Two Film Rate-Based Model Multicomponet Gas Acid Absorption in Promoted Potassium Carbonate Solution

by

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ABSTRACT

Absorption of gases in liquids accompanied by chemical reaction (reactive absorption) is a fundamental operation in a broad spectrum of chemical process technologies. In oil refineries, flue and tail gases need to be purified to meet pollution standards, in fertilizer and petrochemical plants acid gases have to be removed from the feed to ammonia synthesis plants and polymerization units to avoid catalyst poisoning. The absorption of carbon dioxide with alkanolamine or potassium carbonate solvent has gained widespread acceptance for the removal of CO_2 and H_2 from natural gas. However, alkanolamine solution are prone to oxidative degradation at high temperature. The main advantages of potassium carbonate solution for CO_2 removal are the high chemical solubility of CO_2 in the carbonate/bicarbonate system, low solvent costs and the low energy requirement for solvent regeneration. The major challenge concerning absorption of CO_2 into aqueous solution of potassium carbonate is a relatively slow rate of reaction in the liquid phase causing low mass transfer rates. It is often advantageous to add a promoter to increase the absorption rate. While piperazine is often used for this purpose. In this work we consider methyl-diethanolamine (MDEA) and boric acid as an alternative promoter.

Experimental studies have been conducted to determine the reaction kinetics data of CO_2 absorption with K_2CO_3 solvent and promoter MDEA or boric acid using WWC. Data were obtained over the temperature range of 303-323K and for 1-3 wt% MDEA or boric acid. The addition of 1, 2, and 3 wt% MDEA or boric acid to 30 wt% K_2CO_3 system results in a significant enhancement of CO_2 absorption rates. Both of the promotor, two kinetic models were proposed in this work. The first model, based on second-order reaction rate constant measurement, the second model, based on pseudo first-order reaction rate constant measurement. The rate of absorption of CO_2 in a solution of 30 wt% K_2CO_3 with the promoter MDEA is greater than the rate of absorption of CO_2 in 30wt% K_2CO_3 solution with boric acid promoter. Research experiments have also been conducted to determine equilibria data of gas-liquid electrolyte system for CO_2-MDEA-K_2CO_3-H_2O. Effect of the addition of MDEA in a solution of K_2CO_3 can increase the CO_2 loading and lowering the partial pressure of CO_2. CO_2 absorption rate has been measured using the Packed Column on atmospheric conditions for model validation.

Beside experimental work, this study developed mathematical model of the proposed process. Modeling of reactive absorption are based on the theoretical description of the

reaction and mass transport in multi component systems. The multi component nature of these phenomena leads to complex process behavior due to the superposition of many driving forces multi component difusion, chemical interactions, etc. For this reason, adequate theoretical description of multi component reactive systems calls for the application of the Maxwell-Stefan equations and, further, for the use of coupled mass transfer equations together with the relevant reaction kinetics. On this basis, a two-phase, gas-liquid reactive system is considered and a general static model is developed for its design. Absorption flux of each component (Ni) were determined using steady-state film model film with Maxwell-Stefan multi component difusion theory, which has been solved analytically by Kenig (2001). Mathematical modeling is done by making a mass balance on a *Packed column*. Microscopic mass balance is performed for each component in the liquid and gaseous phase. As an application, the reactive absorption of sour gases with *Packed column*s is simulated. For the validation of the model, experiments were carried out. The study showed that the rate-based model simulation results using Maxwell-Stefan difusion theory are in a good agreement with the experimental data.

From the theoretical study using Maxwell-Stefan diffusion approach, it can be concluded that increasing CO_2 concentration (so increasing the gas side driving force) does not significantly affect the calculated CO_2 absorption flux because the gas side resistance also increases. However if enhancement factor approach is used, increasing CO_2 concentration does significantly affect the calculated CO_2 absorption flux. The predicted concentration distribution in the column shows that on the top column position the effect of gas side resistance is more dominant than the liquid side resistance, however in the bottom column position opposite phenomena occured. The effects of process variables and operating parameters on the performance of absorber were investigated.The effect of process variables and operating parameters such the flow rate of solution, inlet temperature of solution, the pressure of *Packed column* and type of promoter on the performance of a *Packed column* absorber have been examined, which has been discussed in this report.

Key words: reactive absorption, enhancement factor, potassium carbonate, Maxwell-Stefan, multicomponent, promoter, rate-based model.