Density, viscosity and ultrasonic speed based acoustical studies of structural properties of 1, 1'-bis (4-amino phenyl) cyclohexane symmetric double Schiff bases in THF solutions at 303.15, 308.15 and 313.15K

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Keywords: Ultrasonic speed, density, viscosity, symmetric double Schiff bases, molecular interactions and solvation number

ABSTRACT The density (ρ), viscosity (η) and ultrasonic speed (U) (2MHz) of THF solutions of symmetric double Schiff bases (SDSB-1, SDSB-2 and SDSB-3) were determined at 303.15, 308.15 and 313.15 K. Various acoustical parameters such as specific acoustical impedance (Z), isentropic compressibility (κ_s), Rao's molar sound function (R_m), Van der Waals constant (b), internal pressure (π), free volume (V_f), intermolecular free path length (L_f), viscous relaxation time (τ) and classical absorption coefficient ($(\alpha/f^2)_{Cl}$), were determined using ρ , η and U data. The results are interpreted in terms of molecular interactions occurring in the solutions at different temperatures and concentrations. Linear increase of ρ , η , U , Z , R_m , b , $(\alpha/f^2)_{Cl}$ and τ with increasing C , linear decrease of κ_s , L_f and π with increasing T , V_f increased linearly with C and T except SDSB-3 supported existence of strong molecular interactions in the solutions and confirming solvophilic nature of the Schiff bases. The structure, nature and size of the solutes and solvent, concentration and temperature affected molecular interactions.

1. INTRODUCTION

Symmetric double Schiff bases or imines or azomethines have played vital role in the progress of chemical sciences [1]. Symmetric double Schiff bases or bis Schiff bases are synthesized by acid catalyzed condensation of aromatic or aliphatic primary diamines with aromatic aldehydes by conventional and microwave irradiation methods [2-4]. Schiff bases are well known due to their wide range of applications such as a corrosion inhibitors [5], analytical reagents, catalyst, catalysis, for synthesis of metal complexes and additives in synthetic lubricant [6]. Schiff bases are most widely used as pigments, dyes, polymer stabilizers and intermediate in organic synthesis [7]. Schiff bases and their metal complexes have attracted a lot of interest due to their potent biological activities such as antifungal, antibacterial, antimicrobial [8], antitumor, anticancer [9], anti-inflammatory, antiphlogistic, anti-HIV activities and antidepressant [10].

Ultrasonic technique is one of the most useful techniques to study the molecular interactions in the solution; so many scientists have observed close relation between ultrasonic velocity and chemical or structural characteristic of molecule of fluid [11-13]. The ultrasonic velocity and viscosity measurements have proved important for studying molecular and structural properties of liquid solution [14]. Therefore by measuring density of liquid and its ultrasonic velocity many acoustical parameters can be determined [15]. Acoustical parameters provide information about molecular interactions, the nature and strength of interactions, solute-solute and solute-solvent interactions in pure solvents and their solutions [16-17]. Drug action is affected by various kinds of physico-chemical interactions e.g. ionic or covalent, charge-transfer, hydrogen bonding, ionic-dipole interaction, hydrophilic interaction [18], which can be understood by thermo physical and transport properties [19] e.g. ultrasonic velocity, viscosity and thermal conductivity. The uses of

drugs involved physiological and biological effect and their mechanism of action at macromolecular, sub cellular organ system. Various pharmacokinetics processes involves transport of drugs across biological membrane, which can be understood by transport property e.g. ultrasonic speed, viscosity diffusion and thermal conductivity [20, 21].

In continuation of ultrasonic study of symmetric double Schiff bases [22, 23] in this paper we have reported determination of density, viscosity and ultrasonic speed of the solution of symmetric double Schiff bases of 1,1'-bis (4-amino phenyl)cyclohexane (Scheme-I) in THF at 303.15, 308.15 and 313.15 K and at different concentrations. Various acoustical parameters have been determined and discussed to understand molecular interactions in the solutions.

2. EXPERIMENTAL AND MEASUREMENTS

THF used in the present study was supplied by Allied Chemical Corporation Vadodara, and purified according to literature method [24]. THF is cyclic ether have IUPAC name oxolane, $\rho = 0.8892 \text{ g/cm}^3$ at 298.15K, molecular shape- envelope, dipole moment 1.63D with low viscosity. Schiff bases SDSB-1, SDSB-2 and SDSB-3 (Scheme-I) were synthesized and crystallized according to our previous work [3]. The stock Schiff bases solutions (0.10 mol) were prepared and from them a series of solutions were prepared. The solutions were stored in air tight flasks.

The density (ρ) measurements were performed for different solutions at 303.15, 308.15 and 313.15K ± 0.1 K with the help of specific gravity bottle. The estimated errors in density measurements were found to be $\pm 0.1 \text{ kg/m}^3$ as reported in our earlier work [15, 16]. Viscosity (η) and ultrasonic speed (U) of Schiff bases solutions (SDSB-1 to 3) were measured with an Ubbelohde suspended level viscometer and Mittal Enterprise Interferometer (New Delhi) Model No F-81, operating at 2 MHz at 303.15, 308.15 and 313.15K ± 0.1 K respectively. The η and U measurements were accurate to 0.01 m Pa s and $\pm 0.15\%$, respectively as described in our earlier paper [22, 23]. Various thermodynamic parameters have been evaluated from the experimental values of ρ , η and U data.

3. RESULTS AND DISCUSSION

The ρ , η and U of THF and SDSB-1 to SDSB-3 solutions are reported in Table 1. Acoustical properties are of great signification in studying the physico-chemical behavior and molecular interactions of component of solutions. The molecular interactions exist in Schiff bases solutions in THF are discussed in terms of acoustical parameters. Various acoustical parameters such as specific acoustical impedance (Z), isentropic compressibility (κ_s), Rao's molar sound function (R_m), Vander Waals constant (b), intermolecular free path length (L_f), internal pressure (π), free volume (V_f),

viscous relaxation time (τ), classical absorption coefficient $(\alpha/\Gamma^2)_{Cl}$ and solvation number (S_n) of Schiff bases solutions were derived according to our previous work [15, 22] and are reported in Table 2. All these parameters were correlated with concentration(C) of Schiff bases at different temperatures (T).

Table-1 The density (ρ), viscosity (η) and sound velocity (U) of SDSB-1, SDSB-2 and SDSB-3 at 303.15, 308.15 and 313.15K

Conc., mol/ dm ³	Density ρ, kg / m ³	Viscosity η, 10 ³ ,Pa s	U, ms ⁻¹	Density ρ, kg / m ³	Viscosity η, 10 ³ ,Pa s	U, ms ⁻¹	Density ρ, kg / m ³	Viscosity η, 10 ³ ,Pa s	U, ms ⁻¹
THF-SDSB-1 at 303.15K				THF-SDSB-2 at 303.15K			THF-SDSB-3 at 303.15K		
0	882.3	0.470	1263.8	882.3	0.467	1263.8	882.3	0.470	1263.8
0.01	888.9	0.543	1277.2	886.3	0.504	1265.0	886.5	0.476	1265.8
0.02	892.1	0.566	1283.2	888.9	0.534	1275.2	889.5	0.482	1269.0
0.04	895.4	0.604	1289.4	892.7	0.562	1280.2	893.1	0.517	1272.2
0.06	898.6	0.631	1296.6	895.9	0.579	1287.0	896.0	0.549	1276.6
0.08	900.7	0.670	1303.4	898.0	0.604	1293.0	898.3	0.589	1281.4
0.10	902.7	0.694	1309.6	900.7	0.631	1299.0	900.5	0.626	1285.4
THF-SDSB-1 at 308.15K				THF-SDSB-2 at 308.15K			THF-SDSB-3 at 308.15K		
0	881.8	0.446	1233.6	881.8	0.446	1233.6	881.8	0.446	1233.6
0.01	887.9	0.478	1249.4	885.4	0.464	1243.4	884.8	0.451	1255.4
0.02	891.2	0.492	1255.6	888.0	0.487	1249.2	887.7	0.464	1259.0
0.04	894.4	0.541	1263.4	891.5	0.506	1257.0	891.6	0.487	1263.6
0.06	897.5	0.579	1268.8	893.9	0.524	1262.8	893.7	0.533	1267.2
0.08	899.5	0.625	1275.4	896.1	0.559	1269.2	896.9	0.572	1272.4
0.10	902.1	0.657	1280.8	897.9	0.595	1275.2	898.1	0.593	1279.2
THF-SDSB-1 at 313.15K				THF-SDSB-2 at 313.15K			THF-SDSB-3 at 313.15K		
0	881.2	0.429	1216.8	881.2	0.429	1216.8	881.2	0.429	1216.8
0.01	882.9	0.431	1235.4	884.6	0.453	1220.4	883.9	0.437	1233.4
0.02	886.3	0.460	1241.8	887.2	0.467	1229.2	886.0	0.456	1235.0
0.04	889.9	0.503	1247.0	890.1	0.487	1235.2	888.3	0.475	1239.6
0.06	892.3	0.541	1256.0	892.7	0.507	1240.6	891.5	0.498	1245.2
0.08	895.0	0.580	1261.2	895.1	0.531	1247.2	893.8	0.557	1251.4
0.10	897.3	0.615	1265.0	896.5	0.562	1253.0	896.6	0.574	1256.6

From Table 1, it is evident the ρ , η and U increased with C and decreased with T suggested powerful solute-solvent interactions. The increase of ρ led to quick transfer of sound velocity and hence U increased with increasing C. The law of additivity is observed in present case confirming that the density of Schiff bases is greater than that of THF. The viscosity (η) of the solvent and solutions are measure of cohesiveness or rigidity present between components of the solutions. The variation of η and U with C and T are considerably more than ρ due to specific solute and solvent interactions. The nature of solute and solvent play an important role in molecular interactions such as ionic-covalent, inter-intra molecular H-bonding, dipole-dipole interaction, weak van der waals force of attraction as well as London forces. The η increased linearly with increasing C confirmed existence of strong molecular interactions in the solution [25]. The decrease of η with increasing in temperature showing that solute-solvent interaction is influenced by the temperature. Thus Schiff bases molecule can labeled as structure makers in THF solutions.

From Table 2 to 5, it is observed that in THF, Z ($\gamma = 0.989$ to 0.999) increased linearly with C and decreased with T , while κ_s ($\gamma = -0.986$ to -0.999) and L_f ($\gamma = -0.987$ to -0.998) decreased linearly with increasing C and increased with T . The increasing trend of Z supported the molecular interactions. Z is directly proportional to U and inversely proportional to κ_s . The predominance of particular solute-solute or solute-solvent interaction can be detected by κ_s . The decrease in κ_s with increase in C is due to aggregation of solvent molecules around solute molecules indicating presences of solute-solvent interaction. This phenomenon can be explained by assuming that the solvated molecules are fully compressed by the electric force of the ions. The κ_s of solution is mainly due to free solvent molecules but due to solute-solvent interaction κ_s of solution decrease with increase in concentration. The decrease of L_f with C increase in sound velocity and vice versa supported strong solute-solvent interactions. The linear change in R_m ($\gamma = 0.993$ to 1.000) and b ($\gamma = 0.999$ to 1.000) suggested the absence of any complex formation in THF system. V_f ($\gamma = -0.846$ to 0.993) increased linearly with increasing in C and T except SDSB-3. The internal pressure (π) is the result of forces of attraction and repulsion between molecules in solutions. From Table 2 to 5 π ($\gamma = -0.983$ to -0.998) decreased linearly with increasing C and decreased with T . The decrease in π indicates the loosening of cohesive forces leading breaking of structure formed and indicated existence of solute-solute interaction in THF solution at higher concentration and temperature. This is further supported by a free volume (V_f). Free volume of solute molecule at constant temperature and pressure depend on the internal pressure of liquid in which it is dissolved. The decrease in π caused increase in V_f which is an inverse function of π .

From Table 2 to 5 $(\alpha/f^2)_{cl}$ ($\gamma = 0.979$ to 0.997) and τ ($\gamma = 0.985$ to 0.998) increased linearly with C and decreased with T . $(\alpha/f^2)_{cl}$ and τ are dependent on ρ , η and U at constant temperature. Increase of $(\alpha/f^2)_{cl}$ and τ with C can be explained in terms of motion of intermolecular forces. A contribution of acoustical relaxation is accounted due to entropy fluctuation associated in solution of dynamically formed physical entity. The presences of polar groups in the solute molecule enhance molecular interactions. Thus, various acoustical parameters suggested solute-solute and solute-solvent interaction in THF solutions. Solvation number (S_n) [26] the number of grams of solvent molecules connected in the apparent solvation of 1 g of solute-assuming the solvent molecules participating in the solvation are effectively incompressible due to strong localized electronic fields is expressed as:

$$S_n = \frac{M_2}{M_1 \left(1 - \frac{\kappa_s}{\kappa_{s_1}} \right) \left(\frac{100 - X}{X} \right)} \quad (1)$$

Where X is the number of grams of solute in 100g of the solution

Table-2 Acoustical parameters of SDSB-1, SDSB-2 and SDSB-3 in THF solutions at 303.15, 308.15 and 313.15 K

Conc., mol/ lit	303.15K	308.15K	313.15K	303.15K	308.15K	313.15K	303.15K	308.15K	313.15K
	SDSB-1			SDSB-2			SDSB-3		
	$Z \times 10^{-6}, \text{kg.m}^{-2} \text{s}^{-1}$			$Z \times 10^{-6}, \text{kg.m}^{-2} \text{s}^{-1\text{S}}$			$Z \times 10^{-6}, \text{kg.m}^{-2} \text{s}^{-1\text{S}}$		
0.0	1.115	1.088	1.072	1.115	1.088	1.072	1.115	1.088	1.072
0.01	1.135	1.109	1.091	1.121	1.101	1.080	1.122	1.111	1.090
0.02	1.145	1.119	1.101	1.134	1.109	1.091	1.129	1.118	1.094
0.04	1.155	1.130	1.110	1.143	1.121	1.099	1.136	1.127	1.101
0.06	1.165	1.139	1.121	1.153	1.129	1.107	1.144	1.132	1.110
0.08	1.174	1.147	1.129	1.161	1.137	1.116	1.151	1.141	1.119
0.10	1.182	1.155	1.135	1.170	1.145	1.123	1.158	1.149	1.127
	$\kappa_S \times 10^{+10}, \text{Pa}^{-1}$			$\kappa_S \times 10^{+10}, \text{Pa}^{-1}$			$\kappa_S \times 10^{+10}, \text{Pa}^{-1}$		
0.0	7.096	7.452	7.665	7.096	7.452	7.665	7.096	7.452	7.665
0.01	6.987	7.215	7.422	7.051	7.305	7.590	7.040	7.171	7.437
0.02	6.808	7.117	7.317	6.918	7.216	7.460	6.981	7.107	7.400
0.04	6.717	7.055	7.227.	6.835	7.099	7.364	6.918	7.024	7.326
0.06	6.619	6.921	7.104	6.739	7.015	7.278	6.848	6.968	7.235
0.08	6.535	6.835	7.025	6.661	6.928	7.182	6.780	6.887	7.144
0.10	6.459	6.757	6.964	6.580	6.849	7.105	6.721	6.805	7.063
	$R_m \times 10^4, \text{m}^{10/3} \text{s}^{1/3} \text{mol}^{-1}$			$R_m \times 10^4, \text{m}^{10/3} \text{s}^{1/3} \text{mol}^{-1}$			$R_m \times 10^4, \text{m}^{10/3} \text{s}^{1/3} \text{mol}^{-1}$		
0.0	8.834	8.768	8.734	8.834	8.768	8.734	8.834	8.768	8.734
0.01	9.096	9.040	9.059	9.134	9.091	9.043	9.134	9.127	9.083
0.02	9.371	9.313	9.333	9.466	9.412	9.370	9.444	9.440	9.399
0.04	9.935	9.880	9.893	10.102	10.056	10.015	10.076	10.072	10.050
0.06	10.497	10.436	10.471	10.742	10.703	10.656	10.712	10.718	10.687
0.08	11.067	11.005	11.031	11.390	11.349	11.299	11.351	11.346	11.332
0.10	11.634	11.558	11.581	12.023	11.997	11.951	11.984	12.006	11.960
	$b \times 10^5, \text{m}^3$			$b \times 10^5, \text{m}^3$			$b \times 10^5, \text{m}^3$		
0.0	8.041	8.044	8.048	8.039	8.042	8.047	8.039	8.042	8.047
0.01	8.252	8.260	8.307	8.311	8.318	8.325	8.309	8.325	8.332
0.02	8.490	8.497	8.546	8.592	8.601	8.607	8.586	8.604	8.620
0.04	8.989	8.999	9.048	9.161	9.173	9.188	9.156	9.172	9.209
0.06	9.483	9.495	9.558	9.728	9.752	9.765	9.725	9.754	9.780
0.08	9.985	9.999	10.058	10.302	10.328	10.340	10.297	10.312	10.358
0.10	10.480	10.489	10.558	10.862	10.903	10.920	10.864	10.900	10.921
	$L_f \times 10^{11}, \text{m}$			$L_f \times 10^{11}, \text{m}$			$L_f \times 10^{11}, \text{m}$		
0.0	5.58	5.72	5.80	5.58	5.72	5.80	5.58	5.72	5.80
0.01	5.50	5.62	5.70	5.56	5.66	5.77	5.56	5.61	5.71

0.02	5.46	5.59	5.66	5.51	5.62	5.72	5.53	5.58	5.70
0.04	5.43	5.54	5.63	5.47	5.58	5.68	5.51	5.55	5.67
0.06	5.39	5.51	5.58	5.44	5.55	5.65	5.48	5.53	5.63
0.08	5.35	5.47	5.55	5.40	5.51	5.61	5.45	5.49	5.60
0.10	5.32	5.44	5.53	5.37	5.48	5.58	5.43	5.46	5.56
	$\pi \times 10^{-8}$, Pa			$\pi \times 10^{-8}$, Pa			$\pi \times 10^{-8}$, Pa		
0.0	3.972	3.917	3.865	4.103	4.046	3.992	4.103	4.046	3.992
0.01	4.106	3.894	3.701	4.078	3.942	3.930	3.963	3.868	3.839
0.020	4.040	3.805	3.685	4.017	3.870	3.8218	3.825	3.762	3.760
0.04	3.889	3.716	3.592	3.808	3.643	3.601	3.665	3.565	3.543
0.06	3.719	3.599	3.477	3.592	3.442	3.414	3.511	3.463	3.371
0.08	3.597	3.508	3.382	3.420	3.315	3.255	3.392	3.350	3.323
0.10	3.448	3.390	3.284	3.274	3.199	3.131	3.279	3.188	3.162
	$V_f \times 10^7$, m ³			$V_f \times 10^7$, m ³			$V_f \times 10^7$, m ³		
0.01	2.625	3.070	3.533	2.909	3.214	3.239	3.173	3.397	3.469
0.02	2.604	3.109	3.383	2.849	3.179	3.297	3.305	3.458	3.449
0.04	2.606	2.980	3.260	2.944	3.352	3.458	3.315	3.519	3.614
0.06	2.679	2.948	3.224	3.114	3.521	3.595	3.336	3.454	3.724
0.08	2.672	2.873	3.165	3.220	3.515	3.705	3.302	3.415	3.467
0.10	2.753	2.892	3.140	3.303	3.512	3.730	3.286	3.550	3.623
	$\tau \times 10^{13}$, s			$\tau \times 10^{13}$, s			$\tau \times 10^{13}$, s		
0.0	4.444	4.435	4.383	4.444	4.435	4.383	4.444	4.436	4.383
0.01	4.989	4.599	4.261	4.738	4.516	4.581	4.468	4.313	4.334
0.02	5.136	4.668	4.488	4.927	4.680	4.646	4.481	4.392	4.494
0.04	5.407	5.053	4.486	5.117	4.787	4.779	4.764	4.557	4.635
0.06	5.567	5.345	5.121	5.204	4.901	4.927	5.011	4.947	4.803
0.08	5.839	5.695	5.431	5.363	5.167	5.084	5.320	5.249	5.035
0.10	5.979	5.920	5.713	5.532	5.431	5.320	5.612	5.374	5.408
	$(\alpha/f^2)_{cl} 10^{14}$, s ² m ⁻¹			$(\alpha/f^2)_{cl} 10^{14}$, s ² m ⁻¹			$(\alpha/f^2)_{cl} 10^{14}$, s ² m ⁻¹		
0.01	7.703	7.251	6.801	7.386	7.161	7.403	6.961	6.775	6.929
0.02	7.892	7.331	7.126	7.618	7.388	7.453	6.963	6.879	7.176
0.04	8.269	7.886	7.667	7.882	7.509	7.630	7.385	7.112	7.373
0.06	8.466	8.307	8.039	7.974	7.652	7.831	7.741	7.698	7.606
0.08	8.834	8.804	8.492	8.179	8.028	8.038	8.187	8.134	8.359
0.10	9.002	9.115	8.905	8.398	8.398	8.372	8.609	8.284	8.486
	Sn			Sn			Sn		

0.01	1.40	1.24	1.25	6.96	2.26	4.60	5.65	1.18	1.50
0.02	1.95	1.77	1.76	3.56	2.83	3.35	5.51	1.93	2.60
0.04	3.93	3.56	3.54	7.18	5.70	6.77	11.1	3.89	5.25
0.06	4.52	4.03	4.25	7.40	5.77	6.97	10.9	4.76	6.21
0.08	4.84	4.57	4.47	7.29	6.27	7.31	10.5	5.66	6.57
0.10	5.19	4.95	4.94	7.55	6.60	7.40	10.4	6.12	6.86

Solvation number (S_n) is used to decide the predominance of particular interaction in solution. At constant temperature the concentration of solute and dielectric constant of the solvent play an important role in determining the molecular interactions occurring in the solutions. Solvation number (S_n) is the number of the solvent molecules attached to the central atoms or ions by their translational degree of freedom. Thus strength of solute-solvent interaction is reflected by solvation number (S_n).

The presence of polar groups in the solute molecule enhances molecular interactions and the solvation phenomena. The plots of S_n against C at different T are presented in Fig. 1 to 3 from which it is observed that S_n increased nonlinearly with C . The positive value of S_n with C indicated appreciable solvation of SDSB-1 to 3 in THF. This confirmed the structure forming nature of the solutes in the solvent due to association between various components of solution. The nature of solute, concentration, temperature and position of functional group play an important role on the magnitude of solvation. R_m increased linearly with C and slightly decreased with T . π decreased linearly with increasing C and decreased with T , while V_f increased linearly with increasing C and T supporting effect of C and T on cohesive forces and hence molecular interactions.

Table-3 The least squares equations and correlation coefficients for SDSB-1 + THF

Parameter	Correlation equations (Correlation coefficients, γ)		
	303.15K	308.15K	313.15K
ρ , kg.m ⁻³	148.77C+888.71 (0.985)	150.36C+887.66 (0.988)	152.52C+ 882.74 (0.987)
η , mPa s	1.6811C+ 0.531 (0.997)	2.0519 C+0.456 (0.998)	1.8807C+0.4194 (0.985)
U , ms ⁻¹	351.4 C+1275.1 (0.997)	338.03C+1248.1 (0.993)	328C+1234.1 (0.989)
$Z \times 10^{-6}$, kg.m ⁻² s ⁻¹	0.5058C+1.1332 (0.993)	0.4912C+1.1078 (0.990)	0.4792C+1.0897 (0.989)
$\kappa_s \times 10^{10}$, Pa ⁻¹	-4.740 C+6.918 (- 0.995)	-4.891C+7.228 (- 0.991)	-5.006C+7.435 (- 0.988)
$R_m \times 10^4$, m ^{10/3} s ^{1/3} mol ⁻¹	27.006C+10.759 (1)	26.824C +10.696 (1)	26.945C+10.716 (1)
$b \times 10^5$, m ³	23.606C+9.7778 (0.999)	23.721 C+9.802 (0.999)	23.845C+9.8413 (0.999)
$L_f \times 10^{11}$, m	-1.937C+5.5084 (- 0.994)	-1.9699 C +5.6301 (-0.994)	-1.8712C+5.705 (- 0.987)
$\pi \times 10^{-8}$, Pa	-4.2011C+3.3207 (- 0.984)	-2.5753 C +3.1247 (-0.993)	-2.18 C+2.9978 (- 0.983)
$V_f \times 10^7$, m ³	-2.4293C +3.5203 (- 0.907)	-6.3082C+4.1744 (- 0.974)	-8.4915C+4.6824 (-0.962)
$\tau \times 10^{13}$, s	11.05C +4.9153 (0.997)	15.392 C+4.4181 (0.997)	15.855 C+ 4.158 (0.998)
$(\alpha/f^2)_{cl} \times 10^{14}$, s ² m ⁻¹	14.564C+7.6085 (0.994)	21.801C+6.9906 (0.997)	22.936C+6.6533 (0.997)

Table-4 The least squares equations and correlation coefficients for SDSB-2 + THF

Parameter	Correlation equations (Correlation coefficients, γ)		
	303.15K	308.15K	313.15K
ρ , kg.m ⁻³	142.55C+886.72 (0.996)	135.56 C+885.13 (0.986)	130.47 C+884.29 (0.988)
η , mPa s	1.3101C+0.5013 (0.989)	1.3704C+ 0.4515 (0.992)	1.1403 C+0.4434 (0.997)
U , ms ⁻¹	348.44C+1265.2 (0.983)	343.12C+1241.7 (0.995)	337.32 C+1220.2 (0.987)
$Z \times 10^{-6}$, kg.m ⁻² s ⁻¹	0.489C+ 1.1222 (0.994)	0.4756C+1.0991 (0.992)	0.4526 C+1.0793 (0.989)
$\kappa_S \times 10^{+10}$, Pa ⁻¹	-4.7699C+7.0411 (-0.988)	-4.9178 C+7.3228 (-0.992)	-5.0792C+7.5913 (-0.986)
$R_m \times 10^4$, m ^{10/3} s ^{1/3} mol ⁻¹	32.223 C+8.8078 (0.999)	32.292C +8.7662 (1)	32.255C+8.7225 (0.999)
$b \times 10^5$, m ³	28.527 C+ 8.0155 (1)	28.673C+ 8.0232 (1)	28.872C+8.0328 (1)
$L_f \times 10^{11}$,m	-1.9178 C+5.556 (-0.992)	-1.9178C+5.6658 (-0.992)	-1.9863 C+5.771 (-0.995)
$\pi \times 10^{-8}$, Pa	-9.331C + 4.1814 (- 0.998)	-8.5679C+4.0118 (- 0.992)	-9.000C+3.990 (- 0.995)
$V_f \times 10^7$,m ³	5.92C+2.7308 (0.993)	3.145C+3.2258 (0.972)	5.265C +3.2351 (0.957)
$\tau \times 10^{13}$, s	8.2156 C+4.721 (0.985)	9.4545 C+4.425 (0.985)	7.9701 C+ 4.4777 (0.994)
$(\alpha/f^2)_{cl} \cdot 10^{14}$, s ² m ⁻¹	1.0499C+ 0.7361 (0.984)	1.2707C+6.7033 (0.979)	1.0575C+0.724 (0.990)

Table-5 The least squares equations and correlation coefficients for SDSB-3 + THF

Parameter	Correlation equations (Correlation coefficients, γ)		
	303.15K	308.15K	313.15K
ρ , kg.m ⁻³	150.93C+886.19 (0.988)	146.08 C+884.59 (0.982)	138.05 C+882.88 (0.999)
η , mPa s	1.7148C+ 0.4512 (0.997)	1.6751C+0.4295 (0.994)	1.5592C+ 0. 4189 (0.985)
U , ms ⁻¹	214.25C+ 1264 (0.998)	249.97C+ 1253.2 (0.995)	265.7 C+1229.8 (0.997)
$Z \times 10^{-6}$, S.kg.m ⁻² s ⁻¹	0.3879C+1.12 (0.997)	0. 4033C+1.1088 (0.995)	0.4145 C+1.0854 (0.999)
$\kappa_S \times 10^{+10}$, Pa ⁻¹	-3.4674C+7.0605 (-0.997)	-3.8934 C+7.1948 (- 0.997)	-4.2247C+7.4853 (- 0.999)
$R_m \times 10^4$, m ^{10/3} s ^{1/3} mol ⁻¹	31.711 C+8.8118 (1)	31.947C + 8.801 (0.999)	32.039C+8.7633 (1)
$b \times 10^5$, m ³	28.434C+8.0206 (1)	28.612 C+8.034 (1)	28.803C+ 8.0488 (1)
$L_f \times 10^{11}$, m	-1.4027 C+5.566 (- 0.993)	-1.589C+5.619 (- 0.994)	-1.6849C+5.7321 (-0.998)
$\pi \times 10^{-8}$, Pa	-7.4233C + 3.9894 (- 0.992)	-7.2373 C+3.9066 (-0.993)	-7.4444 C+3.8843 (-0.986)
$V_f \times 10^7$, m ³	-45.485C ² +5.7171C + 3.1585 (-0.846)	-52.841C ² +7.5415C +3.2313 (-0.958)	-74.325C ² +10.492C +3.3268 (- 0.933)
$\tau \times 10^{13}$, s	13.166 C +4.262 (0.995)	12.779 C+4.145 (0.989)	12.272C+4.195 (0.979)
$(\alpha/f^2)_{cl} \cdot 10^{14}$, s ² m ⁻¹	19.049C+6.6568 (0.994)	18.397C+6.53 (0.987)	18.05C+6.7133 (0.979)S

Figure 1 The plots of S_n against C for SDSB-1 in THF at 303.15, 308.15 and 313.15 K

Figure 2 The plots of S_n against C for SDSB-2 in THF at 303.15, 308.15 and 313.15 K

Figure 3 The plots of S_n against C for SDSB-3 in THF at 303.15, 308.15 and 313.15 K

4. CONCLUSION

Studied acoustical parameters supported existences of strong molecular interactions in THF-Schiff bases solution at different temperatures. The non linear increase of S_n with C suggested competing solvent-solute and solute-solute interaction in the solutions. At higher concentration and low temperature solute-solvent interactions are predominant over solute-solute interactions. The strength of solute-solvent interaction is given in order SDSB-3 > SDSB-2 > SDSB-1. The strength of interaction is affected by concentration, temperature, nature and position of functional group.

ACKNOWLEDGEMENTS

The authors are thankful to Department of Chemistry, Saurashtra University, Rajkot, for instrumentation and research facilities.

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