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

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http://dx.doi.org/10.13005/ojc/380523

(Received: August 10, 2022; Accepted: October 03, 2022)

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 employed³. Some of the demerits associated with alkanolamines in CO₂ capture process are their degradation in oxygen-rich atmosphere and corrosion in the process equipment⁴. 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
functional group and acts in similar manner in the CO₂
capture process. Amino acids have certain unique
advantages over alkanolamines like fast reaction
kinetics, very low volatility, more stability towards
oxidative degradation⁷, higher surface tension, and
having a significant absorption capability⁸.

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 CO₂ capture rate experiments⁹-¹². These properties are also essential for the deduction of chemical reaction
kinetics from CO₂ absorption rate experiments¹³,¹⁴.

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, thereafter Jones-Dole coefficient (B),
temperature derivative of B i.e. (dB/dT), free energy
of activation(ΔG̅_0#), the enthalpy and entropy of
activation(ΔH̅_0# and ΔS̅_0#) for sodium and potassium
salt solutions of above mentioned amino acid.

**EXPERIMENTAL**

**Materials and preparation of salt amino acid**

L-leucine (CAS No. 61-90-5, 99.0% purity) was supplied by LOBA CHEMIE PVT. LTD., NaOH
(CAS No. 1310-73-2, GR, 98% purity) and KOH
(CAS No. 1310-58-3, GR, 98% purity) were bought
from Merck. All chemicals were used as received.

The aqueous salt solutions of leucine were
made by neutralizing leucine with an equimolar
amount of NaOH and KOH in triply distilled water.
Using the weight/weight method the solutions were
made in dry, airtight glass bottles with stoppers.
Electronic balance accurate to ± 0.1 mg was used
to record the masses.

**Structure of sodium and potassium salt of L-leucine**

Dynamic viscosity values of aqueous solutions of sodium and potassium salt of L-leucine
were measured using Ubbelohde suspended-level
viscometer¹⁵,¹⁶ for concentrations range 0.01 to 0.15
m and at temperatures (298.15, 303.15, 308.15, and
313.15) K at atmospheric pressure. Triply distilled
water and pure AR grade solvents were used to calibrate viscometer. The viscometer was placed
straight in a transparent glass water bath with a
openings above the water level, and a thermostat
was used to maintain the constant temperature at
±0.01 K. a digital stopwatch that is electronic. The
flow-time(t) measurements were performed using
an electronic digital sport stopwatch with a precision
of 0.01 s. Minimum three readings were recorded of
each viscosity data point with a ±0.05 s reproducibility
and their averaged values were considered.

**RESULTS AND DISCUSSION**

Dynamic viscosities (η) were determined via;

\[
\eta = \rho \frac{t}{t_0 \rho_0}
\]

(1)

Where t, ρ, η, t₀, ρ₀, η₀ are flow time,
density, and viscosity of solution and solvent,
respectively.

The viscosity data were
analysed using the
Jones-Dole equation;¹⁷

\[
\frac{\eta}{\eta_0} = 1 + Am^{0.5} + Bm
\]

(2)

A is a constant term that provides data
on the strength of ion-ion interactions in a solution.
Above equation can be modified as;

\[
\left[\frac{\eta}{\eta_0} - 1\right]m^{0.5} = A + Bm^{0.5}
\]

(3)

Equation 3 resembles the straight line
equation (y=mx+c) with B as a slope and A as an
intercept. The values of \[\frac{\eta}{\eta_0}\] 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. B value of sodium and potassium salt of amino
Acid decreases with an increasing temperature.

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

\[
ΔG_{sol}^{0#} = \Delta H_{sol}^{0#} - TΔS_{sol}^{0#}
\]

\[
ΔG_{solute}^{0#} = ΔH_{solute}^{0#} - TΔS_{solute}^{0#}
\]

Where \( η_0 \), \( N_A \), and \( h \), are the viscosity of the solvent, Avogadro number and Planck’s constant, respectively.

The enthalpy and entropy of activation \( ΔH_{act}^{0#} \) and \( ΔS_{act}^{0#} \), respectively are calculated by the following equation.

\[
(ΔG_{act}^{0#}) = ΔH_{act}^{0#} - TΔS_{act}^{0#}
\]

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

Jones-Dole coefficient \( (B) \) and \( (ΔG_{act}^{0#}) \) values of sodium leucinate are found to be greater than potassium leucinate.
Table 1: Viscosities ($\eta$) of sodium and potassium leucinate at different temperatures

<table>
<thead>
<tr>
<th>m(kg.mol$^{-1}$)</th>
<th>$\eta$($m^{2}$.kg.s$^{-1}$)</th>
<th>$\eta$($m^{2}$.kg.s$^{-1}$)</th>
<th>$\eta$($m^{2}$.kg.s$^{-1}$)</th>
<th>$\eta$($m^{2}$.kg.s$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>298.15 K</td>
<td>308.15 K</td>
<td>313.15 K</td>
<td>298.15 K</td>
</tr>
<tr>
<td>0.00000</td>
<td>0.8903</td>
<td>0.7975</td>
<td>0.7195</td>
<td>0.6535</td>
</tr>
<tr>
<td>0.01002</td>
<td>0.8943</td>
<td>0.8018</td>
<td>0.7240</td>
<td>0.6582</td>
</tr>
<tr>
<td>0.03050</td>
<td>0.9043</td>
<td>0.8110</td>
<td>0.7327</td>
<td>0.6665</td>
</tr>
<tr>
<td>0.05098</td>
<td>0.9147</td>
<td>0.8205</td>
<td>0.7414</td>
<td>0.6746</td>
</tr>
<tr>
<td>0.06973</td>
<td>0.9242</td>
<td>0.8291</td>
<td>0.7493</td>
<td>0.6819</td>
</tr>
<tr>
<td>0.08976</td>
<td>0.9345</td>
<td>0.8385</td>
<td>0.7578</td>
<td>0.6896</td>
</tr>
<tr>
<td>0.10979</td>
<td>0.9448</td>
<td>0.8478</td>
<td>0.7662</td>
<td>0.6974</td>
</tr>
<tr>
<td>0.13074</td>
<td>0.9558</td>
<td>0.8575</td>
<td>0.7750</td>
<td>0.7055</td>
</tr>
<tr>
<td>0.15169</td>
<td>0.9667</td>
<td>0.8674</td>
<td>0.7839</td>
<td>0.7133</td>
</tr>
</tbody>
</table>

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 $\Delta G$ values indicate strong water and amino acid salt interactions. The negative value of $\Delta G$ 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 CO$_2$ capture.
ACKNOWLEDGMENT

Author wants to thank the Director of Government Vidarbha Institute of Science, and Humanities, Amravati for permission for the research facility and the Principal, HPT Arts and RYK Science College of Nashik for his kind support.

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