

KINETICS OF CARBON DIOXIDE REMOVAL BY AQUEOUS ALKALINE AMINO ACID SALTS

Prakash Vaidya,¹ Prashanti Konduru,¹ Mukanth Vaidyanathan¹
and Eugeny Y. Kenig^{*,2}

¹Department of Chemical Engineering, Institute of Chemical Technology,
Mumbai-400 019, India

²Chair of Fluid Process Engineering, Faculty of Mechanical Engineering,
University of Paderborn, D-33098, Paderborn, Germany

Summary

Aqueous solutions containing salts of carboxylic or sulfonic amino acids represent candidate solvents having good potential for carbon dioxide (CO₂) capture. In the present work, the CO₂ reactions with potassium salts of glycine (aminoacetic acid) and taurine (2-aminoethanesulfonic acid) in aqueous solutions are investigated, using a stirred-cell reactor. The reaction kinetics is described using the zwitterion mechanism. The observed reaction rate constants for these systems are measured. Furthermore, the rate constants for the investigated reactions are evaluated and compared with the values in literature. Finally, it is found that potassium glycinate promoted the activity of amines (e.g., N,N-diethylethanolamine).

Keywords

CO₂ Capture, Chemical Kinetics, Reactive Absorption

Introduction

Carbon dioxide (CO₂) is a major Greenhouse gas responsible for global warming, and hence, much effort is being put on the development of technologies for its capture from process gas streams. Currently, a number of different CO₂ separation technologies are available, absorption performed with chemical solvents representing the most feasible option. In such operations, alkanolamine-based absorbents and their blends are being extensively applied. Along with amines, carbonate-bicarbonate buffers are used in bulk CO₂ removal, too.

Aqueous solutions containing salts of amino acids represent further candidate solvents having good potential for CO₂ capture. Due to their ionic nature, these salt solutions exhibit low volatility, high surface tension, and increased resistance to oxidative degradation.¹ Their reactivity and CO₂ absorption capacity are comparable to those of aqueous amines of the related classes.² They are also added as promoters to conventional solvents. Some examples of commercial interest are glycine (Giammarco-Vetrocoke), alanine, and diethyl or dimethyl glycine (Alkacid, BASF).³

In the present work, the CO₂ reactions with potassium salts of glycine (or aminoacetic acid) and taurine (or 2-aminoethanesulfonic acid) in aqueous solutions are studied. By now, there is scarce information available in the literature on the chemical kinetics, and hence, a comprehensive study appears desirable.

Experimental

A batch-operated stirred cell reactor with a plane, horizontal gas-liquid interface was used to study reaction kinetics.⁴ In each experiment, a certain amount of CO₂ was rapidly introduced into the reactor and the pressure decrease caused by absorption and reaction was recorded. From this record, the absorption rate at a particular temperature and liquid-phase composition was determined. This measurement method based on the fall-in-pressure technique is very simple and straightforward; besides, no analysis of the liquid phase is required for the evaluation of the kinetic parameters.

* To whom all correspondence should be addressed

Results and Discussion

The two-step zwitterion mechanism, which describes the CO₂ reaction with primary and secondary alkanolamines, can also be used to explain the reactions with potassium glycinate and taurate. These alkaline salts form a zwitterion-type complex that is deprotonated by the bases present in the solution. Consequently, this results in carbamate formation.

The reaction with glycinate was studied at 298 and 303 K over a range of salt concentrations (0.1 - 0.5 kmol/m³). Besides, solution densities and viscosities were determined. CO₂ absorption rates into taurate solutions were measured at 298, 303 and 308 K. The observed reaction rate constants for these systems were estimated. The second-order rate constants for the investigated reactions were evaluated and compared with the values in literature.

N,N-Diethylethanolamine (DEEA), which can be prepared from renewable resources, represents a promising solvent for CO₂ capture.⁵ Due to its tertiary amine characteristics, DEEA has low reactivity with respect to CO₂. Therefore, it is desirable to identify absorption activators promoting the reaction with DEEA. Bearing this in mind, we measured CO₂ absorption rates into aqueous mixtures of DEEA and potassium glycinate. The results appear encouraging due to the acceleration of reaction by glycinate.

References

- (1) Hook, R. J. An investigation of some sterically hindered amines as potential carbon dioxide scrubbing compounds. *Ind. Eng. Chem. Res.* **1997**, *36*, 1779.
- (2) Penny, D. E.; Ritter, T. J. Kinetic study of the reaction between carbon dioxide and primary amines. *J. Chem. Soc., Faraday Trans. 1* **1983**, *79*, 2103.
- (3) Kumar, P. S.; Hogendoorn, J. A.; Versteeg, G. F.; Feron, P. H. M. Kinetics of the reaction of CO₂ with aqueous potassium salt of taurine and glycine. *AIChE J.* **2003**, *49*, 203.
- (4) Vaidya, P. D.; Mahajani, V. V. Kinetics of the reaction of CO₂ with aqueous solutions of MEA formulated with N-methyl-2-pyrrolidone and diethylene glycol. *Ind. Eng. Chem. Res.* **2005**, *44*, 1868.
- (5) Vaidya, P. D.; Kenig, E. Y. Acceleration of CO₂ reaction with N,N-diethylethanolamine in aqueous solutions by piperazine. *Ind. Eng. Chem. Res.* **2008**, *47*, 34.