Viscometric Properties of Aqueous Sodium and Potassium Salt of L-Leucine

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ABSTRACT

For capturing Carbon dioxide (CO₂) from flue gases after combustion, amino acid salt solutions are considered superior solvents over alkanolamine due to their certain advantages. In the present work, the viscosities measurements of aqueous sodium and potassium salt solutions of L-leucine were made at 298.15, 303.15, 308.15, and 313.15 K, and their concentrations range from 0.01 to 0.15 mol L⁻¹. Thereafter, the Jones-Dole coefficient (B), temperature derivative of B i.e. (dB/dT), the free energy of activation, the enthalpy as well as the entropy of activation of viscous flow were derived from experimental data on viscosity.

Keywords: Carbon dioxide (CO₂), Viscosity, Potassium salt of L-leucine, Jones-Dole coefficient.

INTRODUCTION

Global warming is the most alarming environmental problem. Excessive emissions of carbon dioxide (CO₂) from several sources, including the burning of fuels, both human and other industrial activities, are the primary cause of global warming¹.². The reduction of CO₂ from the flue gas is a vital step in many industrial activities required for economic and environmental aspects. There are many post-combustion capture technologies to separate CO₂ from flue gas, before it enters the atmosphere. The goal is to collect pure CO₂ channels that could be compressed and transported to a storage area. In general, this process is known as CO₂ capture and storage(CCS).

For CO₂ capture chemical absorption using alkanolamine absorbents have been extensively employed². Some of the demerits associated with alkanolamines in CO₂ capture process are their degradation in oxygen-rich atmosphere and corrosion in the process equipment⁵. These drawbacks of alkanolamine solvents limits their application for carbon dioxide capture procedures.

Recently, salts of amino acid have been investigated as good substitutes for amines and many researchers have examined their interaction with CO₂⁵,⁶. Amino acids resembles amines in their
Physicochemical properties are essential in the simulation and design of gas-liquid contactors, heat exchangers, working of the equipment, process modelling, and for the evaluation of proper absorbents for CO$_2$ capture rate experiments. These properties are also essential for the deduction of chemical reaction kinetics from CO$_2$ absorption rate experiments.

For aqueous sodium and potassium leucinate solutions, such properties still have not been described in the existing literature at a lower concentration range. Thus, we provided fresh experimental data on viscosity, therefor Jones-Dole coefficient (B), temperature derivative of B, and the enthalpy and entropy of activation for sodium and potassium salt solutions of above mentioned amino acid.

**RESULTS AND DISCUSSION**

Dynamic viscosities ($\eta$) were determined via:

$$\frac{\eta}{\eta_0} = 1 + A m^{0.5} + B m$$

Where $t$, $\rho$, $\eta$, and $t_0$, $\rho_0$, $\eta_0$ are flow time, density, and viscosity of solution and solvent, respectively.

The measured values of viscosity for aqueous solution of sodium and potassium salt of L-leucine at concentration range (0.01 to 0.15) m and temperatures at (298.15, 303.15, 308.15, and 313.15) K are placed in Table 1. It is observed that viscosity increases with concentration. Table 1, Fig. 1, Fig. 2 indicates that density increases with molality of the solutions and decreases with the increase in the temperature.

The viscosity data were analysed using the Jones-Dole equation:

$$\frac{\eta/\eta_0 - 1}{m^{0.5}} = A + B m$$

Equation 3 resembles the straight line equation ($y=mx+c$) with $B$ as a slope and $A$ as an intercept. The values of $[\eta/\eta_0 - 1]/m^{0.5}$ presented in Table 2. Least square method was employed to obtain Jones-Dole coefficient (B). B values for sodium and potassium salt of leucine at (298.15, 303.15, 308.15 and 315.15) K are presented in Table 3.
acid decreases with an increasing temperature.

Activation Free energy of solvent ($\Delta \mu_{\text{sol}}^{0\#}$) and activation free energy of solute ($\Delta \mu_{\text{solute}}^{0\#}$) can be calculated by the following equations.

\[
\begin{align*}
(\Delta \mu_{\text{sol}}^{0\#}) &= (\Delta G_{\text{sol}}^{0\#}) = RT \ln \frac{n_0 v_0^2}{N_A h} \\
(\Delta \mu_{\text{solute}}^{0\#}) &= (\Delta G_{\text{solute}}^{0\#}) = (\Delta H_{\text{solute}}^{0\#}) + \frac{RT}{v_1} \left[ B - (v_1^0 - v_1^0) \right]
\end{align*}
\]

Where $n_0, N_A,$ and $h,$ are the viscosity of the solvent, Avogadro number and Planck’s constant, respectively.

The enthalpy and entropy of activation $\Delta H^{0\#}$ and $\Delta S^{0\#},$ respectively are calculated by the following equation.

\[
(\Delta G^{0\#}) = \Delta H^{0\#} - T\Delta S^{0\#}
\]

Equation 4 is similar to the straight line equation ($y = mx + C$) where intercept is equal to $\Delta H^{0\#}$ and the slope is $-\Delta S^{0\#}$. $\Delta S^{0\#}$ and $\Delta H^{0\#}$ values were calculated using Least square method. Fig. 5 and Fig. 6 show the variation of $\Delta G^{0\#}$ vs temperature.

Jones-Dole coefficient ($B$) and ($\Delta G^{0\#}$) values of sodium leucinate are found to be greater than potassium leucinate.

Fig. 1. Plot of $\eta/(\text{m}^2, \text{kg.s}^{-1})$ versus $m/(\text{kg.mol}^{-1})$ of sodium leucinate in water at different temperatures (T)

Fig. 2. Plot of $\eta/(\text{m}^2, \text{kg.s}^{-1})$ versus $m/(\text{kg.mol}^{-1})$ of potassium leucinate in water at different temperatures (T)

Fig. 3. Plot of $\left(\eta/\eta_0\right)^{m^{1.5}}$ versus $(m/\text{kg.mol}^{1.5})^{m^{1.5}}$ of sodium leucinate in water at different temperature (T)

Fig. 4. Plot of $\left(\eta/\eta_0\right)^{m^{1.5}}$ versus $(m/\text{kg.mol}^{1.5})^{m^{1.5}}$ of potassium leucinate in water at different temperature (T)

Fig. 5. Plot of $\Delta G/(\text{KJ.mol}^{-1})$ of aqueous sodium leucinate vs T/K

Fig. 6. Plot of $\Delta G/(\text{KJ.mol}^{-1})$ of aqueous potassium leucinate vs T/K
The observations of above Tables and Figures shows that

a. Viscosity of aqueous solution of sodium and potassium salt of leucine increases with increase in the concentration of sodium and potassium of salt amino acid.

b. Viscosity decreases with an increase in the temperature. Temperature increases cause thermal energy to rise, which causes the breakdown of amino acid salt/water aggregates.

CONCLUSION

B value for sodium and potassium salt of leucine decreases as the temperature rises. The positive B and ΔG values indicate strong water and amino acid salt interactions. The negative value of (dB/dT) for investigated amino acid salt-water systems confirms structure making behavior of studied amino acid salts. As a result, it can be said that sodium and potassium salt of leucine is a water structure maker.

Reported data and the related parameters presented in this work may be helpful in the design, improvement, and evaluation of techniques and processes that use the amino acid salt systems for CO₂ capture.
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