



Thermophysical property characterization of aqueous amino acid salt solution containing serine



Shanille S. Navarro^a, Rhoda B. Leron^{a,b}, Allan N. Soriano^a, Meng-Hui Li^{b,*}

^a School of Chemical Engineering and Chemistry, Mapúa Institute of Technology, Manila 1002, Philippines

^b R&D Center for Membrane Technology and Department of Chemical Engineering, Chung Yuan Christian University, Chung Li 32023, Taiwan, ROC

ARTICLE INFO

Article history:

Received 28 January 2014

Received in revised form 25 May 2014

Accepted 28 May 2014

Available online 9 June 2014

Keywords:

Amino acid salt solution

Density

Electrical conductivity

Refractive index

Viscosity

Thermophysical property characterization

ABSTRACT

Thermophysical property characterization of aqueous potassium and sodium salt solutions containing serine was conducted in this study; specifically the system's density, refractive index, electrical conductivity, and viscosity. Measurements were obtained over a temperature range of (298.15 to 343.15) K and at normal atmospheric pressure. Composition range from $x_1 = 0.009$ to 0.07 for aqueous potassium and sodium salt solutions containing serine was used. The sensitivity of the system's thermophysical properties on temperature and composition variation were discussed and correlated based on the equations proposed for room temperature ionic liquids. The density, viscosity, and refractive index measurements of the aqueous systems were found to decrease as the temperature increases at fixed concentration and the values increase as the salt concentration increases (water composition decreases) at fixed temperature. Whereas, a different trend was observed for the electrical conductivity data; at fixed concentration, the conductivity values increase as the temperature increases and at fixed temperature, its value generally increases as the salt concentration increases but only to a certain level (specific concentration) wherein the conductivity of the solution starts to decrease when the concentration of the salt is further increased. Calculation results show that the applied models were satisfactory in representing the measured properties in the aqueous amino acid salt solution containing serine.

© 2014 Elsevier Ltd. All rights reserved.

1. Introduction

As the issue on global warming and climate change rises, scientists and researchers are now conducting studies that compromise different approaches on carbon dioxide diminution or absorption. Chemical absorption in liquid solutions is a proven technology for CO₂ removal from a variety of gas streams [1–3]. Substantial interest to boost the rate of absorption of CO₂ leads to analysis of different amino acid solvents. A comprehensive and systematic characterization of thermophysical properties of solvent systems is a significant requirement in the development of such process. Thermophysical properties affect mass and heat transfer processes in solutions; provide useful information that further explains the capacity of certain chemical substances or liquid solutions to absorb concentrations of carbon dioxide. Amino acid solvents are attractive for post combustion CO₂ absorption because of their low environmental impact, with characteristics such as zero volatility, low ecotoxicity, and high biodegradability [4].

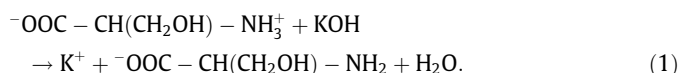
Studies involving thermophysical characterization of some solvent systems have already been conducted: aqueous solutions of alkanolamines [5–12], ionic liquids [13], and glycol-amines [14,15]. The use of aqueous solutions of alkanolamines (organic solvents with –NH₂) is one of the most widely applied technologies for removing carbon dioxide industrially via chemical absorption [16]. However, this system has setbacks such as intensive energy consumption, cost increases, and corrosion problems [13]. Researchers and scientists are still making an effort to discover other systems that are more efficient and economical to use.

In this regard, amino acid salt solutions are being studied for its potential to absorb concentrations of carbon dioxide gases. Their specific properties make them suitable for application in membrane gas absorption units, allowing compact equipment design and potentially leading to reductions in investment costs. A further advantage can be achieved by the interesting feature of several amino-acid salts – solid precipitates are produced as the CO₂ loading exceeds a certain value which significantly improves the absorber performance and reduce energy consumption during regeneration [17]. Sodium and potassium salt solutions of serine react in much the same way as amines with CO₂ via carbamate and bicarbonate formation. When the amino acid is reacted with

* Corresponding author. Tel.: +886 3 265 4109; fax: +886 3 265 4199.

E-mail address: mhli@cycu.edu.tw (M.-H. Li).

a base such as potassium hydroxide, a proton is removed from the $-\text{NH}_3^+$ group and the potassium serine salt is obtained [17]:



The potassium salt is the active component, which reacts with CO_2 like amines via the NH_2 group. One study conducted by Song *et al.* [18], the CO_2 absorption performances of the potassium salts of 16 common amino acids were evaluated using cyclic absorption and desorption experiments. To fully utilize such promising properties of this solvent system application in absorption process, exhaustive knowledge of thermophysical properties is imperative. However, very few have performed an extensive thermophysical characterization, especially of aqueous salt system of amino acids. Also, correlations among these important thermophysical properties have not been investigated widely.

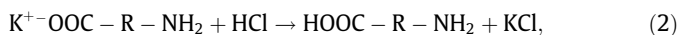
Thus, the main aim of this study is to conduct a thermophysical characterization of aqueous potassium and sodium salt solutions of serine. The study is only concerned on the measurement of thermophysical properties including refractive index, density, viscosity, and electrical conductivity of serine-salt-water aqueous solution and not on how these properties contribute to the capacity of certain systems to absorb CO_2 . The thermophysical properties are to be measured over a temperature range of (293.15 to 343.15) K with increments of 5 K and at normal atmospheric pressure; the composition range of $x_1 = 0.009$ to 0.07 for aqueous potassium and sodium salt solutions containing serine were used. A modified Graber *et al.* [19] equation was used for the density, refractive index and electrical conductivity, and an Arrhenius-type asymptotic exponential function from the modification of the Vogel–Tamman–Fulcher (VTF) equation was used for the viscosity to generally correlate its temperature and compositional dependence.

2. Experimental

2.1. Preparation of solutions

The purities (in mass fraction) of the chemicals as reported by their corresponding suppliers are presented in table 1. The potassium and sodium salts of the selected amino acid were prepared by neutralizing the amino acid, dissolved in degassed deionised water, with an equimolar amount of potassium hydroxide/sodium hydroxide. All weight measurements were performed in a digital balance (Mettler Toledo, model AL204) having an uncertainty of $\pm 1 \times 10^{-4}$ g. The water used to prepare the aqueous solutions was Type 1 reagent-grade (resistivity = $18.3 \text{ M}\Omega \cdot \text{cm}$; total organics 15×10^{-9}) which was purified using a compact ultrapure water system (Barnstead Thermodyne Easy Pure LF). The aqueous solutions were degassed using ultrasonic cleaner (Branson, Model 3510) before their properties were measured. The concentration of each solution was determined through 888 Titrand Metrohm (having an uncertainty of $\pm 0.005 \text{ mL}$) which is connected to a monitor that displays the end points of the solution and the volume of 1 M HCl used. A volume of 1 mL of the sample was placed in a 50 mL beaker using a graduated pipette and diluted with distilled water. With triplicate runs, the concentration of each solution was obtained by getting the average of the three runs. The reaction

mechanisms involved in the titration of the salt solutions with HCl are shown below:



Purity assessment for the synthesized compounds was done by comparing the theoretical (0.5, 1.0, 1.5, 2.0, 2.5) M and actual concentrations of the prepared solutions. This is to assure that the data presented in this study is reliable. Given the weight measurements of the chemicals used to prepare the solutions, the theoretical number of moles formed was determined. And from the actual concentration of the solution measured by the 888 Titrand Metrohm, the moles of the product were calculated. With the actual and theoretical moles of the product calculated, the purity of the synthesized compound was determined. For potassium serine solutions, the average purity was calculated as 100% or simply all reactants were converted to products. However, the average purity of sodium serine solutions was calculated as 98%.

2.2. Property measurements

Prior to the measurements of the systems, substances having available literature data of the considered properties were first measured. This was done to ensure that the applied procedures and the apparatus for each property measurements could give acceptably accurate results. These solutions were referred to as calibration systems. For the measurement of density, viscosity and refractive index, the degassed deionised water was used as the calibration system, whereas for electrical conductivity measurements, the standard KCl solution (0.1 N) from Merck was used.

All measurements were carried out in three to five replicate runs and the average values were reported. The thermophysical property measurements for the considered aqueous amino acid salt solutions were measured as follows:

2.2.1. Specific density, ρ

The densities were measured in triplicate by means of the SVM 3000 Stabinger density measuring cell (Anton Paar GmbH), which uses the principle of oscillating U-tube. The sample is introduced into a U-shaped tube that is electronically excited to oscillate at its characteristic frequency. The characteristic frequency changes depending on the density of the sample. Through precise determination of the characteristic frequency and an appropriate adjustment, the density of the sample was determined. But due to the high temperature dependency of the density, the measuring cell was accurately thermostated. Calibration of the equipment was done using the degassed deionized water. Correction factors were used to account for the measurement discrepancies as based on the change in the density of air inside the tube before and after the sample was run. The estimated uncertainties for temperature and density were $\pm 0.002 \text{ K}$ and $\pm 0.0004 \text{ g} \cdot \text{cm}^{-3}$, respectively. For each concentration, 5 cm^3 were placed in a syringe, and 1.5 cm^3 of it were used per trial. The overall uncertainty of the density measurement was estimated to be $\pm 5 \times 10^{-4} \text{ g} \cdot \text{cm}^{-3}$.

2.2.2. Viscosity, η

The viscosities of the systems studied were measured using an automated microviscometer from Anton Parr GmbH (model AMVn). This viscometer operates on the principle of rolling ball or falling ball in accordance with DIN 53015 and ISO 12058. It consists of the measurement of a ball's rolling time in a diagonally mounted glass capillary filled with sample. The viscometer has a built-in Pt-100 temperature sensor for temperature measurements and regulation. Calibration with water and validation with APS3 oil

TABLE 1
Provenance and purity of the major chemicals used.

Chemical name	Mass fraction purity	Molar mass	Supplier
DL-serine	>0.99	105.09	Alfa Aesar
Potassium hydroxide	>0.85	56.11	Sigma-Aldrich
Sodium hydroxide	>0.99	40.00	Sigma-Aldrich

Download English Version:

<https://daneshyari.com/en/article/215356>

Download Persian Version:

<https://daneshyari.com/article/215356>

[Daneshyari.com](https://daneshyari.com)