International Journal of Research in Engineering and Science (IJRES)
ISSN (Online): 2320-9364, ISSN (Print): 2320-9356
www.ijres.org Volume 11 Issue 8 ǁ August 2023 ǁ PP. 137-142

Jones-Dole Coefficient and related parameters of some potassium amino acids and water system as potential CO_2 absorbent

[1]Mahendra B. Dhande, [2*]P. V. Raut, [3]Dipak. T. Tayade
[1]Department of Chemistry, HPT Arts and RYK Science College, Nashik, 422009, India
*[*2]Department of Chemistry, Smt. R. S. Arts, Com and Sci College, Anjangaon (Surji), India*
[3]Department of Chemistry, Institute of Science, Nagpur, 440012, India
Corresponding author: ***pavanraut523@gmail.com***

Abstract
In this study; viscosities of aqueous potassiumsalt solutions of L-sarcosine, L-alanine, taurine and L-proline were measured at 298.15, 303.15, 308.15 and 313.15 K temperatures in 0.01-0.15 mol.L^{-1} concentrations range, on the basis of measured experimental viscosity values, Jones-Dole coefficient (B) and free energy of activation ($\Delta G^{0\#}$) were determined.

Keywords: *L-Alanine; CO_2 ; Density; Apparent molar volume; Jones-Dole coefficient.*

Date of Submission: 05-08-2023 Date of acceptance: 20-08-2023

I. INTRODUCTION

Today's most challenging and serious problem throughout for us is global warming and increase in the percentage of CO_2 in environment. Excessive CO_2 (carbon dioxide) emissions from a number of sources, including the combustion of fossil fuels for energy production, is the primary contributor to global warming [1,2].

The major target for researchers to reduce emission of CO_2 by several pre and post techniques which have been introduced in the gas sweetening industries. Additionally, it may be necessary for operational, financial, or environmental considerations. In the processes of CO_2 removal before they escape in the atmosphere, alkanolamines scrubbers and their combinations are mostly used[3]. It degrades in oxygen-rich environments, producing very hazardous degradation compounds [4]. These demerits of amine-based solvents create limitations as an absorbent in CO_2 absorption operations.

The better solvents in the CO_2 separation process are used in order to reduce the process cost. Aqueous solution of Alkali metal amino acid salts (AAS) could be an alternative for alkanolamines. Several studies have presented the reactions of SAA with CO_2[5,6]. AAS resembles amines in functional group and interacts with CO_2 in similar way. Despite being costlier than alkanolamines, AAS offer several special benefits such greater resistance to oxidation [7], minimal volatility, increased surface tension and rapid absorption [8].

For designing gas–liquid contactors, process modelling, and working of the equipments for a particular absorbent, its physico-chemical properties like density and viscosity are needed [9-12]. These details are also required to predict kinetics study from experiments on CO_2 absorption rates [13,14].

For aqueous potassium salt solutions of L-sarcosine, L-alanine, taurine and L-proline as of yet, there are no reports of such properties and related parameters in the open literature by using this technique and at such concentration range. Thus, in these work, a new data is presented on viscosity, 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 $\Delta S^{0\#}$) of aqueous potassium salt solutions of above mentioned amino acids.

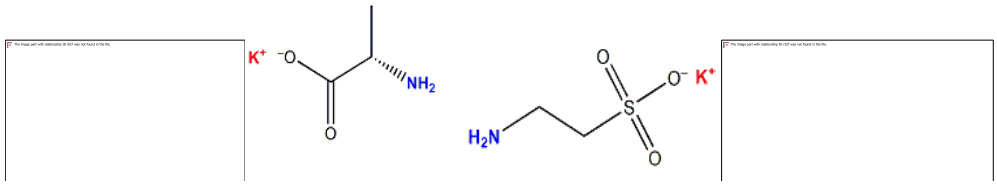
II. EXPERIMENTAL SECTION

2.1. Materials and AAS preparation.

The amino acids, L-sarcosine (Sar, $C_3H_7NO_2$, CAS No. 107-97-1, 99% purity) was purchased from Loba Chemie Pvt. Ltd., while L-alanine (Ala CAS No. 56-41-7, 99% purity) and L-proline (Pro, C_5 H_9 NO_2 , CAS No. 147-85-3, 99% purity) were purchased from S D Fine-Chem Ltd., India, respectively. Taurine (Tau, $C_2H_7NO_3S$, CAS No. 107-35-7, ≥99.00% purity) and potassium hydroxide (KOH, CAS No. 1310-58-3, GR, 98 % purity) from Merck.

All chemicals were used as obtained. The aqueous AAS solutions were made by dissolving equimolar amount of KOH and amino acid in triple distilled water [15]. Masses of materials were taken on Electronic balance accurate to ±0.1mg.

Figure 1. Structures of potassium salt of L-sarcosine, L-alanine, taurine and L-proline.



2.2. Viscosity measurements

Dynamic viscosity values were measured using Ubbelohde suspended-level viscometer [16] for concentrations range 0.01 to 0.15 m and at temperatures (298.15, 303.15, 308.15 and 313.15) K. Viscometer was calibrated using triple distilled water and pure solvents [17]. A thermostat with a glass wall was used to measure viscosity at various temperatures and atmospheric pressure. All of the measurements were made three times and their average was considered.

Viscosities (η) of systems were determined via

$$\frac{\eta}{\eta_0} = \frac{\rho t}{t_0 \rho_0} \qquad (1)$$

where t, ρ, η, and t_o, ρ_o,η_o represents flow time, density, and viscosity of studied system and solvent, respectively.

III. RESULTS AND DISCUSSIONS

The viscosity data for aqueous potassium salt of L-sarcosine, L-alanine taurine and L-proline solutions at concentration range (0.01 to 0.15) m and at temperatures (298.15, 303.15, 308.15 and 313.15) K are presented in Table 1.

From Table 1, it is observed that viscosity increases with the molality whereas falls with rise in temperature.

3.1. Viscosity parameters

The Jones-Dole equation was applied to analyse the data on viscosity. The obtained viscosity data were analysed with the help of following Jones-Dole equation [18].

$$\eta / \eta_0 = 1 + Am^{0.5} + Bm \qquad (2)$$

where, B is Jones-Dole coefficient and A is a constant that provides data on the strength of ion-ion interactions in a solution. Least square method was applied to obtain Jones-Dole coefficient (B)for potassium prolinate, potassium alaninate, potassium taurinate and potassium sarcosinate. It is found that B valuesare positive and highest for potassium prolinate compare to potassium alaninate, potassium taurinate and potassium sarcosinate at same temperature.

The solute's structural effect in the solvent could be more accurately depicted dB/dT values.The negative dB/dT demonstrates that the solute prefers to serve as a structure-maker in the solution [19, 20].

The prior equation (2) can be changed to the following (3), which resembles the straight line equation (y = mx + c) with B and A as a slope and intercept, respectively

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

The values of $[(\eta / \eta_0)\text{-}1] / m^{0.5}$ are presented in Table 2.

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,

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

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

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 resembles the straight line equation (y = - mx + C) where intercept is equal to $\Delta H^{0\#}$ and the slope is $-\Delta S^{0\#}$. Using Least square method the $\Delta S^{0\#}$ and $\Delta H^{0\#}$ values were obtained. All the values of *B*, d*B*/dT, $\Delta G^{0\#}$, $\Delta S^{0\#}$ and $\Delta H^{0\#}$ are kept in Table 3. Figure 6, Figure 7, Figure 8, and Figure 9 shows the variation of $\Delta G^{0\#}$ vs temperature.

Table 1. Viscosities (η) ofpotassium salt of sarcosine, alanine, taurine and proline at different temperatures.

m (mol. kg $^{-1}$)	η (m^{-1}.kg.s^{-1})				m (mol. kg $^{-1}$)	η (m^{-1}.kg.s^{-1})			
	298.15 K	303.15 K	308.15 K	313.15 K		298.15 K	303.15 K	308.15 K	313.15 K
	potassium sarcosinate					**potassium alaninate**			
0.00000	0.8903	0.7975	0.7195	0.6535	0.00000	0.8903	0.7975	0.7195	0.6535
0.01168	0.8925	0.7999	0.7221	0.6563	0.01000	0.8920	0.7995	0.7217	0.6559
0.03137	0.8975	0.8046	0.7265	0.6605	0.03163	0.8974	0.8046	0.7266	0.6606
0.05103	0.9027	0.8094	0.7309	0.6646	0.05155	0.9027	0.8095	0.7312	0.6648
0.07087	0.9079	0.8142	0.7353	0.6686	0.07331	0.9086	0.8148	0.7361	0.6695
0.08987	0.9129	0.8187	0.7395	0.6725	0.08932	0.9130	0.8189	0.7396	0.6728
0.11479	0.9199	0.8250	0.7452	0.6777	0.10603	0.9176	0.8231	0.7435	0.6763
0.12524	0.9229	0.8276	0.7475	0.6799	0.13095	0.9247	0.8293	0.7491	0.6813
0.15060	0.9300	0.8339	0.7532	0.6851	0.15514	0.9314	0.8352	0.7545	0.6861
	potassium taurinate					**potassium prolinate**			
0.01168	0.8919	0.7995	0.7218	0.6560	0.00962	0.8943	0.8016	0.7237	0.6578
0.03137	0.8956	0.8032	0.7254	0.6594	0.03077	0.9020	0.8088	0.7305	0.6643
0.05610	0.9005	0.8078	0.7297	0.6635	0.04830	0.9082	0.8145	0.7359	0.6692
0.06980	0.9034	0.8104	0.7321	0.6657	0.07008	0.9159	0.8215	0.7423	0.6751
0.09267	0.9080	0.8148	0.7361	0.6693	0.08586	0.9215	0.8265	0.7468	0.6793
0.11479	0.9127	0.8189	0.7399	0.6729	0.10103	0.9267	0.8313	0.7511	0.6833
0.13524	0.9170	0.8227	0.7434	0.6761	0.13157	0.9374	0.8408	0.7597	0.6912
0.15060	0.9201	0.8257	0.7461	0.6784	0.14960	0.9436	0.8463	0.7648	0.6958

Table 2. [(η/η_o)-1]/$m^{0.5}$ values forpotassium salt of sarcosine, alanine, taurine and proline in water at different temperatures.

m (mol. kg $^{-1}$)	[(η / η$_o$)-1]/$m^{0.5}$				m (mol. kg $^{-1}$)	[(η / η$_o$)-1]/$m^{0.5}$			
	298.15 K	303.15 K	308.15 K	313.15 K		298.15 K	303.15 K	308.15 K	313.15 K
	potassium sarcosinate					**potassium alaninate**			
0.01168	0.02286	0.02785	0.03344	0.03965	0.01175	0.03627	0.04396	0.05129	0.05929
0.03137	0.04566	0.05027	0.05493	0.06048	0.02839	0.06466	0.07219	0.07754	0.08537
0.05103	0.06166	0.06605	0.07014	0.07519	0.05285	0.09381	0.10036	0.10640	0.11183
0.07087	0.07426	0.07866	0.08249	0.08680	0.07062	0.11074	0.11702	0.12238	0.12841
0.08987	0.08468	0.08867	0.09272	0.09698	0.09194	0.12854	0.13440	0.13934	0.14484
0.11479	0.09813	0.10178	0.10543	0.10930	0.11155	0.14293	0.14830	0.15231	0.15852
0.12524	0.10347	0.10665	0.10997	0.11415	0.12812	0.15470	0.15939	0.16347	0.16887
0.15060	0.11491	0.11761	0.12069	0.12460	0.15264	0.16991	0.17460	0.17858	0.18330
	potassium taurinate					**potassium prolinate**			
0.01168	0.01663	0.0232	0.02958	0.03540	0.00962	0.04581	0.05242	0.05952	0.06709
0.03137	0.03361	0.04035	0.04630	0.05097	0.03077	0.07492	0.08078	0.08716	0.09421
0.05610	0.04837	0.05453	0.05985	0.06461	0.04830	0.09148	0.09699	0.10371	0.10932
0.06980	0.05569	0.06123	0.06628	0.07066	0.07008	0.10862	0.11368	0.11970	0.12486

0.09267	0.06531	0.07126	0.07579	0.07942	0.08586	0.11960	0.12410	0.12949	0.13473
0.11479	0.07426	0.0792	0.08368	0.08762	0.10103	0.12863	0.13334	0.13818	0.14346
0.13524	0.08155	0.08592	0.09033	0.09404	0.13157	0.14585	0.14969	0.15403	0.15904
0.15060	0.08625	0.09112	0.09512	0.09818	0.14960	0.15478	0.15821	0.16278	0.16735

Table 3. (*B*), (*A*), d*B*/d*T*, (Δ*G*), (Δ*H*), and (Δ*S*) values for potassium salt of sarcosine, alanine, taurine and proline in water at different temperatures.

Parameter	298.15 K	303.15 K	308.15 K	313.15 K	298.15 K	303.15 K	308.15 K	313.15 K
	potassium sarcosinate					**potassium alaninate**		
B	0.3271	0.3195	0.3115	0.3029	0.3343	0.3246	0.3161	0.3076
A	-0.013	-0.0065	-0.0003	0.0067	-0.0145	-0.0075	-0.0007	0.0064
d*B*/d*T*		-0.0016				-0.0018		
Δ*G*	61.72	61.38	60.95	60.43	62.10	61.37	60.86	60.33
Δ*H*		87.3899				95.2192		
Δ*S*		-85.94957				-111.489		
	potassium taurinate					**potassium prolinate**		
B	0.2497	0.2417	0.2333	0.2250	0.3780	0.3673	0.3572	0.3470
A	-0.0105	-0.0027	0.0046	0.0112	0.0086	0.0164	0.0247	0.0331
d*B*/d*T*		-0.0017				-0.0021		
Δ*G*	52.71	52.19	51.58	50.96	71.48	70.86	70.28	69.65
Δ*H*		87.6720				107.6325		
Δ*S*		-117.171				-121.267		

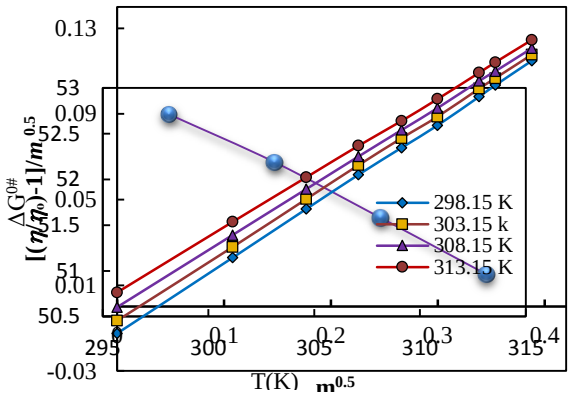


Figure 8 Figure 2. Plot of $[(\eta/\eta_0)-1]$ vs $m^{0.5}$ of potassium sarcosinate in water at different temperatures (T)

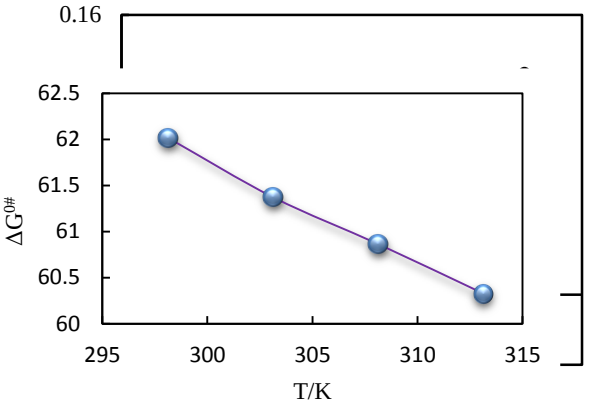


Figure 7. Plot of $\Delta G(KJmol^{-1})$ vs T/K of aqueous potassium alaninate

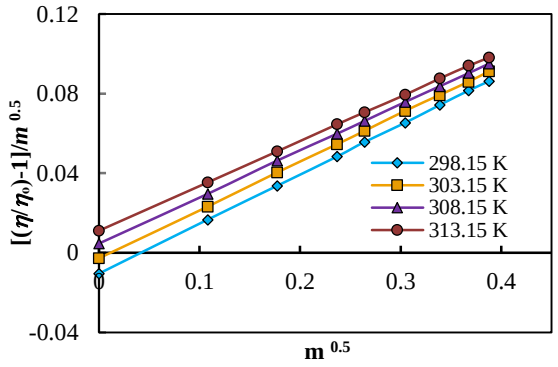


Figure 4. Plot of $[(\eta/\eta_0)-1]$ vs $m^{0.5}$ of potassium taurinate in water at different temperatures (T)

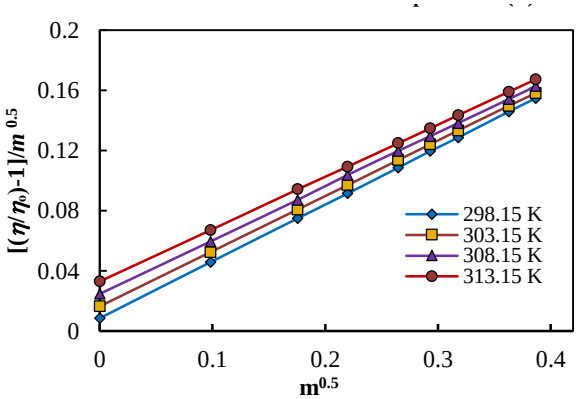


Figure 5. Plot of $[(\eta/\eta_0)-1]$ vs $m^{0.5}$ of potassium prolinate in water at different temperatures (T)

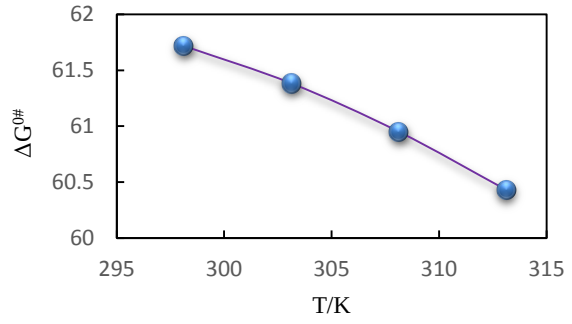


Figure 6. Plot of $\Delta G(KJmol^{-1})$ vs T/K of aqueous potassium sarcosinate

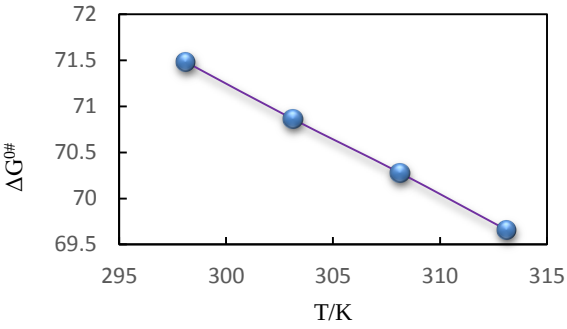


Figure 9. Plot of $\Delta G(KJmol^{-1})$ vs T/K of aqueous potassium prolinate

IV. CONCLUSION

B value for all studied potassium salt of amino acids decreases as the temperature rises. The positive *B* and $\Delta G^{0\#}$values indicate strong water and amino acid salt interactions.The negative value of (d*B*/d*T*) for investigated amino acid salt-water systems confirms structure making behaviour of studied AAS. As a result, it can be said that all studied potassium salt of amino acids are water structure makers.

Declaration of conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgement

MBD thanks Director, Government Vidarbha Institute of Science and Humanities, Amravati, India and Principal, HPT Arts and RYK Science College, Nashik, India.

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. Energy-efficient CO_2 capture using nonaqueous absorbents of secondary alkanolamines with a 2-butoxyethanol cosolvent. ACS Sustainable Chemistry & Engineering, **2020**, 8(49), 18071-18082.
[4]. Vitillo, J. G.; Smit, B.; Gagliardi, L. Introduction: carbon capture and separation. Chemical Reviews, **2017**, 117(14), 9521-9523.
[5]. Liu, M.; Gadikota, G. Single-step, low temperature and integrated CO_2 capture and conversion using sodium glycinate to produce calcium carbonate. Fuel, **2020**, 275, 117887.
[6]. Xu, X.; Myers, M. B.; Versteeg, F. G.; Adam, E.; White, C.; Crooke, E.; Wood, C. D. Next generation amino acid technology for CO_2 capture. Journal of Materials Chemistry A, **2021,** 9(3), 1692-1704.
[7]. Chang, Y. T.; Leron, R. B.; Li, M. H. Carbon dioxide solubility in aqueous potassium salt solutions of l-proline and dl-α-aminobutyric acid at high pressures. The Journal of Chemical Thermodynamics, **2015**, 83, 110-116.
[8]. Garcia, A. A.; Leron, R. B.; Soriano, A. N.; Li, M. H. Thermophysical property characterization of aqueous amino acid salt solutions containing α-aminobutyric acid. The Journal of Chemical Thermodynamics, **2015**, 81, 136-142.
[9]. Meng, X.; Duan, C.; Xu, C.; Fang, D. Physicochemical properties and the molar surface Gibbs energy of the aqueous solution of amino acids ionic liquid 1-pentyl-3-methylimidazolium proline salt [C5mim][Gly]. Chemical Thermodynamics and Thermal Analysis, **2022**, 5, 100025.
[10]. Mondal, B. K.; Samanta, A. N. Equilibrium solubility and kinetics of CO_2 absorption in hexamethylenediamine activated aqueous sodium glycinate solvent. Chemical Engineering Journal, **2020**, 386, 121462.
[11]. Guo, H.; Li, H.; Shen, S. CO_2 capture by water-lean amino acid salts: absorption performance and mechanism. Energy and Fuels, **2018,** 32(6), 6943-6954.
[12]. Garg, S.; Shariff, A. M.; Shaikh, M. S.; Lal, B.; Aftab, A.; Faiqa, N. Selected physical properties of aqueous potassium salt of l-phenylalanine as a solvent for CO_2 capture. Chemical Engineering Research and Design, **2016**, 113, 169-181.
[13]. Li, H.; Shen, S. Kinetics of carbon dioxide absorption into water-lean potassium prolinate/ethylene glycol solutions. Industrial & Engineering Chemistry Research, **2019**, 58(23), 9875-9882.
[14]. Li, H.; Guo, H.; Shen, S. Water-lean blend mixtures of amino acid salts and 2-methoxyethanol for CO_2 capture: Density, viscosity and solubility of CO_2. The Journal of Chemical Thermodynamics, **2020**, 150, 106237.
[15]. Li, C., Shi, X., & Shen, S. Performance evaluation of newly developed absorbents for solvent-based carbon dioxide capture. Energy & Fuels, **2019,** 33(9), 9032-9039.
[16]. Nikam, P. S., Shewale, R. P., Sawant, A. B., & Hasan, M. Limiting ionic partial molar volumes and viscosities of Cs+, Na+,(C4H9) 4N+, Cl-, Br-, I,-, and BPh4-in aqueous acetone at 308.15 K. Journal of Chemical & Engineering Data, **2005**, 50(2), 487-491.
[17]. Dhande, M. B., & Tayade, D. T. (2022). Viscometric Properties of Aqueous Sodium and Potassium Salt of L-Leucine. Oriental Journal of Chemistry, 38(5), 1261.
[18]. Jones, G.; Dole, M. The viscosity of aqueous solutions of strong electrolytes with special reference to barium chloride. Journal of the American Chemical Society, **1929**, 51(10), 2950-2964.
[19]. Riyazuddeen, M.A. Usmani, Densities, speeds of sound, and viscosities of (l-proline + aqueous glucose) and (l-proline + aqueous sucrose) solutions in the temperature range (298.15 to 323.15) K, J. Chem. Eng. Data 56 (2011)3504-3509.
[20]. S.S. Dhondge, D.W. Deshmukh, L.J. Paliwal, Density, speed of sound, viscosity and refractive index properties of aqueous solutions of vitamins B1.HCl and B6.HCl at temperatures (278.15, 288.15, and 298.15)K, J. Chem. Thermodyn. 58 (2013) 149-157.