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Insights into Molecular Interactions of Schiff Base Ligands Through Ultrasonic Velocity Analysis in 1,4-Dioxane–Water at 298 K, 302 K, 306 K

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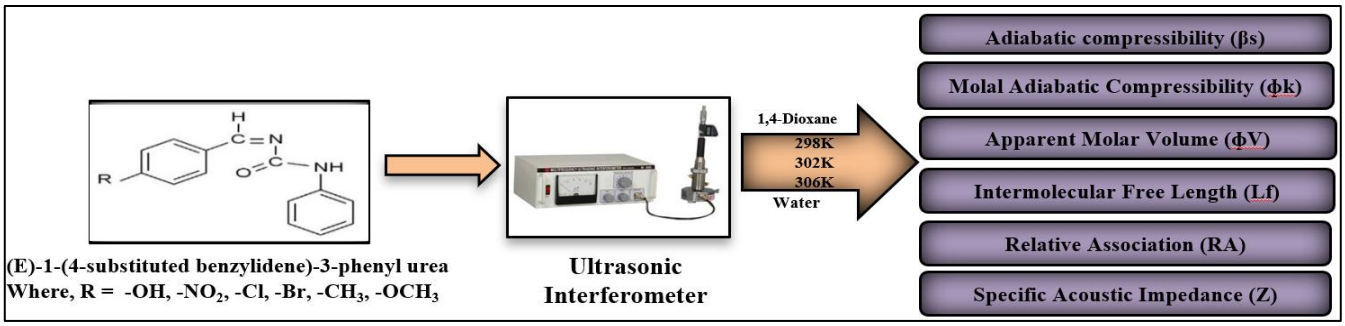
Abstract

The ultrasonic velocity (U), density (ρ) of (E)-1-(4-substituted benzylidene)-3-phenyl urea were measured at three different temperatures 298K, 302K and 306 K. Various acoustic parameters like adiabatic compressibility (βs), molal adiabatic compressibility (ϕ_k), apparent molar volume (ϕ_V), intermolecular free length (L_f), Relative association (R_A) and Specific acoustic impedance (Z) were calculated by measuring ultrasonic velocity at different percentages of 80%, 85%, 90% and 95% 1,4-dioxane-water mixture. The findings suggest that intermolecular forces become weaker as temperature increases, which is reflected by higher compressibility and greater free length. Changes in apparent molar volume, acoustic impedance, and relative association with concentration indicate distinct solute–solvent interactions, where dilution favours stronger solute–solvent association, while concentrated solutions show enhanced solute–solute interactions.

Graphical Abstract



Keywords: Acoustic, Intermolecular interaction, Ultrasonic velocity, Interferometric study, Physicochemical, Schiff base ligands.

1. Introduction

The speed at which ultrasonic waves travel through a medium is known as ultrasonic velocity. This velocity is a crucial characteristic of materials and is influenced by the medium's temperature, elasticity, and density. The velocity of sound through a material is precisely measured using ultrasonic waves in an ultrasonic interferometer. The ultrasonic velocity along with other experimental data such as density and viscosity, furnish wealth of information about the interaction between ions, dipoles. This molecular interactions between like and unlike molecules are influenced by structural arrangement along with shape and size of the molecules [1]. In order to measure the interference pattern that emerges from the interaction of ultrasonic waves within a medium, an ultrasonic interferometer generates ultrasonic waves. The characteristics of the material cause changes in the velocity of ultrasonic waves as they pass through it. These alterations can be utilized to ascertain the material's physical properties, including its viscosity, density, and elasticity.

By analysing the interference patterns produced by the ultrasonic waves, the ultrasonic interferometer can provide highly accurate measurements of sound velocity, making it a valuable tool in various scientific and industrial applications, including material testing, quality control, and the study of acoustic properties of different substances. The relationship between ultrasonic velocity and material properties is important for understanding how sound waves behave in different media and can help in characterizing materials more effectively.

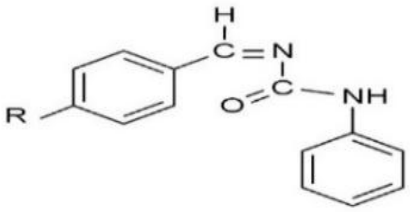
According to the literature review, ultrasonic analysis of liquid mixtures is very helpful in comprehending the physicochemical behavior of liquid mixtures and the nature of molecular interactions [2-4], liquid mixtures and solutions find wide applications in medical, pharmaceutical, chemical, lather, textile, nuclear and solvent, solution related industries [5]. Effect of antidiabetic metformin hydrochloride on physicochemical properties of cationic surfactant cetyltrimethylammonium bromide in aqueous solutions was studied by (S. D. Deosarkar et al., 2021) [6]. (T. M. Bhagat et al., 2021) studied molecular interaction of 2- substituted 4, 5-diphenyl imidazole with ethanol at different temperatures [7]. Ion-Solvent interactions in the inorganic liquid mixtures by ultrasonic technique has been studied by (K. Rathina et al., 2019) [8]. The acoustic parameters of different chloro substituted azetidin-2-one at different concentration and temperature in 90% (EtOH+ water) solvent by (Ashfaq Husain M. Saudagar et al., 2018) [9]. Recently, (Dhirendra Kumar Sharma et al., 2025) have studied the excess adiabatic compressibility, molar volume, acoustic impedance and excess viscosity in the binary liquid mixtures of 1, 3-Dioxolane with Alkanols (C5-C10) at 298.15k [10]. Many researchers studied ultrasonic properties Schiff base derivatives at different temperatures [11-16].

In the present study, the molecular interactions of following six schiff base ligands were studied 80%, 85%, 90% and 95% of 1,4-dioxane-water mixture by acoustical measurements at 298k, 302k and 306k.

1. (E)-1-(4-hydoxy benzylidene)-3-phenyl urea (L1)
2. (E)-1-(4-nitro benzylidene)-3-phenyl urea (L2)
3. (E)-1-(4-chloro benzylidene)-3-phenyl urea (L3)
4. (E)-1-(4-bromo benzylidene)-3-phenyl urea (L4)

5. (E)-1-(4-methyl benzylidene)-3-phenyl urea (L5)
6. (E)-1-(4-methoxy benzylidene)-3-phenyl urea (L6)

Following is the general structure of the Schiff base ligand.



(E)-1-(4-substituted benzylidene)-3-phenyl urea

Where, R = -OH, -NO_2, -Cl, -Br, -CH_3, -OCH_3

2. Materials and Methods

- **Experimental**

A.R. grade compounds were used for the synthesis. The ligands (L1-L6) were recrystallized before use. Using standard procedure the solvent 1,4-dioxane was purified. Deionized water was used during the experiment to avoid ionic contamination. Each ligand's 0.01M solutions were made in varying percentages of the 1,4-dioxane-water mixture (80%, 85%, 90% and 95%). Measurement of density and ultrasonic velocity of ligand solutions were conducted at 298, 302 and 306 K using the standard procedure.

- **Instrumentation**

Densities of the ligand solutions were determined using standardized capillary pyknometer with a capillary of an internal diameter of about 1 mm and a bulb with a volume of roughly 10 cm^3. The Citizen CY 104 one pan digital balance was used for all of the weighing. In the current study, the ultrasonic velocity was measured using a variable path ultrasonic interferometer (Model MX-3, Mittal Enterprises, New Delhi) with an accuracy of ± 0.03% and operating frequency of 1 MHz.

3. Results and Discussion

By measuring the various acoustic parameters such as, ultrasonic velocity (V), adiabatic compressibility (βs), molal adiabatic compressibility (ϕ_k), apparent molar volume (ϕ_V), intermolecular free length (L_f), Relative association (R_A) and Specific acoustic impedance (Z) the structural interaction between the solute and the solvents can be ascertained. It discusses the stability, molecular association, internal structure, and complex formation tendency of the ligands under investigation. It provides details about the stability, molecular association, internal structure, and complex formation of the ligands being studied. The ultrasonic velocity obtained is used to derive the acoustic parameters for ligands L1, L2, L3, L4, L5 and L6 in 80%, 85%, 90% and 95% percentage of dioxane-water, at three varying temperatures 298K, 302K and 306K. The findings are displayed in tabular and graphical formats (Table 1-18 and Figure 1-21).

- **Ultrasonic velocity (V):**
  The ultrasonic velocity is the measure of speed of sound waves in a liquid. It depends upon the density and compressibility of the medium.

- **Adiabatic compressibility (β_s):** This acoustic property quantifies the volume change of a substance under pressure during a process that does not involve heat transfer. Using Laplace's equation, the adiabatic compressibility may be calculated using the ultra sonic velocity V and density d.

$$\beta = \frac{1}{v^2 \times d} \qquad (1)$$

- **Molal adiabatic compressibility (ϕ_k):** Molal adiabatic compressibility is the property derived from adiabatic compressibility and molecular weight of the solute by the relation,

$$\phi_K = \frac{1000(\beta_s \cdot d_0 - \beta_0 \cdot d_s)}{C \cdot d_s \cdot d_0} + \frac{\beta_s \cdot M}{d_s} \qquad (2)$$

- **Apparent molar volume (ϕ_V):** The apparent molar volume is the variation in the total volume of a solution upon the addition of one mole of a solute, provides insights into the volume occupied by the solute in the solution as well as the interactions between solute and the solvent. The apparent molar volume is determined by the densities of the solution and solvent, the molecular weight of the solute, and the concentration of the solution. It is represented by the equation,

$$\phi_v = \frac{1000(d_o - d_s)}{C \cdot d_s \cdot d_0} + \frac{M}{d_s} \qquad (3)$$

- **Intermolecular free length (L_f):**
  Intermolecular free length has been evaluated from adiabatic compressibility by Jacobson's formula. The average distance between the centres of neighbouring molecules. It responds to shifts in the liquid's molecular associations and structure.

$$L_f = K\sqrt{\beta_s} \qquad (4)$$

- **Relative association (R_A):** A parameter that quantifies the association between solvent and solute molecules. A higher relative association suggests stronger interactions computed by the formula,

$$R_A = \frac{d_s}{d_0} \times \left(\frac{V_0}{V_s}\right)^{1/3} \qquad (5)$$

- **Specific acoustic impedance (Z):** The acoustic impedance is determined from the measurement of ultrasonic velocity and density by the formula,

$$Z = V_s \,.\, d_s \qquad (6)$$

Table 1: Acoustic Parameters at Different % Of 1,4-Dioxane-Water

System: Ligand L1 Temp. = 298 K

% 1,4-Dioxane	V x 10^3 (m sec^{-1})	ds x 10^3 (kg m^{-3})	$\beta_s \times 10^{-10}$ (pa^{-1})	$\phi_k x 10^{-10}$ ($m^3 mol^{-1}$ pa^{-1})	$\phi_v x 10^{-3}$ (m^3 mol^{-1})	L_f x10^{-1} (m^{-1})	R_A	Z x 10^6 (kg m^{-2} sec^{-1})
80%	1.8246	1.0172	0.2953	-1821.55	783.76	342.89	0.9822	1.8559
85%	1.594	1.0171	0.3869	-9661.25	640.29	392.49	0.9575	1.6213
90%	1.534	1.0103	0.4206	-12059.48	394.06	409.23	0.9619	1.5498
95%	1.4514	1.0092	0.4704	-7147.42	463.12	432.78	0.9732	1.4648

Table 2: Acoustic Parameters at Different % Of 1,4-Dioxane-Water

System: Ligand L2 Temp. = 298 K

% 1,4-Dioxane	V x 10^3 (m sec^{-1})	ds x 10^3 (kg m^{-3})	$\beta_s \times 10^{-10}$ (pa^{-1})	$\phi_k x 10^{-10}$ ($m^3 mol^{-1}$ pa^{-1})	$\phi_v x 10^{-3}$ (m^3 mol^{-1})	L_f x10^{-1} (m^{-1})	R_A	Z x 10^6 (kg m^{-2} sec^{-1})
80%	1.6226	1.0224	0.3715	5511.94	310.92	384.59	1.0266	1.6589
85%	1.6222	1.0178	0.3734	-4120.64	601.01	385.58	0.9526	1.6511
90%	1.5706	1.0124	0.4004	-12256.36	216.89	399.28	0.9563	1.5901
95%	1.5488	1.0117	0.4121	-13027.56	246.35	405.07	0.9547	1.5669

Table 3: Acoustic Parameters at Different % Of 1,4-Dioxane-Water

System: Ligand L3 Temp. = 298 K

% 1,4-Dioxane	V x 10^3 (m sec^{-1})	ds x 10^3 (kg m^{-3})	$\beta_s \times 10^{-10}$ (pa^{-1})	$\phi_k x 10^{-10}$ ($m^3 mol^{-1}$ pa^{-1})	$\phi_v x 10^{-3}$ (m^3 mol^{-1})	L_f x10^{-1} (m^{-1})	R_A	Z x 10^6 (kg m^{-2} sec^{-1})
80%	2.0172	1.0164	0.2418	-7070.77	879.04	310.28	0.9491	2.0503
85%	1.6342	1.0157	0.3687	-11398.34	793.86	383.15	0.9465	1.6599
90%	1.4138	1.0149	0.4929	-3220.61	-37.91	443.01	0.9928	1.4349
95%	1.3752	1.0132	0.5219	2227.52	88.12	455.85	0.9952	1.3934

Table 4: Acoustic Parameters at Different % Of 1,4-Dioxane-Water

System: Ligand L4 Temp. = 298 K

% 1,4-Dioxane	V x 10^3 (m sec^{-1})	ds x 10^3 (kg m^{-3})	$\beta_s \times 10^{-10}$ (pa^{-1})	$\phi_k x10^{-10}$ ($m^3 mol^{-1}$ pa^{-1})	$\phi_v x10^{-3}$ (m^3 mol^{-1})	L_f $x10^{-1}$ (m^{-1})	R_A	Z x 10^6 (kg m^{-2} sec^{-1})
80%	1.648	1.0189	0.3614	4655.21	681.17	379.34	1.0178	1.6791
85%	1.6336	1.0169	0.3685	-11444.75	721.63	383.04	0.9494	1.6612
90%	1.4644	1.0168	0.4586	-6673.37	-178.25	427.31	0.9831	1.4890
95%	1.3932	1.0105	0.5098	-3267.36	397.69	450.54	0.9878	1.4078

Table 5: Acoustic Parameters at Different % Of 1,4-Dioxane-Water

System: Ligand L5 Temp. = 298 K

% 1,4-Dioxane	V x 10^3 (m sec^{-1})	ds x 10^3 (kg m^{-3})	$\beta_s \times 10^{-10}$ (pa^{-1})	$\phi_k x10^{-10}$ ($m^3 mol^{-1} pa^1$)	$\phi_v x10^{-3}$ (m^3 mol^{-1})	L_f $x10^{-1}$ (m^{-1})	R_A	Z x 10^6 (kg m^{-2} sec^{-1})
80%	1.9626	1.0192	0.2547	-5872.22	588.42	318.45	0.9604	2.0003
85%	1.6516	1.0173	0.3604	-12280.70	618.95	378.81	0.9464	1.6802
90%	1.46	1.0151	0.4622	-6271.48	-77.07	428.99	0.9824	1.4821
95%	1.4028	1.0081	0.5041	-3746.53	569.52	448.01	0.9832	1.4142

Table 6: Acoustic Parameters at Different % Of 1,4-Dioxane-Water

System: Ligand L6 Temp. = 298 K

% 1,4-Dioxane	V x 10^3 (m sec^{-1})	ds x 10^3 (kg m^{-3})	$\beta_s \times 10^{-10}$ (pa^{-1})	$\phi_k x10^{-10}$ ($m^3 mol^{-}$ pa^{-1})	$\phi_v x10^{-3}$ (m^3 mol^{-1})	L_f $x10^{-1}$ (m^{-1})	R_A	Z x 10^6 (kg m^{-2} sec^{-1})
80%	1.6244	1.0148	0.3735	5976.93	1030.42	385.63	1.0186	1.6484
85%	1.5964	1.0125	0.3875	-9423.27	1101.88	392.79	0.9526	1.6164
90%	1.4962	1.0122	0.4413	-8203.45	221.65	419.18	0.9717	1.5144
95%	1.4006	1.0054	0.5070	-3214.72	852.46	449.29	0.9811	1.4082

Table 7: Acoustic Parameters At Different % Of 1,4-Dioxane-Water

System: Ligand L1 Temp.= 302K

% 1,4-Dioxane	V x 10^3 (m sec^{-1})	ds x 10^3 (kg m^{-3})	$\beta_s \times 10^{-10}$ (pa^{-1})	$\phi_k x10^{-10}$ ($m^3 mol^{-1} pa^{-1}$)	$\phi_v x10^{-3}$ (m^3 mol^{-1})	L_f x10^{-1} (m^{-1})	R_A	Z x 10^6 (kg m^{-2} sec^{-1})
80%	1.7986	1.0095	0.3062	-7039.94	784.22	349.17	0.9584	1.8158
85%	1.5232	1.0093	0.4271	-7281.05	648.38	412.38	0.9681	1.5375
90%	1.4638	1.0026	0.4655	-9205.16	398.29	430.52	0.9679	1.4676
95%	1.3984	1.0015	0.5106	-10306.89	458.51	450.89	0.9667	1.4005

Table 8: Acoustic Parameters At Different % Of 1,4-Dioxane-Water

System: Ligand L2 Temp.= 302K

% 1,4-Dioxane	V x 10^3 (m sec^{-1})	ds x 10^3 (kg m^{-3})	$\beta_s \times 10^{-10}$ (pa^{-1})	$\phi_k x10^{-10}$ ($m^3 mol^{-1} pa^{-1}$)	$\phi_v x10^{-3}$ (m^3 mol^{-1})	L_f x10^{-1} (m^{-1})	R_A	Z x 10^6 (kg m^{-2} sec^{-1})
80%	1.6182	1.0146	0.3764	-246.43	313.68	387.12	0.9978	1.6418
85%	1.5834	1.0122	0.3941	-10659.33	392.48	396.13	0.9585	1.6027
90%	1.5508	1.0046	0.4139	-14361.54	228.12	405.95	0.9514	1.5579
95%	1.4572	1.0039	0.4691	-14604.19	267.76	432.18	0.9558	1.4629

Table 9: Acoustic Parameters At Different % Of 1,4-Dioxane-Water

System: Ligand L3 Temp.= 302K

% 1,4-Dioxane	V x 10^3 (m sec^{-1})	ds x 10^3 (kg m^{-3})	$\beta_s \times 10^{-10}$ (pa^{-1})	$\phi_k x10^{-10}$ ($m^3 mol^{-1} pa^{-1}$)	$\phi_v x10^{-3}$ (m^3 mol^{-1})	L_f x10^{-1} (m^{-1})	R_A	Z x 10^6 (kg m^{-2} sec^{-1})
80%	1.6724	1.0087	0.3545	-2209.67	880.82	375.69	0.9812	1.6869
85%	1.581	1.0079	0.3969	-10218.57	804.19	397.53	0.9552	1.5935
90%	1.387	1.0071	0.5161	-4367.49	-30.57	453.31	0.9899	1.3968
95%	1.3386	1.0054	0.5551	-6058.47	88.15	470.13	0.9846	1.3458

Table 10: Acoustic Parameters At Different % Of 1,4-Dioxane-Water

System: Ligand L4 Temp.= 302k

% 1,4-Dioxane	V x 10^3 (m sec^{-1})	ds x 10^3 (kg m^{-3})	$\beta_s \times 10^{-10}$ (pa^{-1})	$\phi_k x10^{-10}$ ($m^3 mol^{-1} pa^{-1}$)	$\phi_v x10^{-3}$ (m^3 mol^{-1})	L_f x10^{-1} (m^{-1})	R_A	Z x 10^6 (kg m^{-2} sec^{-1})
80%	1.6426	1.0111	0.3666	-1077.19	689.41	382.05	0.9895	1.6608
85%	1.4394	1.0092	0.4783	-2161.48	720.64	436.39	0.9865	1.4526
90%	1.4212	1.0091	0.4906	-6980.98	-183.28	441.97	0.9839	1.4341
95%	1.3764	1.0027	0.5264	-8755.46	401.55	457.81	0.9729	1.3801

Table 11: Acoustic Parameters at Different % Of 1,4-Dioxane-Water

System: Ligand L5 Temp.= 302K

% 1,4-Dioxane	V x 10^3 (m sec^{-1})	ds x 10^3 (kg m^{-3})	$\beta_s \times 10^{-10}$ (pa^{-1})	$\phi_k x10^{-10}$ ($m^3 mol^{-1} pa^{-1}$)	$\phi_v x10^{-3}$ (m^3 mol^{-1})	L_f x10^{-1} (m^{-1})	R_A	Z x 10^6 (kg m^{-2} sec^{-1})
80%	1.6618	1.0114	0.3581	63.55	595.71	377.59	0.9858	1.6807
85%	1.5042	1.0095	0.4378	-6227.84	626.72	417.51	0.9725	1.5185
90%	1.41	1.0073	0.4993	-6059.74	-70.19	445.87	0.9846	1.4203
95%	1.2714	1.0004	0.6184	549.62	566.56	496.21	0.9967	1.2719

Table 12: Acoustic Parameters at Different % Of 1,4-Dioxane-Water

System: Ligand L6 Temp.= 302K

% 1,4-Dioxane	V x 10^3 (m sec^{-1})	ds x 10^3 (kg m^{-3})	$\beta_s \times 10^{-10}$ (pa^{-1})	$\phi_k x10^{-10}$ ($m^3 mol^{-1}$ pa^{-1})	$\phi_v x10^{-3}$ (m^3 mol^{-1})	L_f x10^{-1} (m^{-1})	R_A	Z x 10^6 (kg m^{-2} sec^{-1})
80%	1.6186	1.0071	0.3791	293.76	1034.75	388.51	0.9903	1.6301
85%	1.5488	1.0047	0.4149	-8298.27	1117.03	406.44	0.9584	1.5561
90%	1.4154	1.0044	0.4969	-6147.89	233.06	444.79	0.9806	1.4216
95%	1.3666	0.9977	0.5367	-7482.42	853.75	462.27	0.9703	1.3635

Table 13: Acoustic Parameters at Different % Of 1,4-Dioxane-Water

System: Ligand L1 Temp.= 306K

% 1,4-Dioxane	V x 10^3 ($m\ sec^{-1}$)	ds x 10^3 ($kg\ m^{-3}$)	$\beta_s \times 10^{-10}$ (pa^{-1})	$\phi_k x 10^{-10}$ ($m^3 mol^{-1}\ pa^{-1}$)	$\phi_v x 10^{-3}$ ($m^3\ mol^{-1}$)	L_f x10^{-1} (m^{-1})	R_A	Z x 10^6 ($kg\ m^{-2}\ sec^{-1}$)
80%	1.5664	1.0018	0.4068	1484.59	794.46	402.46	0.9983	1.5692
85%	1.4732	1.0017	0.4599	-9466.03	646.54	427.92	0.9751	1.4757
90%	1.3664	0.9950	0.5383	-4800.36	402.56	462.96	0.9838	1.3596
95%	1.3648	0.9939	0.5402	-13936.68	463.69	463.77	0.9603	1.3565

Table 14: Acoustic Parameters at Different % Of 1,4-Dioxane-Water

System: Ligand L2 Temp.= 306K

% 1,4-Dioxane	V x 10^3 ($m\ sec^{-1}$)	ds x 10^3 ($kg\ m^{-3}$)	$\beta_s \times 10^{-10}$ (pa^{-1})	$\phi_k x 10^{-10}$ ($m^3 mol^{-1}\ pa^{-1}$)	$\phi_v x 10^{-3}$ ($m^3\ mol^{-1}$)	L_f x10^{-1} (m^{-1})	R_A	Z x 10^6 ($kg\ m^{-2}\ sec^{-1}$)
80%	1.6172	1.0069	0.3797	-1408.53	316.45	388.82	0.9928	1.6284
85%	1.4512	1.0045	0.4727	-8303.34	396.47	433.83	0.9712	1.4577
90%	1.3754	0.9970	0.5302	-5718.18	229.55	459.46	0.9833	1.3713
95%	1.3398	0.9964	0.5591	-11852.71	239.75	471.82	0.9686	1.3349

Table 15: Acoustic Parameters at Different % Of 1,4-Dioxane-Water

System: Ligand L3 Temp.= 306K

% 1,4-Dioxane	V x 10^3 ($m\ sec^{-1}$)	ds x 10^3 ($kg\ m^{-3}$)	$\beta_s \times 10^{-10}$ (pa^{-1})	$\phi_k x 10^{-10}$ ($m^3 mol^{-1}\ pa^{-1}$)	$\phi_v x 10^{-3}$ ($m^3\ mol^{-1}$)	L_f x10^{-1} (m^{-1})	R_A	Z x 10^6 ($kg\ m^{-2}\ sec^{-1}$)
80%	1.4512	1.0011	0.4743	8280.35	882.41	434.57	1.0233	1.4528
85%	1.388	1.0003	0.5189	-3479.89	804.59	454.54	0.9817	1.3884
90%	1.357	0.9995	0.5433	-4533.28	-33.01	465.10	0.9902	1.3563
95%	1.3338	0.9978	0.5633	-11515.80	87.53	473.59	0.9713	1.3309

Table 16: Acoustic Parameters at Different % Of 1,4-Dioxane-Water

System: Ligand L4 Temp.= 306k

% 1,4-Dioxane	V x 10^3 ($m\ sec^{-1}$)	ds x 10^3 ($kg\ m^{-3}$)	$\beta_s \times 10^{-10}$ (pa^{-1})	$\phi_k x10^{-10}$ ($m^3 mol^{-1}\ pa^{-1}$)	$\phi_v x10^{-3}$ ($m^3\ mol^{-1}$)	L_f x10^{-1} (m^{-1})	R_A	Z x 10^6 ($kg\ m^{-2}\ sec^{-1}$)
80%	1.6018	1.0027	0.3887	-336.98	767.48	393.40	0.9918	1.6061
85%	1.417	1.0015	0.4973	-5682.19	729.43	444.98	0.9761	1.4191
90%	1.2394	0.9978	0.6524	6551.25	182.99	509.67	1.1556	1.2367
95%	1.1812	0.9952	0.7202	4470.99	395.25	535.49	1.0089	1.1755

Table 17: Acoustic Parameters at Different % Of 1,4-Dioxane-Water

System: Ligand L5 Temp.= 306k

% 1,4-Dioxane	V x 10^3 ($m\ sec^{-1}$)	ds x 10^3 ($kg\ m^{-3}$)	$\beta_s \times 10^{-10}$ (pa^{-1})	$\phi_k x10^{-10}$ ($m^3 mol^{-1}\ pa^{-1}$)	$\phi_v x10^{-3}$ ($m^3\ mol^{-1}$)	L_f x10^{-1} (m^{-1})	R_A	Z x 10^6 ($kg\ m^{-2}\ sec^{-1}$)
80%	1.5532	1.0037	0.4129	2015.93	603.05	405.46	1.0031	1.5589
85%	1.4306	1.0018	0.4877	-6689.93	634.55	440.66	0.9734	1.4332
90%	1.3384	0.9997	0.5584	-3041.01	-73.08	471.52	0.9951	1.3379
95%	0.9536	0.9928	1.1077	43723.22	573.42	664.11	1.0809	0.9467

Table 18: Acoustic Parameters at Different % Of 1,4-Dioxane-Water

System: Ligand L6 Temp.= 306K

% 1,4-Dioxane	V x 10^3 ($m\ sec^{-1}$)	ds x 10^3 ($kg\ m^{-3}$)	$\beta_s \times 10^{-10}$ (pa^{-1})	$\phi_k x10^{-10}$ ($m^3 mol^{-1}\ pa^{-1}$)	$\phi_v x10^{-3}$ ($m^3\ mol^{-1}$)	L_f x10^{-1} (m^{-1})	R_A	Z x 10^6 ($kg\ m^{-2}\ sec^{-1}$)
80%	1.5982	0.9995	0.3917	69.36	1038.72	394.92	0.9894	1.5974
85%	1.384	0.9971	0.5236	-2842.50	1122.24	456.59	0.9797	1.3799
90%	1.347	0.9968	0.5529	-3422.32	-20.13	469.19	0.9899	1.3427
95%	1.335	0.9902	0.5666	-10749.55	854.69	474.97	0.9638	1.3219

Figure 1: Plot Between % 1,4-Dioxane-Water Vs Ultrasonic Velocity (V) At 298 K

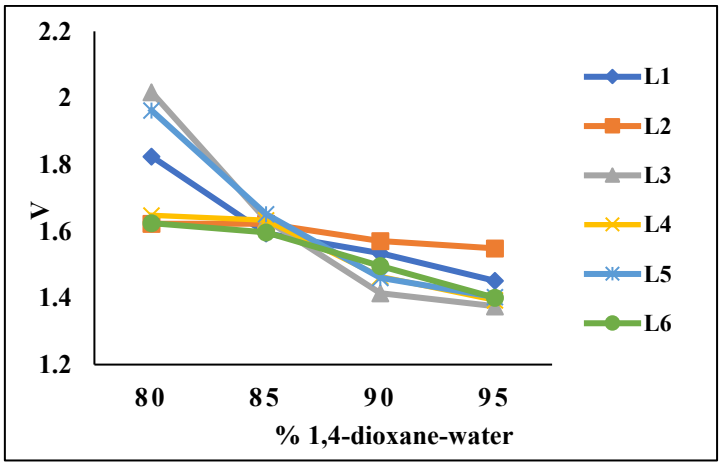


Figure 2: Plot Between % 1,4-Dioxane-Water Vs Ultrasonic Velocity (V) At 302 K

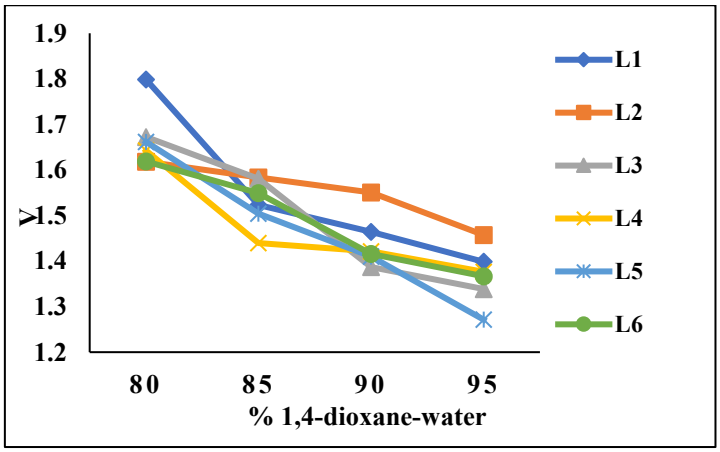


Figure 3: Plot Between % 1,4-Dioxane-Water Vs Ultrasonic Velocity (V) At 306 K

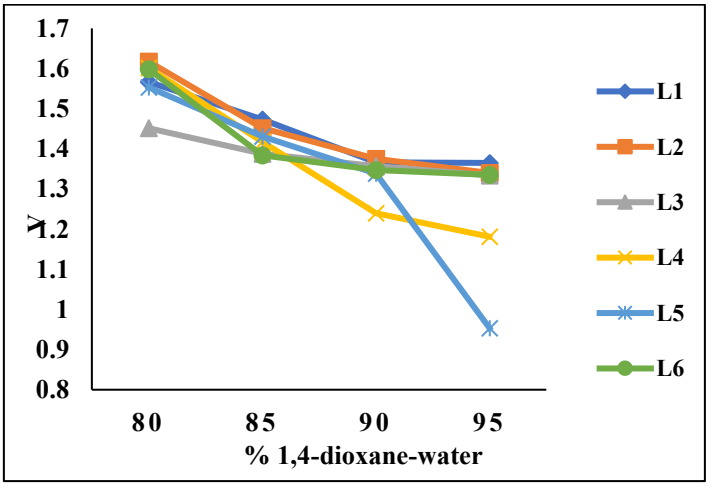


Figure 4: Plot Between % 1,4-Dioxane-Water Vs Adiabatic Compressibility (B_s) At 298 K

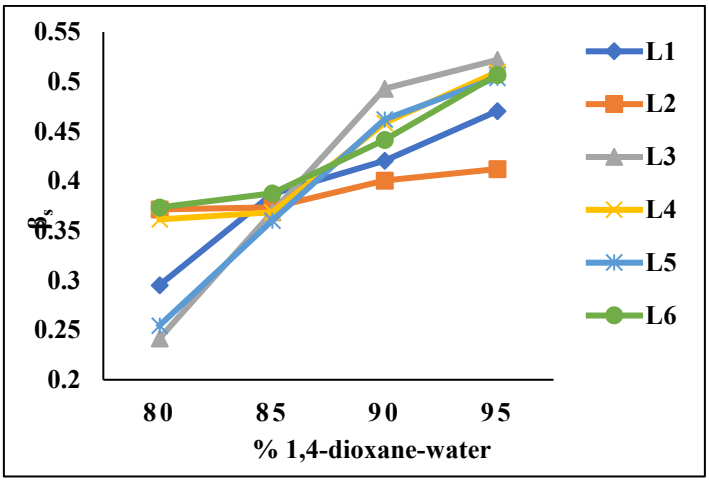


Figure 5: Plot Between % 1,4-Dioxane-Water Vs Adiabatic Compressibility (B_s) At 302 K

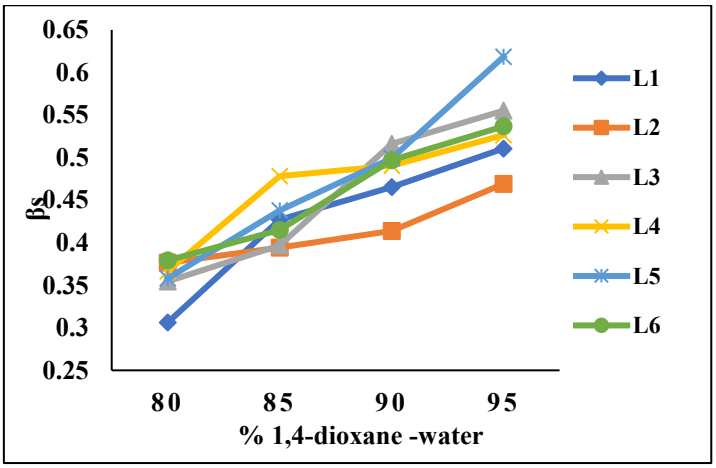


Figure 6: Plot Between % 1,4-Dioxane-Water Vs Adiabatic Compressibility (B_s) At 306 K

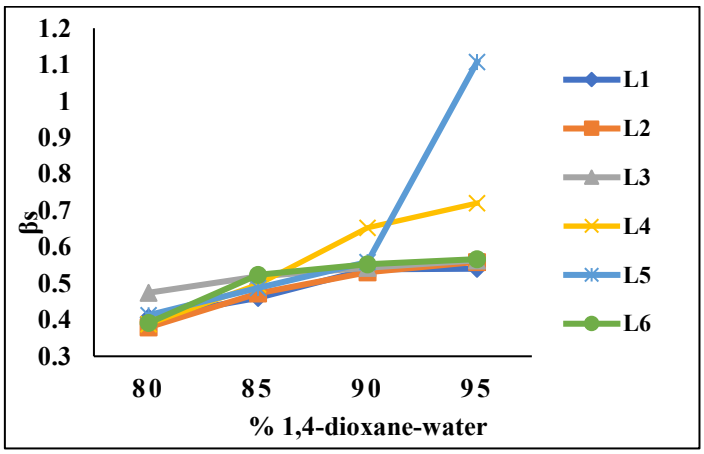


Figure 7: Plot Between % 1,4-Dioxane-Water Vs Molal Adiabatic Compressibility (ϕ_k) At 298 K

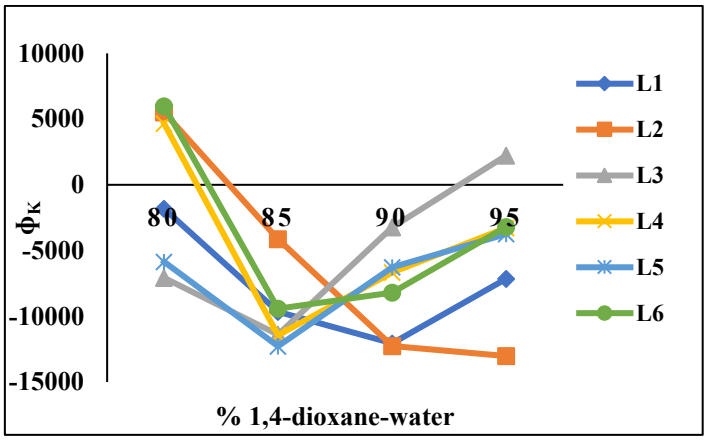


Figure 8: Plot Between % 1,4-Dioxane-Water Vs Molal Adiabatic Compressibility (ϕ_k) At 302 K

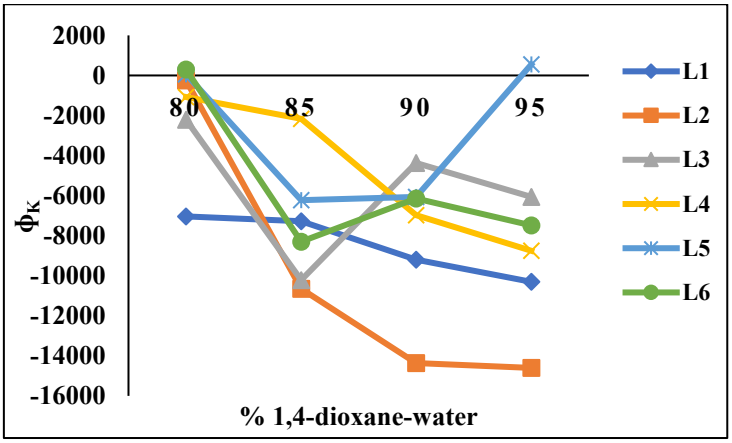


Figure 9: Plot Between % 1,4-Dioxane-Water Vs Molal Adiabatic Compressibility (ϕ_k) At 306 K

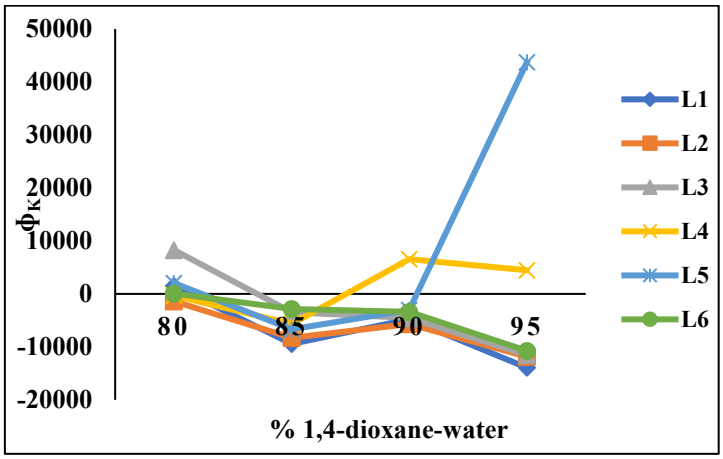


Figure 10: Plot Between % 1,4-Dioxane-Water Vs Apparent Molar Volume (ϕ_v) At 298 K

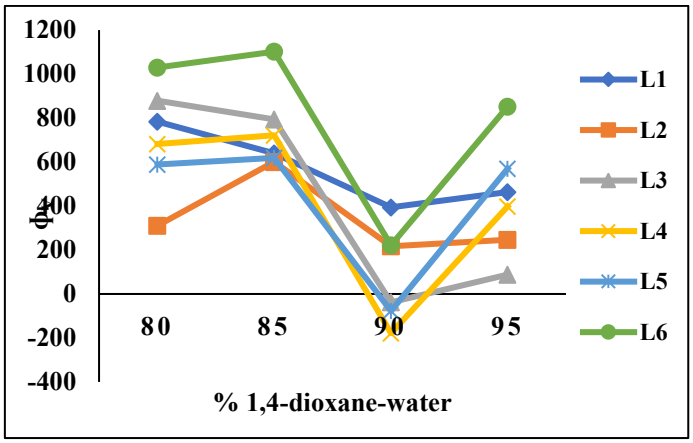


Figure 11: Plot Between % 1,4-Dioxane-Water Vs Apparent Molar Volume (ϕ_v) At 302 K

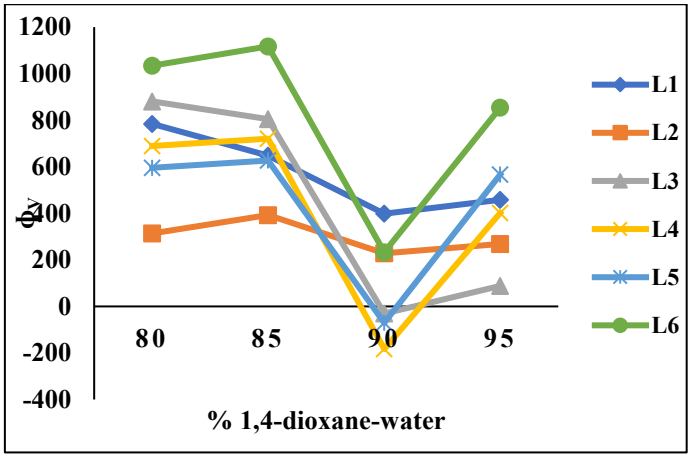


Figure 12: Plot Between % 1,4-Dioxane-Water Vs Apparent Molar Volume (ϕ_v) At 306 K

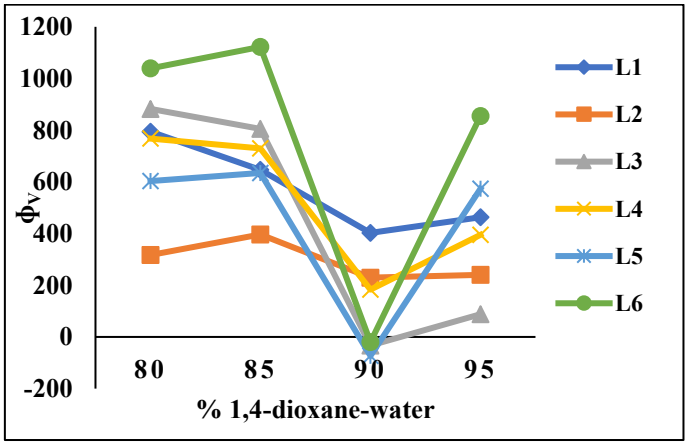


Figure 13: Plot Between % 1,4-Dioxane-Water Vs Intermolecular Free Length (L_f) At 298 K

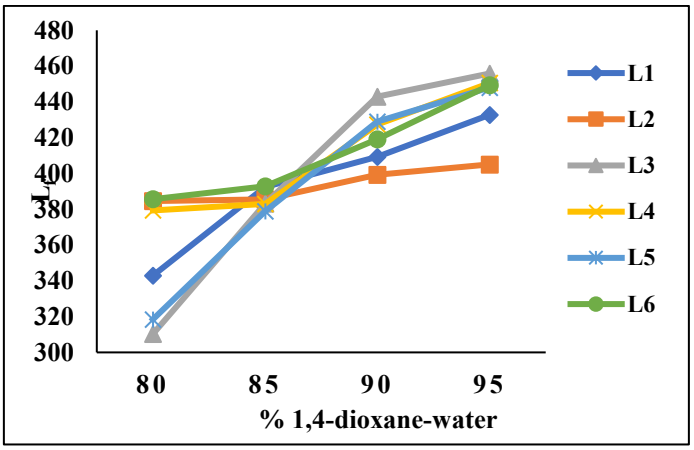


Figure 14: Plot between % 1,4-dioxane-water Vs intermolecular free length (L_f) at 302 K

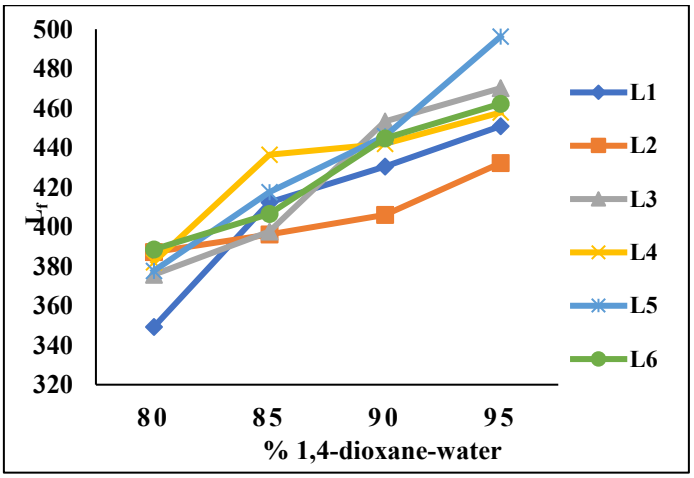


Figure 15: Plot Between % 1,4-Dioxane-Water Vs Intermolecular Free Length (L_f) At 306 K

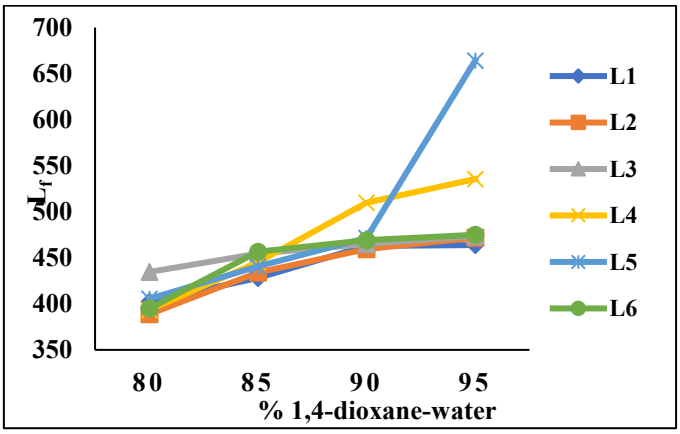


Figure 16: Plot Between % 1,4-Dioxane-Water Vs Relative Association (R_A) At 298 K

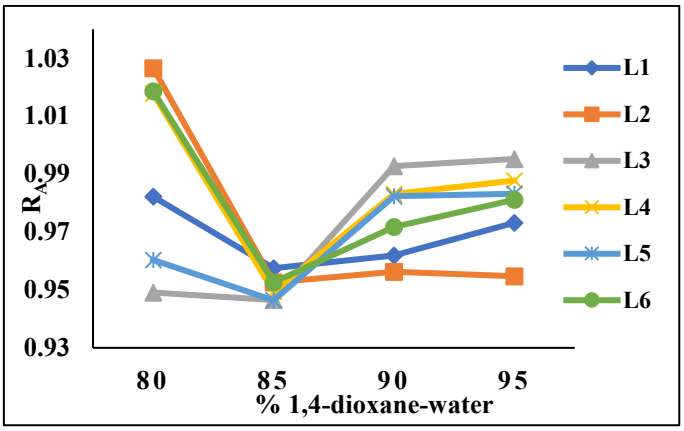


Figure 17: Plot Between % 1,4-Dioxane-Water Vs Relative Association (R_A) At 302 K

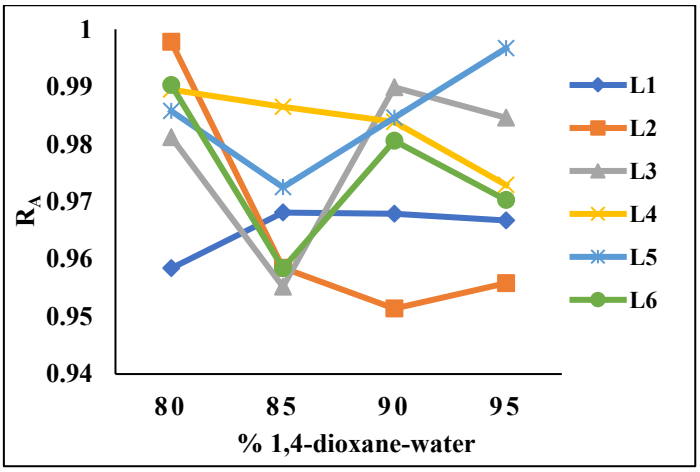


Figure 18: Plot Between % 1,4-Dioxane-Water Vs Relative Association (R_A) At 306 K

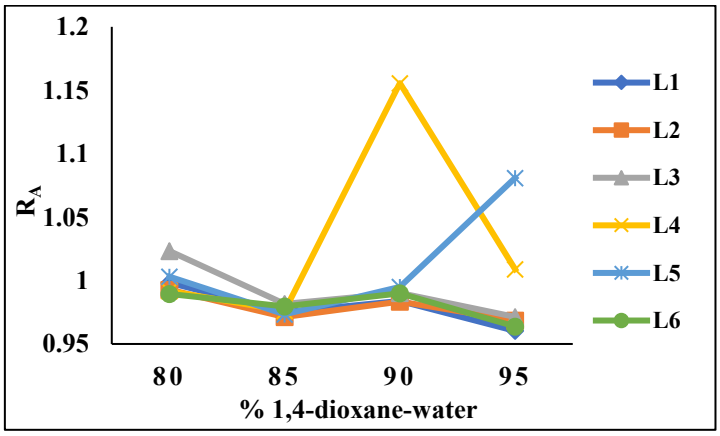


Figure 19: Plot Between % 1,4-Dioxane-Water Vs Specific Acoustic Impedance (Z) At 298 K

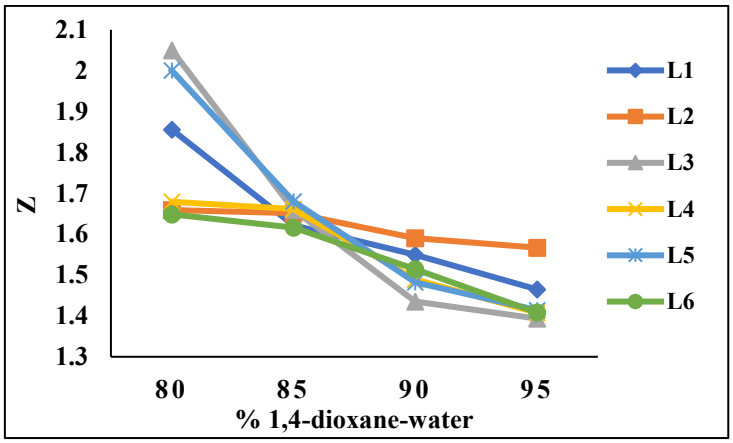


Figure 20: Plot Between % 1,4-Dioxane-Water Vs Specific Acoustic Impedance (Z) At 302 K

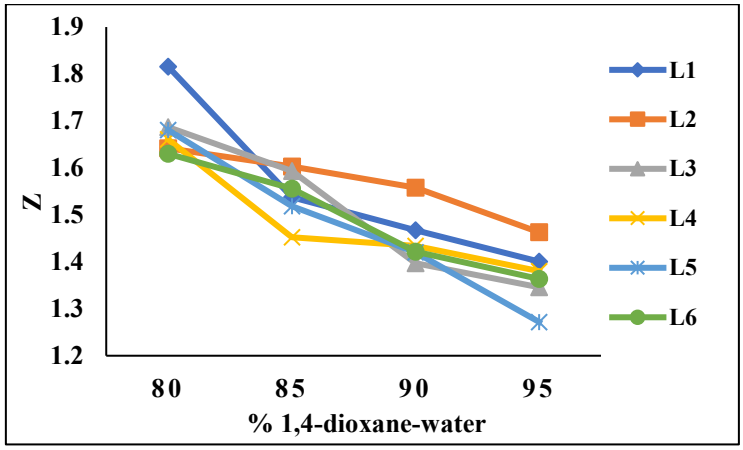
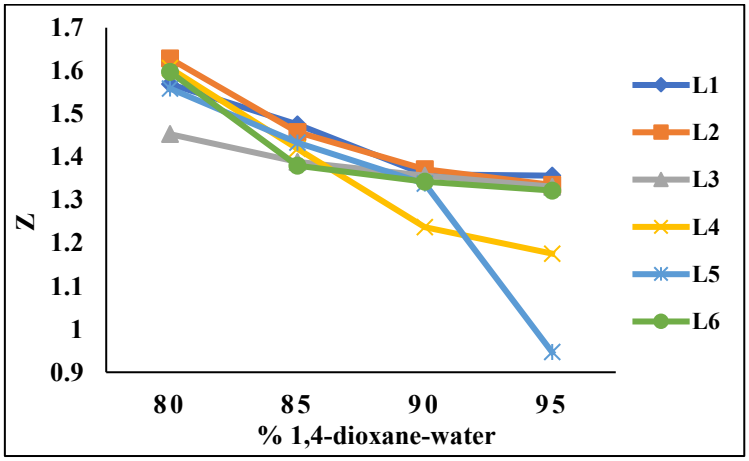


Figure 21: Plot Between % 1,4-Dioxane-Water Vs Specific Acoustic Impedance (Z) At 306 K



4. Conclusion

The study looks at various acoustic characteristics of solutions at various concentrations and temperatures (293K, 298K, and 303K). Significant findings include a decrease in ultrasonic velocity (U) with increase in temperature, increase in adiabatic compressibility (βs) with decreasing concentration and a fall in value with increasing temperature. The apparent molar volumes (ϕ_V) grow as the temperature rises and the concentration drops. It is observed that the molal adiabatic compressibility(ϕ_k) and intermolecular free length (L_f) increase as the concentration and the temperature increases. The relative association (R_A) values increase as the temperature rises and the concentration decreases. Lower concentrations result in a lower specific acoustic impedance (R_A), while higher temperatures cause an increase in the specific acoustic impedance. The findings suggest that intermolecular forces become weaker as temperature increases, which is reflected by higher compressibility and greater free length. Changes in apparent molar volume, acoustic impedance, and relative association with concentration indicate distinct solute–solvent interactions, where dilution favours stronger solute–solvent association, while concentrated solutions show enhanced solute–solute interactions.

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References

1. K. Kannagi, R. Padmavathi, E. Jasmine Vasantha Rani, “Acoustics Thermodynamic and Solvation Study of Protein Salt Solutions using Ultrasonic Technique”, Journal of Basic and Applied Physics, 2012,1(3), 96-101
2. S. V. Tambakhe and P. B. Raghuwanshi, “Conductometric and ultrasonic studies of substituted aryl bisthiourea in binary solution at 300k temperature” Global Journal Of Engineering Science And Researches, 2018, 30-38
3. H. P. Dahikar, S. S. Deo, D. P. Gulwade, S. Halder,“Molecular Interaction Study of β- Benzoyl Propionic Acid in Ethanol at 298K Using Acoustic Parameters” International Journal Of Advance Scientific Research And Engineering Trends, 2018, 3(8), 12-14
4. R. D. Isankar, D. T. Tayade, A. B. Wadekar,“Interferometric investigation of 4-ethylthiocarbamido-phenol in 60% mixed solvent media” International Journal of Engineering Development and Research, 2018, 6(2), 596-598
5. Sunanda S. Aswale, Shashicant R. Aswale, Rajesh S. Hajare, “adiabatic compressibility, intermolecular free length and specific acoustic impedance of antibiotic ampicillin sodium” International Journal Of Pharmaceutical Science, 2013, 5(1), 76-79
6. S. D. Deosarkar, A. D. Arsule, and T. M. Kalyankar, “Effect of antidiabetic metformin hydrochloride on physicochemical properties of cationic surfactant cetyltrimethylammonium bromide in aqueous solutions” Colloids Surf. Physicochem. Eng. Asp., 2021, 613

7. T. M. Bhagat, Kalyani K. Kumbhare, Pradip B. Rathod, "Ultrasonic Study of Molecular Interaction of 2- Substituted 4, 5-Diphenyl Imidazole with Ethanol at Different Temperature" International Journal of Scientific Research in Science and Technology, 2021, 9(4), 25-29
8. K. Rathina, M. Umadevi, C. Senthamil selvi, Ramalatha Marimuthu, "Research on Ion-Solvent Interactions in the Inorganic Liquid Mixtures by Ultrasonic Technique" International Journal of Engineering and Advanced Technology, 2019, 8(6S), 151-159
9. Ashfaq Husain M. Saudagar and Rahimullah S. Shaikh, "Investigations in acoustic parameters of different chloro substituted azetidin-2-one at different concentration and temperature in 90% (EtOH + water) solvent" Global Journal Of Engineering Science And Researches, 2018, 5(12), 272-276
10. Dhirendra Kumar Sharma and Chandra Pal Prajapati, "Excess Adiabatic Compressibility, Molar Volume, Acoustic Impedance and Excess Viscosity in the Binary Liquid Mixtures of 1, 3-Dioxolane with Alkanols (C5-C10) at 298.15k" International Journal of Advanced Research in Chemical Science, 2025, 12(1), 39-49
11. Mrunal M. Mahajan, Pravin B. Raghuwanshi & Mamta Mishra, "Investigation Of Acoustical Parameters Of N-(2'-Hydroxy-3'-Nitrobenzylidene) -3-Substituted Pyridine-2-Amine Schiff Base Derivatives In Dioxane-Water Mixture At 293, 297 And 300 K" Global journal of engineering science and researches, 2019, 6(11), 1-16
12. C. Gopi, N. Santhi, C. Gopi, N. Santhi, "Acoustical studies of some synthesized Schiff base derivatives in dimethylsulphoxide at 303.15 K, by ultrasonic velocity measurement" International Letters of Chemistry, Physics and Astronomy, 2014, 17(1), 50-66
13. Mahajan, M. & Raghuwanshi P., "Acoustical Investigation of N–(2hydroxybenzylidene)-3-Substituted Pyridine -2- Amine Schiff bases by Ultrasonic Velocity Measurements in Dioxane at Different Temperatures" IRA-International Journal of Applied Sciences, 2016, 4(1), 121-132
14. P. P. Choudhari, D. S. Hedaoo and M. P. Wadekar, "Comparative study of interferometric properties of substituted pyridine-2-amine schiff base derivatives in binary mixtures of 1,4-dioxane and ethanol at 293k, 297k and 300 k. Adiabatic compressibility, apparent molal volume, apparent molal compressibility and solvation number of substituted 2-oxo-2-H-chromene-3carbohydrazide derivatives in 70% DMF-Water" Archives of Applied Science Research, 2016, 8(8), 14-20
15. B. J. Gangani and P. H. Parsania, "Density, viscosity and ultrasonic speed of halogenated symmetric double Schiff bases in DMF solutions at 308.15K" Archives of Applied Science Research, 2015, 7(1), 10-14
16. Mrunal M. Mahajan, Pravin B. Raghuwanshi, "camparitive study of interferometric properties of substituted pyridine-2-amine schiff base derivatives in binary mixtures of 1,4-dioxane and ethanol at 293k, 297k and 300 k" Journal of Emerging Technologies and Innovative Research, 2020, 7(11), 451-466