ACOUSTICAL STUDIES ON MOLECULAR INTERACTIONS OF TETRA BUTYL AMMONIUM BEROMIDE IN 2-ETHOXYETHANOL AND WATER MIXTURES AT 288.15K TO 318.15K.

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ABSRACT

ultrasonic velocity (U) and Density (d) of Tetra butyl ammonium bromide in water and 2-Ethoxyethanol mixtures as a function of concentration at 288.15K, 298.15K, 308.15K and 318.15K have been measured. From the measured data, the acoustical properties like adiabatic compressibility (β_{ad}), inter molecular free length (L_f), acoustic Impedance (Z), relative association(R_a), apparent molar compressibility (φ_k), apparent molar volume (φ_V), limiting apparent molar compressibility ($\varphi^0{}_k$), limiting apparent molar volume ($\varphi^0{}_V$) and the constants S_K , S_V were calculated. Gucker and Masson's relation is well fitted. The variations in acoustical properties with respect to composition have been analyzed to understand solvation in terms of solute-solvent and solvent-solvent interactions.

Key words*: *adiabatic compressibility, 2-Ethoxyethanol, Tetra butyl ammonium bromide, ultrasonic velocity

I. INTRODUCTION

Ultrasonic study is used as a versatile tool for understanding the nature of process of ion-ion; solvent-solvent and ion-solvent interactions [1-6].Strong solvation will reduce the effective quantity of free solvent molecules. When two or more liquids mixed together, the resulting changes in physical and thermodynamic properties can be considered as a sum of several contributions due to change in energy, free volume change and molecular orientation [7-10].

Nowadays Ultrasonic techniques find application in fundamental research, chemical and food processing, material testing and pharmaceutical industry [11,12]. The Ultrasonic techniques involving measurement of ultrasonic velocity and their interpretation in the molecular structure was made by many workers [13-17]. Ethoxyethanol belongs to the group cellosolves, are the perfect solvents of many substances, It is used as co emulgators and stabilizers of emulsions, paints, lacquers, plastics .Recently the ionic interactions and ion-solvent interaction for Tetra butyl ammonium bromide (TBAB) in DMF + Water system at different temperatures have been reported [18] from density, viscosity and ultrasonic velocity measurements. No work has been reported on the ultrasonic studies of tetra butyl ammonium bromide in different mole fractions of 2-ethoxyethanol, which will provide the information about molecular interactions between solvents with different compositions in the presence of Tetra butyl ammonium bromide.

II. Experimental

2-ethoxyethanol (analytical grade) purchased from Merck was used without further purification. Freshly prepared distilled water was used for preparing different composition of 2-ethoxyethanol with definite mole fraction (X_{2EE}) ranging from 0.0000 to 1.0000. The recrystallized electrolyte tetrabutyl ammonium bromide (analytical grade) was dried at (90-110) °C in vacuum for 24 h prior to use .TBAB is dissolved in solvent mixture to prepare the desired concentration ranging from 0.01 M to 0.1M.The chemicals were weighed in electrical digital balance (ER-180,Afcoset Balances, Bombay) with a precision of ±0.3%. A digital multi frequency ultrasonic interferometer (M-81S, Mittal New Delhi) at 2 MHz, with a measuring frequency tolerance at 0.03% has been used for velocity measurement. The temperature at 288.15, 298.15, 308.15 and 318.15K of the cell was maintained by circulating water through the double walled measurement cell made up of stain steel containing electrolyte solution from a thermostat (Kumar Make, Bombay) with an accuracy of ±0.01°C. A pyknometer (10 cc capacity) is used to determine the density of all the solutions.

III. RESULTS AND DISCUSSIONS

$$U = \lambda \, x \, F \qquad \text{........ (1)}$$

$$\beta_{ad} = 1/U^2 d \qquad \text{........ (2)}$$

$$L_f = K\sqrt{\beta_{ad}} \qquad \text{........ (3)}$$

$$Z = U \, x \, d \qquad \text{........ (4)}$$

$$R_A = (d/d_0)\,(U_0/U)^{1/3} \qquad \text{........(5)}$$

$$\Phi_k = 1000(d_0\,\beta_{ad} - d_l\,\beta^0_{ad})/d_l d_0 + M\,\beta_{ad}/d_l \qquad \text{........ (6)}$$

$$\Phi_v = M/d_0 - 1000(d-d_0)/Cd_0 \qquad \text{........ (7)}$$

$$S_n = (n_1/n_2)(1-\beta_{ad}/\beta^0_{ad}) \qquad \text{........ (8)}$$

where d_l, d_0 and U, U_0 are the densities and ultrasonic velocities of solution and solvent respectively. λ is the wavelength and F is the frequency of ultrasonic wave. M is the molecular weight of the solute, β^0_{ad} and β_{ad} are the adiabatic compressibilities of solvent and solution, K is the Jacobson constant, n_1 and n_2 are the number of moles of the solvent and solute respectively.

Ultrasonic velocity: Measured ultrasonic velocity of tetrabutyl ammonium bromide (TBAB) in different compositions of water and 2-ethoxyethanol are shown in the Table1.The ultrasonic velocity increased linearly in 2- ethoxy ethanol with the addition of TBAB. When TBAB is dissolved in 2- ethoxy ethanol solution, cation BuN_4^+ and anion Br^- are formed. These ions are attracted by the water molecules introducing a greater cohesion in the solution [19].Ultrasonic velocity is found to increase in temperature for X_{2EE}=0.0000 to X_{2EE} = 0.0052 of solvent mixture. This may be due to the structural changes by powerful molecular interactions brought about by ion solvation .Only few 2-ethoxyethanol molecules undergoes solvation when the $X_{2EE} < 0.0136$. But the formation and aggregation of the clusters [20] takes place resulting in the nonlinear decrease in ultrasonic velocity when the mole fraction $X_{2EE} \geq 0.0136$. Increase in density with concentration indicates the increase in solvent –solvent and solute-solvent interactions. It is due to the contraction in volume, which in turn is due to the consequence of presence of solute molecules. On the other hand, increasing tendency of density may interpreted as structure making tendency of the solvent due to the added solute [21, 22].

Adiabatic compressibility: The adiabatic compressibility is the relative change in the volume of a system per unit adiabatic decrease in its pressure. The variation of β_{ad} with concentration of TBAB in 2-ethoxyethanol and water mixture is presented in table 1. A gradual decline in adiabatic compressibility in these solutions may be attributed to increasing electrostrictive compression of water around the molecules [23] .There is dissociation of TBAB, releasing cloud of ions of cations and anions in solution [24].There exist complex due to the reaction between Br^- and water molecule and also with 2-ethoxyethanol, enhancing the ultrasonic velocity and hence decrease in adiabatic compressibility. This trend is expected due to the structure making behaviour of TBAB [18].

Inter molecular free length: Inter molecular free length is calculated using the equation 3, which is directly related to adiabatic compressibility [25]. Computed values of Inter molecular free length for TBAB in 2-ethoxyethanol +water mixtures are shown in Table.1. L_f is directly related to adiabatic compressibility (β_{ad}).Since adiabatic compressibility is inversely related to density, inter molecular free length decreases linearly with increase in concentration of TBAB in different mole fractions of 2-ezthoxyethanol. Minima in L_f is found at X_{2EE} =0.0316. This decrease is due to decrease in compressibility with increase in concentration TBAB, which in turn indicates significant interaction between Bu_4N^+ of TBAB and solvent molecule [26]. Inter molecular free length is directly proportional to temperature .In general the degree of hydrogen bonding in alcohols, water and their mixture decrease at higher temperatures.

Specific Acoustic Impedance: The characteristic property that determines the amount of reflection is known as Specific Acoustic Impedance. Calculated Z values are shown in the Table 2. It is found to increase with the increase in addition of co-solvent to water. The reason for increasing trend of Impedance in the water rich region and later decrease in the co-solvent rich region is related with ultrasonic velocity. The acoustic impedance increases linearly with concentration and decreases linearly with temperature, indicating the existence of strong intermolecular forces. As a result a strong hydrophobic interaction between BuN_4^+ cations and solvent may exist

[27]. The maxima in Z value is found at X_{2EE} = 0.0136 .This may further support strengthening of molecular interactions which restrict the free flow of ultrasonic wave [20].

Relative association: Relative association is a function of ultrasonic velocity used to understand the interaction solute and solvent. It can be explained by two factors [28]: (1) by the breaking up of solvent molecules on addition of solute to it (2) and solvation of the solute. The former leads to decrease and the latter to the increase in the relative association. The marginal decrease in R_A value with respect to increasing concentration implies the breaking up of the solvent molecules on addition of TBAB. The change in R_A value with increase in temperature for TBAB in water and 2-ethoxyethanol mixture is negligible.

Apparent molar compressibility: Apparent molar compressibility was calculated using the equation (6) is a function of concentration as suggested by Gucker[29] on the basis of Debye-Huckel theory[30]. This equation is given by,

$$\varphi_K = \varphi^0_K + S_K C^{1/2}$$

Where φ^0_k is the limiting apparent molar compressibility which is obtained from the intercept of the linear plot of φ_k versus $\sqrt{C}$ and its related constant S_k from the slope of the plot. The φ^0_k and S_k values are shown in the Table 3. In this study most of the φ^0_k values are found to be negative which suggests that there is loss of compressibility of solvent due to electrostrictive solvation [31].

Apparent molar volume : Apparent molar volume was calculated using equation 7.The values are fitted by least square method as suggested by Masson [32],

$$\varphi_V = \varphi^0_V + S_V C^{1/2}$$

Where φ^0_V is the limiting apparent molar volume and S_V is the experimental slope. The values of limiting apparent molar volume φ^0_v with positive values for all compositions of 2-ethoxyethanol shows the presence of ion – solvent interaction in the solvent media. The plot of φ_V against square root of concentration is shown in Fig 1.The negative S_v value shows the weak ion-ion interactions. This also suggest appreciable inter ionic penetration which occurs due to competition between ions to occupy void space in the solvent structure [33.]. The S_v value increase with an increase of temperature and increase in the concentration of 2-ethoxyethanol in the mixture indicating weakening of solvation. Similar explanations have also been given by Ali et al. [34].

IV. CONCLUSION

In the present investigation density and speed of sound of the tetra butyl ammonium bromide in the mixture of 2-ethoxyethanol and water at four different temperatures have been measured. From the experimental data, various acoustical parameters are discussed in terms of intermolecular interactions in the mixture .The negative S_v Indicates the presence of weak ion- ion interaction.

V. ACKNOWLEDGEMENTS

The authors are grateful to Visvesvaraya Technological University, Belgaum, India for the financial support under the grant, Ref. No. VTU/Aca/2010-11/A-9/11329 dated 17th December 2010 and Dr. Renukaprasad K .V General Secretary, AOLE,Sullia, for providing financial and infrastructural facilities.

Table1. Experimentally determined ultrasonic velocity (*U:* ms^{-1}), adiabatic compressibility (β_{ad}: m^2/N) and intermolecular free length (L_f :m) for TBAB in 2 - ethoxy ethanol + water mixtures with respect to concentration (*C:* Mol dm^{-3}) at different temperatures.

C	Temperature											
	288.15k			298.15k			308.15k			318.15K		
	U	$10^{10}\beta_{ad}$	$10^{10} L_f$	U ms^{-1}	$10^{10}\beta_{ad}$	$10^{10} L_f$	U	$10^{10}\beta_{ad}$	$10^{10} L_f$	U	$10^{10}\beta_{ad}$	$10^{10} L_f$
						X_{2EE} = **0.0000**						
0.01	1466	4.650	0.4092	1490	4.457	0.4153	1520	4.304	0.4173	1522	4.273	0.4282
0.02	1466	4.650	0.4092	1494	4.464	0.4157	1524	4.286	0.4164	1532	4.220	0.4255
0.03	1470	4.625	0.4080	1498	4.443	0.4147	1532	4.239	0.4141	1542	4.164	0.4226
0.04	1470	4.621	0.4070	1500	4.432	0.4141	1532	4.239	0.4141	1548	4.133	0.4222
0.05	1482	4.553	0.4040	1502	4.422	0.4137	1536	4.219	0.4131	1470	4.587	0.4222
0.06	1484	4.544	0.4045	1512	4.365	0.4110	1538	4.204	0.4124	1546	4.148	0.4219
0.07	1488	4.521	0.4034	1516	4.342	0.4099	1534	4.231	0.4137	1548	4.138	0.4213
0.08	1490	4.511	0.4029	1516	4.344	0.4099	1530	4.254	0.4148	1554	4.107	0.4198
0.09	1494	4.487	0.4019	1516	4.346	0.4100	1538	4.211	0.4127	1552	4.118	0.4203
0.1	1502	4.439	0.3998	1518	4.336	0.4096	1540	4.201	0.4122	1562	4.067	0.4177
						X_{2EE} **=0.0023**						
0.01	1532	4.254	0.3914	1550	4.147	0.4006	1568	4.040	0.4042	1580	3.907	0.4094
0.02	1544	4.190	0.3884	1562	4.084	0.3975	1568	4.044	0.4045	1582	3.954	0.4119
0.03	1550	4.160	0.3870	1560	4.096	0.3981	1574	4.015	0.4029	1580	3.963	0.4123
0.04	1550	4.164	0.3872	1564	4.078	0.3972	1576	4.005	0.4025	1582	3.953	0.4118
0.05	1556	4.133	0.3857	1570	4.049	0.3958	1580	3.986	0.4015	1584	3.948	0.4116
0.06	1562	4.103	0.3844	1568	4.059	0.3963	1582	3.976	0.4010	1588	3.928	0.4105
0.07	1558	4.125	0.3854	1572	4.039	0.3953	1582	3.977	0.4011	1588	3.929	0.4106
0.08	1560	4.118	0.3850	1572	4.041	0.3954	1582	3.978	0.4011	1592	3.911	0.4096
0.09	1568	4.079	0.3832	1568	4.063	0.3965	1584	3.969	0.4007	1598	3.882	0.4081
0.1	1572	4.060	0.3823	1220	4.002	0.3935	1586	3.959	0.4002	1598	3.884	0.4082
						X_{2EE} **=0.0052**						
0.01	1610	3.862	0.3720	1650	3.79	0.3829	1610	3.832	0.3937	1604	3.838	0.4058
0.02	1612	3.854	0.3725	1648	3.792	0.3830	1614	3.819	0.3930	1608	3.822	0.4049
0.03	1616	3.837	0.3717	1648	3.803	0.3836	1618	3.799	0.3920	1612	3.807	0.4041

0.04	1620	3.823	0.3709	1654	3.786	0.3828	1620	3.792	0.3916	1610	3.818	0.4047
0.05	1626	3.797	0.3697	1656	3.768	0.3818	1624	3.773	0.3907	1606	3.839	0.4058
0.06	1624	3.804	0.3701	1652	3.75	0.3809	1624	3.774	0.3907	1612	3.812	0.4044
0.07	1626	3.796	0.3697	1652	3.733	0.3801	1624	3.775	0.3908	1608	3.837	0.4057
0.08	1628	3.788	0.3693	1656	3.734	0.3801	1628	3.757	0.3899	1614	3.809	0.4042
0.09	1632	3.770	0.3684	1658	3.745	0.3807	1624	3.777	0.3909	1616	3.802	0.4039
0.1	1636	3.755	0.3677	1650	3.736	0.3802	1630	3.751	0.3895	1616	3.803	0.4039
X_{2EE} =**0.0136**												
0.01	1670	3.595	0.3598	1650	3.659	0.3763	1620	3.776	0.3909	1606	3.808	0.4042
0.02	1670	3.598	0.3599	1648	3.67	0.3768	1622	3.692	0.3865	1608	3.799	0.4037
0.03	1674	3.581	0.3590	1648	3.672	0.3769	1630	3.73	0.3884	1608	3.800	0.4038
0.04	1670	3.599	0.3599	1654	3.646	0.3756	1630	3.732	0.3885	1612	3.783	0.4029
0.05	1668	3.610	0.3605	1656	3.639	0.3753	1630	3.734	0.3886	1604	3.825	0.4051
0.06	1670	3.602	0.3601	1652	3.658	0.3762	1632	3.726	0.3882	1608	3.807	0.4041
0.07	1674	3.586	0.3593	1652	3.659	0.3763	1632	3.726	0.3882	1600	3.846	0.4062
0.08	1674	3.586	0.3593	1656	3.641	0.3754	1634	3.721	0.3879	1602	3.867	0.4073
0.09	1674	3.588	0.3594	1658	3.635	0.3750	1634	3.722	0.3880	1602	6.839	0.5418
0.1	1664	3.633	0.3616	1656	3.644	0.3755	1630	3.742	0.3891	1606	3.824	0.4050
X_{2EE} = **0.0301**												
0.01	1596	3.899	0.3747	1578	3.959	0.3914	1554	4.056	0.4051	1520	4.201	0.4245
0.02	1598	3.891	0.3743	1582	3.94	0.3905	1548	4.088	0.4066	1522	4.204	0.4247
0.03	1596	3.902	0.3748	1582	3.941	0.3905	1548	4.089	0.4067	1520	4.203	0.4246
0.04	1596	3.903	0.3748	1586	3.922	0.3896	1550	4.08	0.4062	1522	4.193	0.4241
0.05	1594	3.916	0.3755	1584	3.933	0.3901	1554	4.061	0.4053	1526	4.173	0.4231
0.06	1600	3.888	0.3741	1584	3.933	0.3901	1554	4.063	0.4054	1526	4.175	0.4232
0.07	1604	3.869	0.3732	1584	3.935	0.3902	1552	4.074	0.4059	1528	4.165	0.4227
0.08	1604	3.869	0.3732	1588	3.917	0.3893	1556	4.054	0.4049	1528	4.165	0.4227
0.09	1608	3.851	0.3723	1590	3.909	0.3889	1558	4.044	0.4045	1534	4.135	0.4212
0.1	1606	3.863	0.3729	1590	3.909	0.3889	1554	4.067	0.4056	1528	4.169	0.4229
X_{2EE} = **0.0765**												
0.01	1490	4.374	0.3968	1458	4.531	0.4187	1424	4.718	0.4369	1404	4.807	0.4541
0.02	1492	4.364	0.3964	1464	4.498	0.4172	1430	4.679	0.4350	1404	4.808	0.4542
0.03	1496	4.340	0.3953	1466	4.488	0.4168	1428	4.694	0.4357	1408	4.783	0.4529
0.04	1502	4.307	0.3938	1466	4.488	0.4167	1428	4.697	0.4359	1408	4.783	0.4529
0.05	1504	4.299	0.3934	1470	4.467	0.4158	1430	4.686	0.4354	1408	4.787	0.4532
0.06	1504	4.304	0.3936	1468	4.479	0.4163	1432	4.675	0.4349	1404	4.814	0.4545
0.07	1500	4.328	0.3947	1470	4.468	0.4158	1428	4.703	0.4362	1408	4.789	0.4533

International Journal of Advance Research in Science and Engineering
Volume No.06, Issue No. 12, December 2017
www.ijarse.com
IJARSE
ISSN: 2319-8354

0.08	1504	4.306	0.3937	1468	4.485	0.4166	1428	4.705	0.4363	1406	4.805	0.4540
0.09	1504	4.306	0.3937	1470	4.473	0.4160	1432	4.682	0.4352	1410	4.779	0.4528
0.1	1506	4.296	0.3932	1472	4.462	0.4155	1436	4.657	0.4340	1406	4.809	0.4542
X_{2EE} = **1.0000**												
0.01	1340	5.202	0.4327	1316	5.356	0.4553	1274	5.668	0.4788	1252	5.808	0.4992
0.02	1344	5.191	0.4323	1318	5.346	0.4548	1278	5.644	0.4778	1256	5.807	0.4991
0.03	1344	5.187	0.4321	1316	5.362	0.4555	1276	5.668	0.4788	1256	5.779	0.4979
0.04	1346	5.175	0.4316	1320	5.335	0.4544	1282	5.616	0.4766	1254	5.806	0.4991
0.05	1346	5.181	0.4319	1326	5.288	0.4524	1284	5.598	0.4759	1248	5.834	0.5003
0.06	1352	5.138	0.4301	1324	5.307	0.4532	1286	5.585	0.4753	1252	5.837	0.5004
0.07	1356	5.113	0.4290	1324	5.312	0.4534	1288	5.569	0.4746	1252	5.829	0.5000
0.08	1354	5.128	0.4297	1320	5.346	0.4548	1288	5.571	0.4747	1256	5.800	0.4988
0.09	1358	5.099	0.4284	1320	5.437	0.4587	1286	5.594	0.4757	1260	5.764	0.4973
0.1	1358	5.101	0.4285	1324	5.318	0.4536	1288	5.583	0.4752	1264	5.732	0.4959

Table 2. Experimentally determined density (d: $kg.m^{-3}$),specific acoustic impedance (Z: kgm^2s^{-1}) and relative association ($R_{A:}$ mol/dm^3)for TBAB in 2 ethoxy ethanol + water mixtures with respect to concentration (*C*) at different temperatures.

C	Temperature											
	288.15k			298.15k			308.15k			318.15K		
	10^{-3}d	10^{-5}Z	R_A	10^{-3}d	10^{-5}Z	R_A	10^{-3}d	10^{-5}Z	R_A	10^{-3}d	10^{-5}Z	R_A
X_{2EE} = **0.0000**												
0.01	0.9995	14.65	1.001	0.9963	14.84	1.001	0.9944	15.11	1.002	0.9898	15.06	1.0004
0.02	0.9994	14.65	1.001	0.9965	14.88	1.000	0.9947	15.15	1.001	0.9905	15.17	0.9989
0.03	0.9995	14.69	1.000	0.9971	14.93	1.000	0.9949	15.24	0.999	0.9901	15.26	0.9973
0.04	0.9985	14.67	0.999	0.9972	14.95	0.999	0.9951	15.24	1.000	0.9904	15.33	1.0150
0.05	1.0001	14.82	0.998	0.9976	14.98	0.999	0.9953	15.28	0.999	0.9912	14.57	0.9988
0.06	1.0008	14.85	0.998	0.9979	15.08	0.997	0.9944	15.29	0.998	0.9913	15.32	0.9985
0.07	1.0011	14.89	0.997	0.9981	15.13	0.997	0.9956	15.27	1.000	0.9917	15.35	0.9975
0.08	1.0013	14.92	0.997	0.9984	15.13	0.997	0.9958	15.23	1.001	0.9918	15.41	0.9981
0.09	1.0015	14.96	0.996	0.9987	15.14	0.997	0.9962	15.32	1.000	0.9920	15.39	0.9962
0.1	1.0016	15.04	0.995	0.9991	15.16	0.997	0.9963	15.34	0.999	0.9921	15.49	0.9964
X_{2EE} = **0.0023**												
0.01	0.9985	15.30	0.9987	0.9963	15.44	0.999	0.9935	15.57	0.999	0.9887	15.62	0.9979
0.02	0.9989	15.42	0.9966	0.9965	15.56	0.996	0.9944	15.59	1.000	0.9896	15.65	0.9983
0.03	0.9995	15.49	0.9958	0.9969	15.55	0.997	0.9947	15.65	0.999	0.9893	15.63	0.9984

International Journal of Advance Research in Science and Engineering
Volume No.06, Issue No. 12, December 2017
www.ijarse.com
IJARSE
ISSN: 2319-8354

0.04	1.0004	15.50	0.9967	0.9974	15.59	0.997	0.9949	15.67	0.999	0.9894	15.65	0.9982
0.05	1.0007	15.57	0.9957	0.9980	15.66	0.996	0.9951	15.72	0.998	0.9906	15.69	0.9989
0.06	1.0010	15.63	0.9948	0.9982	15.65	0.997	0.9953	15.74	0.998	0.9908	15.73	0.9982
0.07	1.0014	15.60	0.9960	0.9982	15.69	0.996	0.9955	15.74	0.998	0.9909	15.74	0.9984
0.08	1.0020	15.63	0.9962	0.9987	15.70	0.996	0.9956	15.75	0.998	0.9913	15.78	0.9979
0.09	1.0031	15.72	0.9955	0.9989	15.66	0.997	0.9958	15.77	0.998	0.9914	15.84	0.9968
0.1	1.0034	15.77	0.9950	0.9990	15.78	1.085	0.9959	15.79	0.998	0.9920	15.85	0.9974
X_{2EE} = **0.0052**												
0.01	1.0011	16.11	0.9872	0.9961	16.18	0.987	0.9935	15.99	0.995	0.9874	15.83	0.9967
0.02	1.0016	16.15	0.9873	0.9967	16.18	0.987	0.9946	16.05	0.995	0.9885	15.89	0.9970
0.03	1.0020	16.19	0.9869	0.9975	16.17	0.988	0.9947	16.09	0.995	0.9893	15.94	0.9970
0.04	1.0032	16.25	0.9872	0.9976	16.21	0.988	0.9951	16.12	0.995	0.9897	15.93	0.9978
0.05	1.0038	16.32	0.9866	0.9981	16.26	0.987	0.9952	16.16	0.994	0.9901	15.90	0.9991
0.06	1.0034	16.29	0.9866	0.9983	16.30	0.986	0.9955	16.17	0.994	0.9906	15.96	0.9983
0.07	1.0035	16.32	0.9863	0.9986	16.35	0.986	0.9957	16.17	0.994	0.9922	15.95	1.0008
0.08	1.0039	16.34	0.9863	0.9988	16.35	0.986	0.9958	16.21	0.994	0.9924	16.01	0.9997
0.09	1.0043	16.39	0.9858	0.9991	16.34	0.987	0.9960	16.17	0.995	0.9927	16.04	0.9995
0.1	1.0052	16.44	0.9859	0.9961	16.36	0.987	0.9965	16.24	0.994	0.9933	16.05	1.0002
X_{2EE} = **0.0136**												
0.01	1.0026	16.74	0.9976	0.9961	16.44	0.996	0.9911	16.05	1.000	0.9821	15.77	0.9957
0.02	1.0036	16.76	0.9985	0.9967	16.43	0.997	0.9916	16.08	1.001	0.9825	15.79	0.9957
0.03	1.0038	16.80	0.9979	0.9975	16.44	0.997	0.9913	16.15	0.999	0.9827	15.80	0.9959
0.04	1.0039	16.76	0.9989	0.9976	16.5	0.996	0.9917	16.16	0.999	0.9831	15.84	0.9955
0.05	1.0044	16.75	0.9998	0.9981	16.52	0.997	0.9921	16.17	0.999	0.9840	15.78	0.9980
0.06	1.0046	16.77	0.9996	0.9983	16.49	0.998	0.9924	16.19	0.999	0.9843	15.82	0.9975
0.07	1.0048	16.82	0.9989	0.9986	16.49	0.998	0.9925	16.19	0.999	0.9846	15.75	0.9995
0.08	1.0049	16.82	0.9991	0.9988	16.53	0.997	0.9935	16.23	1.000	0.9847	15.77	0.9991
0.09	1.0055	16.83	0.9997	0.9991	16.56	0.997	0.9937	16.24	1.000	0.9853	15.78	0.9998
0.1	1.0059	16.74	1.0021	0.9993	16.54	0.998	0.9941	16.20	1.001	0.9862	15.83	0.9999
X_{2EE} = **0.0301**												
0.01	0.9934	15.85	0.9971	0.9859	15.55	0.996	0.9796	15.22	0.998	0.9707	14.75	0.9990
0.02	0.9937	15.87	0.9970	0.9862	15.60	0.996	0.9797	15.16	0.999	0.9739	14.82	1.0019
0.03	0.9939	15.86	0.9976	0.9864	15.60	0.996	0.9799	15.16	0.999	0.9709	14.75	0.9993
0.04	0.9943	15.86	0.9980	0.9866	15.64	0.995	0.9803	15.19	0.999	0.9712	14.78	0.9992
0.05	0.9949	15.85	0.9990	0.9868	15.63	0.996	0.9807	15.24	0.999	0.9719	14.83	0.9990
0.06	0.9952	15.92	0.9980	0.9869	15.63	0.996	0.9812	15.25	0.999	0.9722	14.83	0.9993
0.07	0.9954	15.96	0.9974	0.9874	15.64	0.997	0.9814	15.23	1.000	0.9723	14.85	0.9990
0.08	0.9956	15.96	0.9976	0.9877	15.68	0.996	0.9816	15.27	0.999	0.9724	14.85	0.9991
0.09	0.9959	16.01	0.9971	0.9882	15.71	0.996	0.9818	15.29	0.999	0.9730	14.92	0.9984
0.1	0.9964	16.00	0.9980	0.9883	15.71	0.996	0.9822	15.26	1.000	0.9734	14.87	1.0001
X_{2EE} = **0.0765**												

0.01	0.9711	14.44	0.9976	0.9634	14.04	0.998	0.9567	13.62	0.999	0.9474	13.30	0.9944
0.02	0.9714	14.49	0.9974	0.9640	14.11	0.997	0.9568	13.68	0.998	0.9478	13.30	0.9948
0.03	0.9715	14.53	0.9966	0.9645	14.13	0.997	0.9573	13.67	0.999	0.9481	13.34	0.9947
0.04	0.9717	14.59	0.9955	0.9646	14.14	0.997	0.9579	13.67	1.000	0.9483	13.35	0.9948
0.05	0.9725	14.62	0.9959	0.9652	14.18	0.997	0.9582	13.70	1.000	0.9489	13.36	0.9960
0.06	0.9735	14.64	0.9969	0.9653	14.17	0.997	0.9588	13.73	1.000	0.9490	13.32	0.9952
0.07	0.9738	14.60	0.9981	0.9655	14.19	0.997	0.9590	13.69	1.001	0.9493	13.36	0.9959
0.08	0.9739	14.64	0.9973	0.9666	14.18	0.999	0.9594	13.70	1.001	0.9498	13.35	0.9956
0.09	0.9741	14.65	0.9975	0.9667	14.21	0.998	0.9601	13.74	1.001	0.9503	13.39	0.9965
0.1	0.9743	14.67	0.9974	0.9669	14.23	0.998	0.9603	13.79	1.000	0.9509	13.36	0.9966
X_{2EE} = **1.0000**												
0.01	0.9341	12.51	0.9924	0.9276	12.20	0.9941	0.9199	11.71	0.9965	0.9104	11.39	0.9955
0.02	0.9377	12.60	0.9952	0.9286	12.23	0.9946	0.9217	11.78	0.9975	0.9161	11.5	1.0007
0.03	0.9369	12.59	0.9944	0.9287	12.22	0.9952	0.9228	11.77	0.9992	0.9118	11.45	0.9960
0.04	0.9375	12.61	0.9945	0.9297	12.27	0.9952	0.9229	11.83	0.9977	0.9131	11.45	0.9979
0.05	0.9387	12.63	0.9958	0.9297	12.32	0.9938	0.9229	11.84	0.9971	0.9133	11.39	0.9998
0.06	0.9393	12.69	0.9949	0.9302	12.32	0.9949	0.9236	11.87	0.9974	0.9149	11.45	1.0005
0.07	0.9400	12.74	0.9948	0.9311	12.33	0.9958	0.9238	11.89	0.9971	0.9138	11.44	0.9992
0.08	0.9402	12.73	0.9954	0.9315	12.29	0.9972	0.9243	11.90	0.9977	0.9149	11.49	0.9994
0.09	0.9405	12.77	0.9947	0.9317	12.29	0.9974	0.9251	11.89	0.9991	0.9150	11.52	0.9985
0.1	0.9408	12.77	0.9951	0.9322	12.34	0.9969	0.9261	11.92	0.9996	0.9158	11.58	0.9982

Table 3: Computed limiting Apparent molar compressibility (φ_K^0 :m^2/mol) and the slope S_k for TBAB in 2 - ethoxy ethanol + water mixtures at different temperatures.

X_{2EE} (composition)	**Temperature**							
	288.15K		298.15K		308.15K		318.15K	
	10^{15} $\Phi_k°$	10^{15} S_k	10^{15} $\Phi_k°$	10^{15} S_k	10^{15} $\Phi_k°$	10^{15} S_k	10^{15} $\Phi_k°$	10^{15} S_k
0.0000	5515	-19549	3904	-13031	2050	-4785	-46.27	-732.9
0.0023	-1365	2986	-664	3007	-2551	8299	743	-1743
0.0052	-15432	42217	-12906	35326	-5809	17391	-1962	8017
0.0136	-1398	7425	1248	-2024	-218.8	3226	-3767	18343
0.0301	-807.4	3129	97.05	1638	-108.3	1768	511.1	898.9
0.0765	-741.2	5088	-1977	5476	-658.1	1871	-8854	28603
1.0000	356	-10152	-6034	11306	-4308	6106	2580	-13707

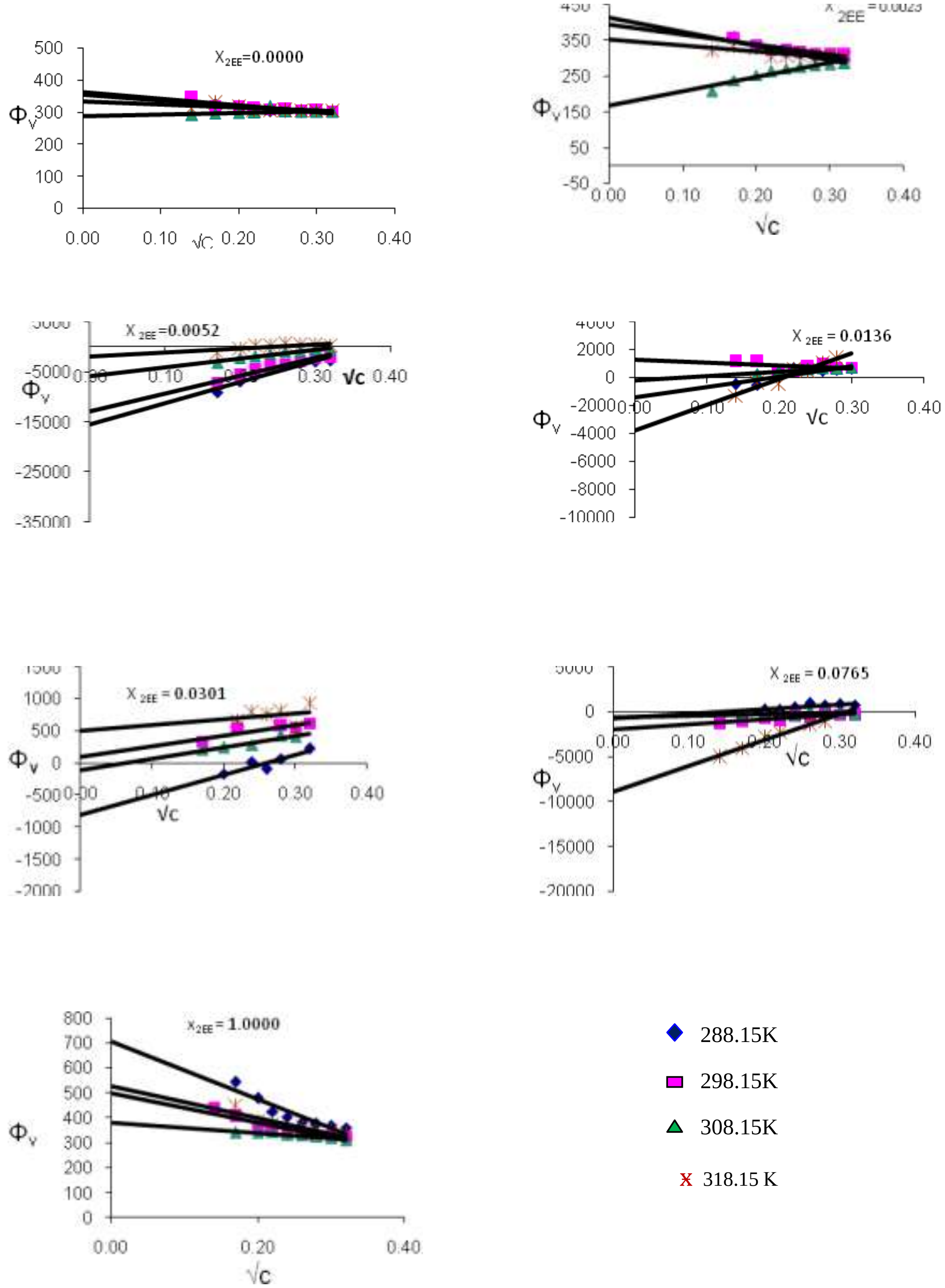

Fig. 1.Plot of Apparent Molar volume (φ_V : m^2mol^{-1}) Vs Square Root of Concentration(√c) for TBAB in 2-ethoxyethanol + water mixture at Different Temperatures.

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