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High-pressure Solubility of Carbon Dioxide in Aqueous Sodium L- Prolinate Solution

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Abstract

An experimental evaluation of CO_2 solubility in aqueous sodium L-prolinate (SP) solution was carried out using high-pressure solubility equipment at three different temperatures, 303.15, 313.15, and 333.15 K. The study was conducted over the pressure range from 2 to 60 bar for 30 wt. % SP solution. It was found that, the CO_2 loading (mole of CO_2 / mole of SP) decreases with increasing temperature, while it increases with increasing the pressure of gas. ANOVA analysis was carried out to determine the statistical significance of the solubility data with respect to temperature and pressure. The CO_2 loading of aqueous SP solution was also compared with MEA and aqueous sodium glycinate (SG) solution. It was observed that the aqueous SP solution has higher CO_2 loading capacity as compared to 30 wt. % MEA, and comparable with aqueous 30 wt. % SG solution.

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Keywords: sodium L-prolinate; carbon dioxide; solubility; high pressure; CO_2 loading

1. Introduction

Absorption by chemical solvent is the widely used technology for CO_2 removal from various streams of gas. The solvents, which are commercially used for years, are alkanolamines such as monoethanolamine (MEA), diethanolamine (DEA), triethanolamine (TEA), methyldiethanolamine (MDEA) [1]. After the long-term research, various issues were identified with the use of alkanolamines solvents. These issues include thermal and oxidative degradation, limited CO_2 loading, shorter life, corrosion, high volatility, and high regeneration energy. [2-5].

Recently, amino acids salt solutions have been proposed as an effective alternative to alkanolamines solvents as they react with CO_2 similar to alkanolamines. Amino acids salts have various benefits such as higher resistance to degradation, negligible volatility, less corrosive, environmental friendly and easily available at commercial level. A part from this, the CO_2 loading capacity of amino

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acid salts is also higher than the alkanolamines, such as MEA [1, 5, 6, 8, 9]. The potential advantages of amino acids for CO_2 capture have motivated us to further investigate the amino acid salts for CO_2 capture.

Nomenclature

ANOVA	analysis of variance
CO_2	carbon dioxide
m_{SP}	mass fraction of SP
M_{SP}	molecular weight of SP
n_{CO2}	moles of CO_2
n^g_{CO2}	moles of CO_2 in gas phase
n^l_{CO2}	moles of CO_2 in liquid phase
n_{SP}	moles of SP
P_{CO2}	equilibrium pressure [bar]
P_T	total pressure [bar]
P_v	vapor pressure [bar]
R	real gas constant [L bar K^{-1} mol^{-1}]
T	temperature [K]
V_g	volume of gas in equilibrium cell
z_1 and z_2	compressibility factors
α	loading [mol / mol]
ρ	density [g·cm^{-3}]

Various studies on the solubility of CO_2 in aqueous potassium salts of amino acids are available in the literature. Solubility of CO_2 in potassium salts of amino acids such as taurine, glycine, threonine, L-proline, and sarcosine have been studied and reported in the literature [10-13]. Most of the studies have been carried out on potassium salts of amino acids; very few studies are available on sodium salts of amino acid such as sodium L-prolinate (SP) [5-7]. Salt of L-proline has been identified as potential solvent for CO_2 capture with fast kinetics and high loading capacity than MEA and DEA [14]. Despite the significant potential of this amino acid, very limited studies are available in the literature. Solubility of CO_2 in aqueous potassium salt of L-proline has been reported in the literature [12]. However, no data on CO_2 solubility in aqueous SP solution is available in the literature. Only physical properties of SP have been reported [15]. Figure 1 shows the chemical structure of SP.

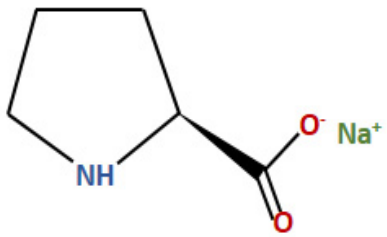

Figure 1. Chemical structure of SP

Since, the solubility of CO_2 in aqueous SP solution is very crucial for the design and development of CO_2 removal process [13]. Moreover, the available studies on CO_2 solubility are limited to low pressure conditions. None of the study has been conducted at high pressure. The CO_2 solubility data for aqueous SP solution at high-pressure conditions are also very crucial for the design and development of high-pressure CO_2 removal process [13]. Therefore, in this study, the experimental solubility of CO_2 in aqueous SP solution at various temperatures (303.15, 313.15, and 333.15 K) over the pressure range from 2 to 60 bar have been carried out. The results of this study will be useful for developing and designing the CO_2 absorption system for low and high-pressure operations, especially at offshore conditions.