

Carbon dioxide loading capacity in aqueous solution of Potassium salt of Proline blended with Piperazine as new absorbents



Mohammad Ehsan Hamzehie, Hesam Najibi*

Faculty of Petroleum Engineering, Petroleum University of Technology (PUT), P.O. Box 63431, Ahwaz, Iran

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ABSTRACT

In this work aqueous solution of potassium proline (KPr) blended with piperazine (PZ) have been utilized through CO₂ solubility measurements in order to investigate the possible use of these salts of amino acid blended with alkanolamine for CO₂ absorption. The equilibrium solubility of CO₂ for KPr blended with PZ solutions at 1.0, 4.0 and 10.0 wt.% overall mass concentration is experimentally measured with an equilibrium cell at CO₂ partial pressure ranging from 4.8 to 2383.2 kPa and temperatures between 293.15 and 323.15 K. Obtained data showed that loading capacity decreases with an increase in temperature and concentration of KPr. Obtained CO₂ loadings are very high at low concentration of KPr. In order to predict CO₂ solubility in KPr blended with PZ, Deshmukh-Mather model is extended. The values of MSE, ARD and R² for the extended Deshmukh-Mather model are 0.0363, 10.7770 and 0.9844, respectively.

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1. Introduction

Many industries release a large value of greenhouse gases (GHG) that cause global warming; therefore, decrease of GHG is vital to avoid climate changes. 55% of global warming is due to presence of Carbon dioxide (CO₂) in atmosphere. Thus, decrease of CO₂ from industries is very important [1].

Absorption process is one of the most important processes to decrease CO₂ from flue gas streams [2]. Also aqueous solution of alkanolamines are the most applicable chemical solvents to decrease CO₂ from flue gases due to low cost, high resistance to thermal degradation, low hydrocarbons loading capacity and high absorption rate [3]. However, alkanolamines have some disadvantages including high-energy requirements for process, degradation in presence of oxygen, also exploiting alkanolamines can cause corrosion, foaming and fouling [3].

Newly, amino acid salt solutions have been introduced as new absorbents for CO₂ absorption [4]. Amino acid salt solutions have a potential alternative for alkanolamines. Although alkanolamines are cheaper than amino acid salt solutions, but due to ionic nature of amino acid salts, they have suitable properties like, high chemical reactivity, low vapor pressures, high stability toward oxidative degradation, suitable binding energy with CO₂ and low viscosities [5].

A few researches on CO₂ absorption in amino acid salt solutions are reported in literature. Song et al. measured CO₂ loading capacity in aqueous solutions of 10 wt.%, 20 wt.% and 30 wt.% of sodium glycinate at CO₂ partial pressure between 0.1 and 200 kPa and operating temperature from 303 to 323 K. Their measurement indicated that loading capacity decreased with an increase in amino acid salt concentration [6]. Munoz et al. measured the CO₂ solubility into 1 M solution of the potassium salts of arginine, glycine, proline, taurine, threonine, ornithine serine, and histidine. Their experiments were done at 293 K and 100 kPa. Their obtained results indicated that solubility of salts of amino acid were similar to MEA [7]. Portugal et al. experimented CO₂ solubility in potassium salt of threonine and glycine. Their experiments indicated that solubility of salts of amino acid were similar to MEA but in their experiments, no solid phase was produced. Their measurements indicated that with an increase in concentration of salt of amino acid, CO₂ solubility decreased [8]. Recently Mazinani et al. measured the CO₂ equilibrium solubility in potassium lysinate at low partial pressures of CO₂. Their investigations indicated that with an increase in concentration and operating temperature of aqueous solution of potassium lysinate, CO₂ solubility decreased [9].

Experimental data that presented in literature for equilibrium absorption of CO₂ into some salts of amino acid are limited in types of amino acid and range.

In current work, suitable properties of alkanolamine and amino acid salt are achieved by blending aqueous solution of potassium proline (KPr) and piperazine (PZ), CO₂ equilibrium loading capacity in solutions of KPr blended with PZ (new kind of solutions

* Corresponding author.

E-mail addresses: hesamnajibi60@gmail.com, najibi@put.ac.ir (H. Najibi).

Nomenclature

T	Temperature (K)
P_{CO_2}	Partial pressure of CO ₂ (kPa)
X	Overall mass concentration of the mixture
M_{app}	Apparent molecular weight (g/mol)
MW_i	Molecular weight component i
N	Number of data point
NC	Number of component in the mixture
i	Integer counter
I	Ionic strength
a	Activity
H	Henry coefficient

Symbols

α	CO ₂ solubility (mole CO ₂ /mole solution)
$\bar{\alpha}$	Average CO ₂ solubility (mole CO ₂ /mole solution)
β	Binary interaction parameter
γ	Activity coefficient
ε	Dielectric constant of the solvent
MEA	Monoethanolamine
PZ	Piperazine
KPr	Potassium proline
Pr	Proline

Subscripts

calcd	Calculated
exp	Experimental
carbAmA	Carbamate that produced by salt of amino acid
carbPZ	Carbamate that produced by piperazine
AmA	Amino acid
w	Water
MLFNN	Multi-layer feed-forward neural network
ANN	Artificial neural network
ARD	Average relative deviation
MSE	Mean square error
R ²	Correlation coefficient

that seem suitable for utilization in industrial applications) are measured at different overall mass concentration and operating conditions. Also by using these experimental data, Deshmukh-Mather model is extended. To our best knowledge, literature data for CO₂ solubility in KPr blended with PZ are not available and it is the first time in literature Deshmukh-Mather model is extended for an aqueous solution of amino acid salt blended with alkanolamine.

2. Experimental

2.1. Materials

Monoethanolamine (99.5%), Glycine (extra pure, 98.5%), Proline (extra pure, 98.5%), Sarcosine (extra pure, 98.5%), Alanine (extra pure, 98.5%), Potassium Hydroxide (extra pure, 99%), Sodium Hydroxide (extra pure, 99%) and Piperazine hexa hydrate (extra pure, 98%) were obtained from Scharlau. 2-amino-2-methyl-1-propanol (95%) was also purchased from Merck.

2.2. Experimental set-up

A schematic of the experimental set-up that is exploited in our previously published works [10,11] is briefly illustrated in Fig. 1. Experimental set-up is contained a stainless steel cell, which can work under pressures up to 5 MPa. The volume of equilibrium cell

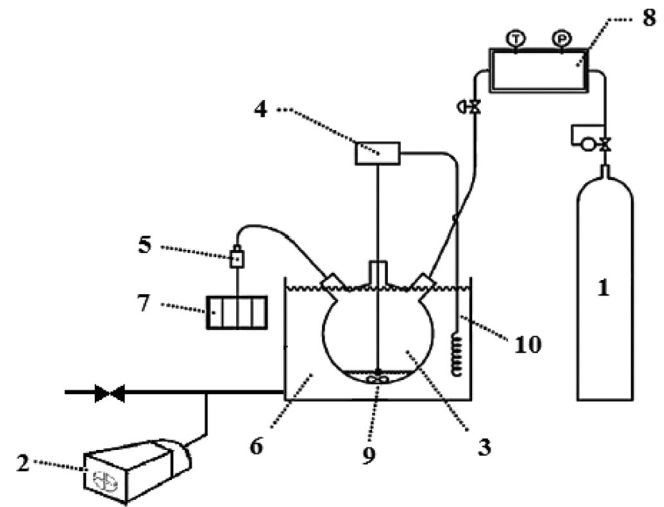


Fig. 1. Schematic of the experimental set-up: (1) gas cylinder; (2) vacuum pump; (3) equilibrium cell; (4) temperature indicator; (5) pressure indicator; (6) constant temperature bath; (7) data logger; (8) gas storage tank; (9) magnetic stirrer and (10) bath temperature thermocouple.

Table 1

Comparison between CO₂ loadings measured in this work with experimental data from literature for different concentration of Sodium Glycinate at 298.15 K.

Present work α (mol CO ₂ /mol solvent)	PCO ₂ (kPa)	Harris et al. [12] α (mol CO ₂ /mol solvent)	PCO ₂ (kPa)
1% wt. Sodium Glycinate		1% wt. Sodium Glycinate	
2.619	496.3	2.688	515
3.411	1563.5	3.375	1527
3.991	2519.5	4.063	2535
5% wt. Sodium Glycinate		5% wt. Sodium Glycinate	
1.339	991.4	1.375	1022
1.483	2106.9	1.413	2020
10% wt. Sodium Glycinate		10% wt. Sodium Glycinate	
1.316	1045.2	1.281	1009
1.389	2104.7	1.363	2024
15% wt. Sodium Glycinate		15% wt. Sodium Glycinate	
0.982	491.6	1.013	526
1.005	1610.5	1.054	1536
1.093	2471.9	1.138	2521
20% wt. Sodium Glycinate		20% wt. Sodium Glycinate	
1.096	1037.3	0.991	1010
1.196	2117.2	1.116	2038
30% wt. Sodium Glycinate		30% wt. Sodium Glycinate	
0.917	527.3	0.906	516
1.092	1631.6	0.967	1526
1.061	2611.6	1.031	2534

is 31.5 cm³. The uncertainties for temperature and pressure measurements are less than 0.1 K and 0.01 MPa, respectively.

2.3. Experimental procedure

In this work, CO₂ loading capacities are measured based on difference between primary and secondary pressures. The cell is first evacuated with a compressor and then 7 ml of prepared solution is added to cell. After that, CO₂ gas is introduced until the cell pressure reached to specified pressure P_1 at the initial temperature T_1 . The cell is left in the bath to reach equilibrium conditions and the cell pressure became constant at pressure P_2 . Based on difference

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