2)+150g HZSM-5 (si/al=19)
- 4M BEA/AMP + 0gHZSM-5
- 4M BEA/AMP (2:2)+ 150g HZSM-5 (si/al=11.5)

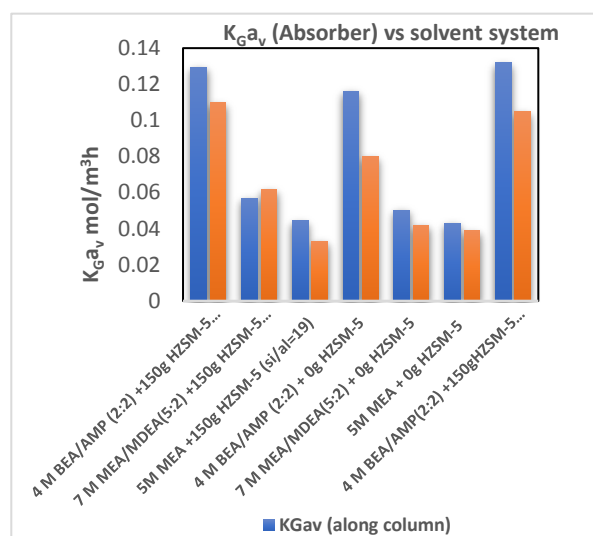Fig 5: Effect of HZSM-5 catalyst strength on K_Ga_V of absorber

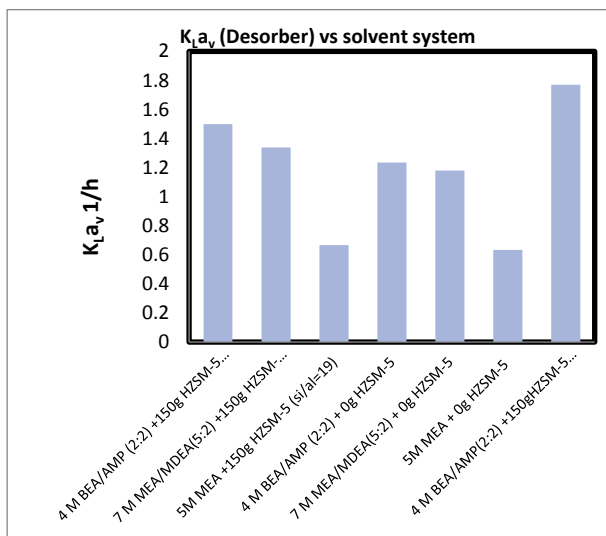Fig 6: : Log mean average K_Ga_V (kmol/m^{3}h)   Fig 7: : Log mean average K_La_V (1/h)

Conclusion

Figures 6 and 7, shows the highest K_Ga_V and K_La_V obtained for amines with catalyst. The results reveal that BEA/AMP blend has the highest overall mass transfer coefficient in agreement with research done on the BEA/AMP blend (Narku-Tetteh J et al 2017).

References

- Naami A. , Edali M., Sema T., Idem R,* and Tontiwachwuthikul P. (2012) *Mass Transfer Performance of CO_2 Absorption into Aqueous Solutions of 4-Diethylamino-2-butanol, Monoethanolamine,and N-Methyldiethanolamine*.
- Narku-Tetteh J., Muchanb P,, Saiwanb C., Supap T., Idem R, (2017) *Selection of components for formulation of amine blends for post combustion CO2 capture based on the side chain structure of primary ,secondary and tertiary amines* (http://www.sciencedirect.com/science/article/pii/S0009250917301446)
- Osei P. A (2016) *Mass transfer studies on catalyst-aided co2 desorption in a Post combustion CO_2 capture plant*. MASc. Thesis, University of Regina, Canada.