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

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ABSTRACT

For capturing Carbon dioxide (CO_2) 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 dioxice ($CO_{2)}$, Viscosity, Potassium salt of L-leucine, Jones-Dole coefficient.

INTRODUCTION

Global warming is the most alarming environmental problem. Excessive emissions of carbon dioxide (CO_2) from several sources, including the burning of fuels, both human and other industrial activities, are the primary cause of global warming[1,2]. The reduction of CO_2 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 CO_2 from flue gas, before it enters the atmosphere. The goal is to collect pure CO_2 channels that could be compressed and transported to a storage area. In general, this process is known as CO_2 capture and storage(CCS).

For CO_2 capture chemical absorption using alkanolamine absorbents have been extensively employed[3]. Some of the demerits associated with alkanolamines in CO_2 capture process are their degradation in oxygen-rich atmosphere and corrosion in the process equipment[4]. 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 CO_2[5,6]. Amino acids resembles amines in their functional group and acts in similar manner in the CO_2 capture process. Amino acids have certain unique advantages over alkanolamines like fast reaction kinetics, very low volatility, more stability towards oxidative degradation[7], higher surface tension, and having a significant absorption capability[8].

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[9-12]. These properties are also essential for the deduction of chemical reaction kinetics from CO_2 absorption rate experiments[13,14].

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($\Delta G^{0\#}$), the enthalpy and entropy of activation ($\Delta H^{0\#}$ and $\Delta S^{0\#}$) for sodium and potassium salt solutions of above mentioned amino acid.

EXPERIMENTAL

Materials and preparation of salt amino acid

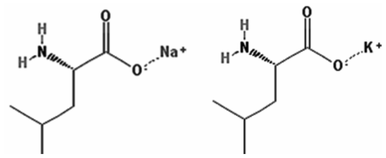
L-leucine (CAS No. 61-90-5, 99.0% purity) was supplied by LOBA CHEMIE PVT. LTD., NaOH (CAS No. 1310-73-2, GR, 98% purity) and KOH (CAS No. 1310-58-3, GR, 98% purity) were bought from Merck. All chemicals were used as received.

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

Viscosity measurements

Dynamic viscosity values of aqueous solutions of sodium and potassium salt of L-leucine were measured using Ubbelohde suspended-level viscometer[15,16] 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 calibrated 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;

$$\frac{\eta}{\eta_0} = \frac{\rho t}{t_0 \rho_0} \tag{1}$$

Where t, ρ, η, and t_o, ρ_o, η_o 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;[17]

$$\eta/\eta_0 = 1 + Am^{0.5} + Bm \tag{2}$$

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

$$[(\eta/\eta_0)-1]/m^{0.5} = A + Bm^{0.5} \tag{3}$$

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. B value of sodium and potassium salt of amino acid decreases with an increasing temperature.

Activation Free energy of solvent ($\Delta\bar{\mu}_1^{0\#}$) and activation free energy of solute ($\Delta\bar{\mu}_2^{0\#}$) can be calculated by the following equations.

$$(\Delta\bar{\mu}_1^{0\#}) = (\Delta G_1^{0\#}) = RT\ \ln\frac{\eta_0 \bar{v}_1^0}{hN_A}$$

$$(\Delta\bar{\mu}_2^{0\#}) = (\Delta G^{0\#}) = (\Delta\bar{\mu}_1^{0\#}) + \frac{RT}{\bar{v}_1^0}\,[B-(\bar{v}_1^0-\bar{v}_2^0)]$$

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

$$(\Delta G^{0\#}) = \Delta H^{0\#} - T\Delta S^{0\#} \qquad (4)$$

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.

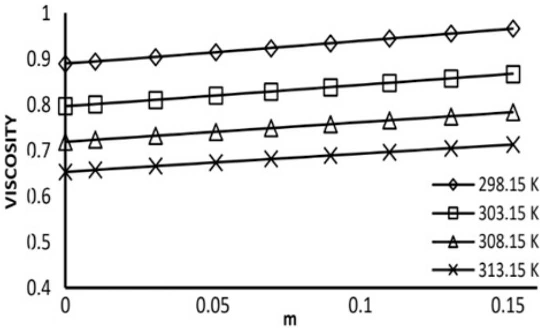


Fig. 1. Plot of η/(m⁻¹.kg.s⁻¹) versus m/(kg.mol⁻¹) of sodium leucinae in water at different temperatures (T)

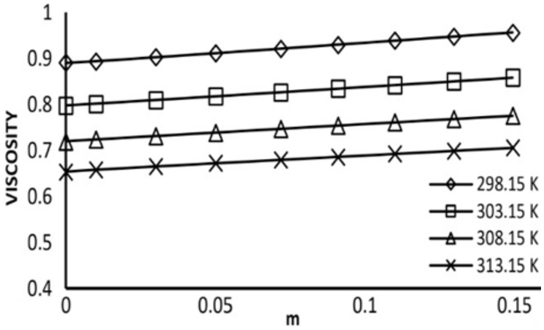


Fig. 2. Plot of $\eta/(m^{-1}.kg.s^{-1})$ versus $m/(kg.mol^{-1})$ of potassium leucinae in water at different temperatures (T)

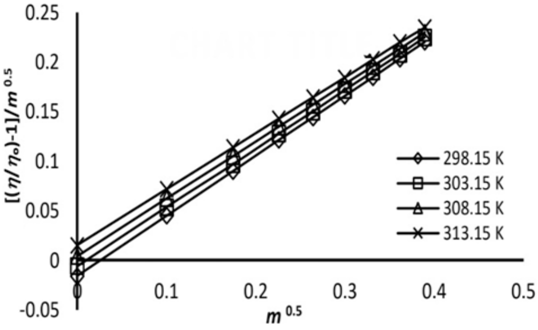


Fig. 3. Plot of $[(\eta/\eta_o)^{-1}]/m^{0.5}$ versus $(m/kg.mol^{-1})^{0.5}$ of sodium leucinate in water at different temperature (T)

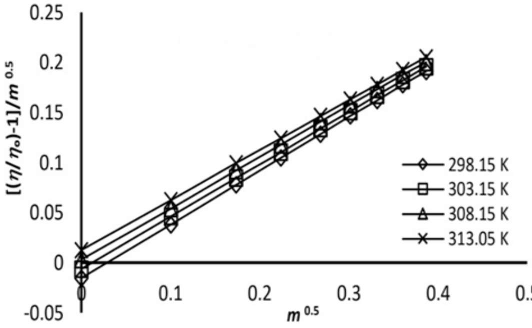


Fig. 4. Plot of $[(\eta/\eta_o)^{-1}]/m^{0.5}$ versus $(m/kg.mol^{-1})^{0.5}$ of potassium leucinate in water at different temperature (T)

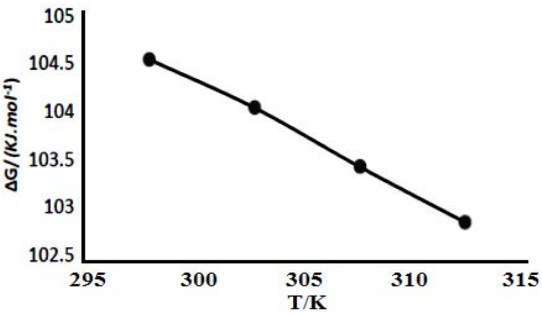


Fig. 5. Plot of $\Delta G/(KJ.mol^{-1})$ of aqueous sodium leucinate vs T/K

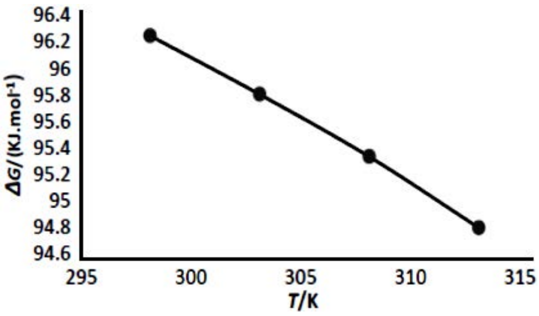


Fig. 6. Plot of $\Delta G/(KJ.mol^{-1})$ of aqueous potassium leucinate vs T/K

Table 1: Viscosities (η) of sodium and potassium leucinate at different temperatures

m(kg.mol^{-1})	η(m^{-1}.kg.s^{-1})				m(kg.mol^{-1})	η(m^{-1}.kg.s^{-1})			
	298.15 K	308.15 K	308.15 K	313.15 K		298.15 K	303.15 K	308.15 K	313.15 K
	Sodium leucinate					Potassium leucinate			
0.00000	0.8903	0.7975	0.7195	0.6535	0.00000	0.8903	0.7975	0.7195	0.6535
0.01002	0.8943	0.8018	0.7240	0.6582	0.01007	0.8937	0.8012	0.7234	0.6576
0.03050	0.9043	0.8110	0.7327	0.6665	0.03010	0.9023	0.8092	0.731	0.6648
0.05098	0.9147	0.8205	0.7414	0.6746	0.05014	0.9112	0.8172	0.7385	0.6717
0.06973	0.9242	0.8291	0.7493	0.6819	0.07199	0.9210	0.8262	0.7467	0.6792
0.08976	0.9345	0.8385	0.7578	0.6896	0.09103	0.9297	0.8339	0.7538	0.6857
0.10979	0.9448	0.8478	0.7662	0.6974	0.11007	0.9382	0.8418	0.7608	0.6921
0.13074	0.9558	0.8575	0.7750	0.7055	0.12977	0.9473	0.8498	0.7681	0.6988
0.15169	0.9667	0.8674	0.7839	0.7133	0.14947	0.9561	0.8579	0.7751	0.7054

Table 2. $[(\eta/\eta_o)^{-1}]/m^{0.5}$ values for sodium and potassium leucinate in water at different temperatures

m(kg.mol^{-1})	$[(\eta/\eta_o)^{-1}]/m^{0.5}$				m(kg.mol^{-1})	$[(\eta/\eta_o)^{-1}]/m^{0.5}$			
	298.15 K	308.15 K	308.15 K	313.15 K		298.15 K	303.15 K	308.15 K	313.15 K
	Sodium leucinate					Potassium leucinate			
0.01002	0.04488	0.05386	0.06248	0.07185	0.01007	0.03806	0.04623	0.05402	0.06252
0.03050	0.09004	0.09693	0.10505	0.11391	0.0301	0.07769	0.08456	0.09213	0.09967
0.05098	0.12138	0.12773	0.13481	0.14300	0.05014	0.10484	0.11032	0.11793	0.12438
0.06973	0.14420	0.15005	0.15685	0.16457	0.07199	0.12852	0.13413	0.14090	0.14657
0.08976	0.16571	0.17160	0.17768	0.18438	0.09103	0.14668	0.15128	0.15801	0.16331
0.10979	0.18475	0.19035	0.19589	0.20274	0.11007	0.16217	0.16743	0.17302	0.17804
0.13074	0.20347	0.20807	0.21333	0.22007	0.12977	0.17773	0.18205	0.18751	0.19243
0.15169	0.22033	0.22504	0.22981	0.23495	0.14947	0.19117	0.19590	0.19988	0.20542

Table 3: (B), (A), dB/dT, (ΔG), (ΔH), and (ΔS) values for sodium and potassium leucinate in water at different temperatures

Parameter	298.15 K	308.15 K	308.15 K	313.15 K	298.15 K	303.15 K	308.15 K	313.15 K
	Sodium leucinate				Potassium leucinate			
B	0.60587	0.59228	0.5784	0.56508	0.5339	0.52163	0.50942	0.49762
A	-0.01572	-0.00597	0.00429	0.01531	-0.0148	-0.00591	0.00392	0.01308
dB/dT		-0.0027244				-0.0024522		
ΔG	104.6072	104.1042	103.4897	102.9127	96.28643	95.84591	95.37608	94.84139
ΔH		138.6106				124.9556		
ΔS		-113.9609				-96.0848		

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 CO_2 capture.

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REFERENCES

1. Alcalde, J.; Flude, S.; Wilkinson, M.; Johnson, G.; Edlmann, K.; Bond, C. E.; Haszeldine, R. S. *Nature communications*., **2018**, *9*(1), 1-13.
2. Olivier, J. G. J.; Peters, J. A. H. W. Trends in global CO_2 and total greenhouse gas emissions. PBL Netherlands Environmental Assessment Agency: The Hague, The Netherlands., **2020**.
3. Ping, T.; Dong, Y.; Shen, S. *ACS Sustainable Chemistry & Engineering*., **2020**, *8*(49), 18071-18082.
4. Vitillo, J. G.; Smit, B.; Gagliardi, L. *Chemical Reviews*., **2017**, *117*(14), 9521-9523.
5. Liu, M.; Gadikota, G. *Fuel*., **2020**, *275*, 117887.
6. Xu, X.; Myers, M. B.; Versteeg, F. G.; Adam, E.; White, C.; Crooke, E.; Wood, C. D. *Journal of Materials Chemistry A*., **2021**, *9*(3), 1692-1704.
7. Chang, Y. T.; Leron, R. B.; Li, M. H. *The Journal of Chemical Thermodynamics*., **2015**, *83*, 110-116.
8. Garcia, A. A.; Leron, R. B.; Soriano, A. N.; Li, M. H. *The Journal of Chemical Thermodynamics*., **2015**, *81*, 136-142.
9. Meng, X.; Duan, C.; Xu, C.; Fang, D. *Chemical Thermodynamics and Thermal Analysis*., **2022**, *5*, 100025.
10. Mondal, B. K.; Samanta, A. N. *Chemical Engineering Journal*., **2020**, *386*, 121462.
11. Guo, H.; Li, H.; Shen, S. *Energy and Fuels*., **2018**, *32*(6), 6943-6954.
12. Garg, S.; Shariff, A. M.; Shaikh, M. S.; Lal, B.; Aftab, A.; Faiqa, N. *Chemical Engineering Research and Design*., **2016**, *113*, 169-181.
13. Li, H.; Shen, S. *Industrial & Engineering Chemistry Research*., **2019**, *58*(23), 9875-9882.
14. Li, H.; Guo, H.; Shen, S. *The Journal of Chemical Thermodynamics*., **2020**, *150*, 106237.
15. Einfeldt, *J. Metrologia*., **2001,** *38*(5), 459.
16. Wankhede, D. S.; Lande, M. K.; Arbad, B. R. *Journal of Chemical & Engineering Data*., **2005**, *50*(1), 261-263.
17. Jones, G.; Dole, M. *Journal of the American Chemical Society*., **1929**, *51*(10), 2950-2964.