

Research Article

An Ultrasonic Exploration of Physico-chemical Properties for Mixtures of Cyclic Diether (1,3-dioxolane) with 1-alkanols (C₅-C₁₀) at 298.15K

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Abstract

The present study is oriented towards the demonstration of physico-chemical properties (PCP) and molecular interactions (MI) of the prepared binary mixture of 1,3-dioxolane with 1-alkanols at 298.15K through ultrasonic non-destructive characterization. In the present paper speed of sound (u), viscosities (η) and densities (ρ) have been experimental measured for the binary liquid mixtures (BLM) of cyclic diether with 1-alkanols at 298.15K by using ultrasonic interferometer technique. From the experimental values of speed of sound (u), viscosities (η) and densities (ρ) have been used for study of the molecular interaction in the different liquid mixtures using the excess values of parameters such as excess surface tension (S^E), excess available volume (V_a^E), excess relaxation strength (r^E), excess enthalpy (H^E) and excess free volume (V_f^E) variation in the above parameters for the different liquid mixtures is indicative of the nature of molecular interaction between them. For all studied systems, excess surface tension (S^E), excess available volume (V_a^E), excess relaxation strength (r^E), excess enthalpy (H^E) and excess free volume (V_f^E) were negative over the entire mole fraction range of 1,3-dioxolane at measured temperatures. Among the six systems, 1,3-dioxolane with 1-alkanols containing system showed more negative. By using the obtained results, intermolecular interactions were discussed between 1,3-dioxolane and 1-alkanols. The obtained results are interpreted in term of intermolecular interaction in binary liquid mixtures.

Keywords

Density, Viscosity, Surface Tension, Available Volume, Binary Mixture

1. Introduction

The ultrasonic studies of a binary liquid mixture are very useful for practical and theoretical points of view to understand in many liquid theories. For these reasons future applications of ultrasound in chemical reactions will be in diverse [1]. In the synthesis of pharmaceuticals, ultrasound will improve chemical yields over conventional methods. The data

of the properties associated with the liquids and liquid mixtures like speed of sound (u), viscosities (η) and densities (ρ) find extensive application in solution theory and molecular dynamics [2]. The present paper is a part of our ongoing research program in the measurement of thermodynamic and transport properties of liquid and liquid mixtures at 298.15K.

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The liquids were chosen in the present study on the basis of their industrial applications [3-7]. Alkanols are used as hydraulic fluids in pharmaceutical and cosmetics, in medications for animals, in manufacturing of perfumes, paint removers, flavors and dyestuffs, as defrosting and as an anesthetic agent. The experimental results have been used to discuss the nature of interaction between unlike molecules in terms of hydrogen bonding [8]. The nature and relative strength of the molecular interaction between the components of the liquid mixtures have been successfully investigated by the ultrasonic methods. Thermodynamic and transport properties of binary liquid mixtures with different organic liquids have been studied by many workers.

Thermodynamic studies of binary liquid mixtures have attracted much attention of scientists. These excess values of surface tension (S^E), available volume (V_a^E), relaxation strength (r^E), enthalpy (H^E) and free volume (V_f^E) in binary liquid mixture are useful in understanding the solute-solvent interactions (SSI) [9, 10]. In recent years ultrasonic study of liquid and liquid mixtures has gained much importance during the last four decades in assessing the nature of molecular interaction and investigating the physiochemical behavior of system. In the present paper we have report the results of study on binary liquid mixture of 1,3-dioxolane (Cyclic di-ether) (CDT) over the entire range of composition at 298.15K. By using the experimental data of sound velocity (u), viscosity (η) and density (ρ), various acoustical parameters like excess surface tension (S^E), excess available volume (V_a^E), excess relaxation strength (r^E), excess Enthalpy (H^E) and excess Free Volume (V_f^E) have been calculated the mixture. The binary liquid mixtures studied in this paper are

as follows:

- (1) 1,3-dioxolane- pentanol
- (2) 1,3-dioxolane- hexanol
- (3) 1,3-dioxolane- heptanol
- (4) 1,3-dioxolane- octanol
- (5) 1,3-dioxolane- nonanol
- (6) 1,3-dioxolane- decanol

2. Materials and Methods

2.1. Materials

The chemicals used were of analytical grade and 1,3-dioxolane, pentanol, hexanol, heptanol, octanol, nonanol, decanol purchased from CDH New Delhi, India. 1,3-dioxolane (CDH New Delhi, India) was supplied with purity $\geq 99.7\%$, pentanol (CDH New Delhi, India) with $\geq 99.7\%$, hexanol (CDH New Delhi India,) with $\geq 99.5\%$, heptanol (CDH New Delhi, India) with $\geq 99\%$, octanol (CDH New Delhi India,) with $\geq 99.7\%$, nonanol (CDH New Delhi, India) with $\geq 99\%$, decanol (CDH New Delhi, India) with $\geq 99\%$, respectively. All the liquids were used after double distillation [11]. All chemicals was purified by the method described by Zhao et al. [12] 1,3-dioxolane was dried over K_2CO_3 , filtered and distilled were discarded. The measured density, viscosity and sound velocity of the pure component at 298.15K with the available literature [13-24] as shown in Table 1. The reported experimental values of density (ρ), sound velocity (u) and viscosity (η) conform closely to their corresponding literature values.

Table 1. Density (ρ), sound velocity (u) and viscosity (η) of pure Components at $T = 298.15K$.

Compound	ρ (g. cm ⁻³)		u (m. s ⁻¹)		η (mPa s)	
	Observed	Literature	Observed	Literature	Observed	Literature
1,3-Dioxolane	1.0616	1.0577 ¹⁷ 1.0586 ¹⁷	1340	1338 ¹⁷ 1338 ¹⁸	0.5885	0.5878 ¹⁷ 0.5873 ¹⁷
Pentanol	0.8124	0.8108 ¹³ 0.8107 ¹³	1198	1197 ¹⁶ 1268 ²²	3.3978	3.5411 ¹³ 3.5424 ¹³
Hexanol	0.8176	0.8187 ¹³ 0.8152 ¹⁵	1306	1304 ¹⁵ 1303 ¹⁵	4.6091	4.5924 ²³ 4.5932 ²⁰
Heptanol	0.8196	0.8187 ¹³ 0.8197 ¹⁹	1325	1327 ¹⁵ 1327 ²⁴	5.9066	5.9443 ¹³ 5.9443 ²⁴
Octanol	0.8236	0.8216 ¹³ 0.8218 ¹³	1350	1348 ¹⁴ 1347 ²²	7.1508	7.6605 ¹³ 7.5981 ¹³
Nonanol	0.8248	0.8244 ¹⁵ 0.8242 ¹⁵	1366	1365 ¹⁵ 1364 ²⁴	8.9258	9.0230 ²¹ 9.0200 ²⁴

Compound	ρ (g. cm ⁻³)		u (m. s ⁻¹)		η (mPa s)	
	Observed	Literature	Observed	Literature	Observed	Literature
Decanol	0.8292	0.8267 ¹⁵	1378	1380 ¹⁵	11.8027	11.825 ¹⁵
		0.8264 ¹⁹		1379 ²⁴		11.829 ¹⁵

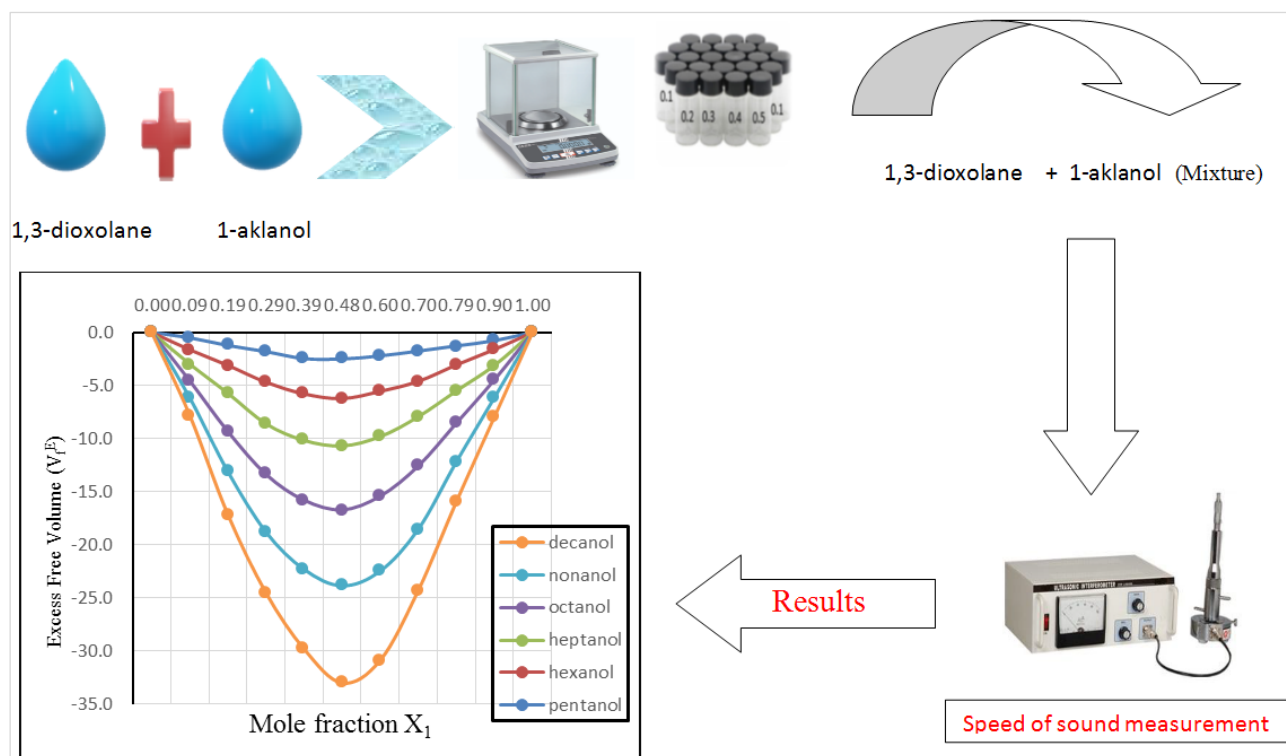
2.2. Methods

All the binary liquid mixtures were prepared by weighing appropriate amount of pure liquids on an electronic balance (Citizen Scale (I) PVT. LTD. Mumbai, India.), with a precision ± 0.1 . The experimental uncertainty in mole fractions did not exceed ± 0.0005 . All the solutions were prepared by mass ratios and stored in the air-tight stopper measuring flasks. Four-Five samples were prepared for same day and their speed of sound, viscosity and density, were measured on the same day. The density was determined at the experimental temperature using a 25ml capacity specific gravity bottle immersed in the thermostatic bath. The volume of the bottle at the experimental temperature viz 298.15K was ascertained using distilled water. Sound velocity determined by the Multi-frequency interferometer (Model F-80D, Mittal Enterprise, New Delhi, India) at 3 MHz and 298.15K, A fixed frequency generator working at 3 MHz. its resonant frequency, the crystal undergoes rapid mechanical oscillations, generating

ultrasonic waves. These waves can propagate through the liquid in the vessel, creating effects like cavitation, acoustic streaming, or enhanced mixing. An experimental setup for measuring the viscosity by ostwald viscometer. The viscometer was calibrated using distilled water at 298.15K, and multiple measurements (five repetitions) were taken for each sample to ensure accuracy. The uncertainty in viscosity measurement is given as $\pm 0.005 \times 10^{-3}$ mPa s, indicating high precision.

3. Results and Discussion

The experimental values of speed of sound (u), viscosities (η) and densities (ρ) of 1,3-dioxolane with 1-alkanol binary liquid mixtures at 298.15K are listed in Table 2. From these values, we have computed surface tension (S), available volume (V_a), relaxation strength (r), interaction parameter (χ), enthalpy (H) and free volume (V_f) are presented in table 2.



Scheme 1. Interactions between 1,3-dioxolane with 1-alkanols at 298.15K.

Table 2. Experimental Values of speed of sound (u), viscosities (η) and densities (ρ) and derived parameter Surface Tension (S), Available volume (V_a), Relaxation Strength (r) and Interaction parameter (χ) for the binary mixtures of 1,3-Dioxolane(1) + Alkanols (2) at 298.15K.

Mole fraction 1,3-Dioxolane (x_1)	Density (ρ) / g. cm ⁻³	Viscosity (η) / mPas	Sound velocity (u) / ms ⁻¹	Surface Ten- sion (S) $\times 10^3$ / N. m ⁻¹	Available volume (V_a) $\times$ 10^{-3} / m ³ mol ⁻¹	Enthalpy (H) J / mol $\times 10^6$	Free Volume (V_f) $\times 10^{-7}$ M ³ mol ⁻¹	Relaxation Strength (r)	Interaction parameter (χ) $\times 10^{-3}$
1,3-Dioxolane + Pentanol									
0	0.8124	3.3978	1198	0.2155	0.0272	0.3156	1.9568	0.0631	0.0000
0.0939	0.8276	2.3973	1284	0.2436	0.0207	0.3450	3.5817	0.0390	0.1236
0.1942	0.8436	1.8970	1290	0.2501	0.0196	0.3468	4.9996	0.0375	0.1079
0.2941	0.8640	1.4437	1296	0.2579	0.0184	0.3384	9.9265	0.0361	0.0928
0.3942	0.8836	1.1866	1300	0.2650	0.0175	0.3341	11.0374	0.0351	0.0748
0.4787	0.9068	1.0904	1304	0.2732	0.0165	0.33.8	10.8499	0.0342	0.0609
0.5999	0.9316	0.9311	1310	0.2826	0.0154	0.3262	13.4125	0.0328	0.0422
0.6972	0.9596	0.7717	1318	0.293.8	0.0143	0.3236	17.4788	0.0310	0.0326
0.7928	0.9876	0.7171	1324	0.3045	0.0134	0.3201	17.4788	0.0297	0.0206
0.9035	1.0260	0.6489	1332	0.3192	0.0123	0.3166	19.1422	0.0280	0.0089
1.0000	1.0616	0.5885	1340	0.3332	0.0113	0.3135	21.7624	0.0264	0.0000
1,3-Dioxolane + Hexanol									
0	0.8176	4.6091	1306	0.2469	0.0229	0.4163	1.7591	0.0337	0.0000
0.0912	0.8252	3.3826	1317	0.2524	0.0213	0.4112	2.7275	0.0312	0.0121
0.1955	0.8432	2.3306	1320	0.2588	0.0200	0.4003	4.5760	0.0306	0.0112
0.2923	0.8584	1.9839	1322	0.2640	0.0190	0.3899	5.5951	0.0301	0.0092
0.3982	0.8792	1.5720	1325	0.2713	0.0177	0.3787	7.5845	0.0295	0.0083
0.4942	0.8992	1.3059	1327	0.2781	0.0167	0.3683	9.5968	0.0291	0.0064
0.6059	0.9264	1.0343	1330	0.2875	0.0155	0.3567	12.9396	0.0284	0.0051
0.6976	0.9508	0.9131	1332	0.2958	0.0145	0.465	14.9307	0.0280	0.0034
0.8018	0.9836	0.7680	1335	0.3070	0.0133	0.3352	18.3980	0.0274	0.0026
0.8914	1.0168	0.7304	1337	0.3181	0.0124	0.3254	18.9465	0.0270	0.0010
1.0000	1.0616	0.5885	1340	0.3332	0.0113	0.3135	24.7413	0.0264	0.0000
1,3-Dioxolane + Heptanol									
0	0.8196	5.9066	1325	0.2529	0.0243	0.4838	1.5030	0.0295	0.0000
0.0928	0.8304	4.3181	1334	0.2589	0.0224	0.4725	2.3075	0.0276	0.0115
0.1905	0.8412	3.2577	1334	0.2623	0.0213	0.4552	3.3296	0.0252	0.0092
0.2939	0.8592	2.5895	1335	0.2682	0.0200	0.4373	4.4224	0.0274	0.0084
0.3894	0.8740	1.9926	1335	0.2728	0.0188	0.4201	6.1746	0.0273	0.0063
0.4818	0.8916	1.5315	1336	0.2786	0.0177	0.4042	8.6425	0.0272	0.0056
0.6021	0.9184	1.2190	1337	0.2873	0.0162	0.3835	11.2315	0.0270	4.4553
0.6952	0.9420	1.0959	1337	0.2947	0.0151	0.3667	12.3322	0.0268	2.3556
0.7892	0.9756	0.9903	1338	0.3055	0.0139	0.3505	13.4017	0.0267	1.7391
0.9006	1.0156	0.7057	1339	0.3184	0.0125	0.3309	20.4381	0.0266	0.7337

Mole fraction 1,3-Dioxolane (x_1)	Density (ρ) / g. cm ⁻³	Viscosity (η) / mPas	Sound velocity (u) / ms ⁻¹	Surface Ten- sion (S) $\times 10^3$ / N. m ⁻¹	Available volume (V_a) $\times$ 10^{-3} / m ³ mol ⁻¹	Enthalpy (H) J / mol $\times 10^6$	Free Volume (V_f) $\times 10^{-7}$ M ³ mol ⁻¹	Relaxation Strength (r)	Interaction parameter (χ) $\times 10^{-3}$
1.0000	1.0616	0.5885	1340	0.3332	0.0113	0.3135	24.7413	0.0264	0.0000
1,3-Dioxolane + Octanol									
0	0.8296	7.1508	1350	0.2633	0.0247	0.5619	1.3767	0.0244	0.0000
0.0885	0.8296	5.6095	1350	0.2645	0.0235	0.5363	1.8692	0.0243	1.3124
0.1967	0.8464	3.9321	1349	0.2683	0.0220	0.5100	2.9529	0.0246	1.3133
0.2998	0.8560	3.2616	1348	0.2711	0.0208	0.4845	3.6234	0.0248	1.4823
0.3902	0.8712	2.4284	1348	0.2759	0.0195	0.4629	5.2656	0.0247	2.8279
0.4963	0.8876	1.9058	1348	0.2811	0.0181	0.4375	6.9577	0.0246	4.4106
0.6008	0.9140	1.3631	1347	0.2891	0.0166	0.4117	10.5160	0.0250	4.4812
0.6925	0.9340	1.1376	1348	0.2958	0.0154	0.3905	12.7180	0.0248	7.3473
0.7975	0.9676	0.9141	1348	0.3064	0.0139	0.3652	15.9753	0.0247	8.9242
0.8940	1.0104	0.7652	1348	0.3200	0.0124	0.3421	18.9060	0.0246	0.0103
1.0000	1.0616	0.5885	1340	0.3332	0.0113	0.3135	24.7413	0.0264	0.0000
1,3-Dioxolane + Nonanol									
0	0.8248	8.9258	1366	0.2665	0.0255	0.6291	1.1714	0.0213	0.0000
0.0876	0.8336	6.8601	1366	0.2693	0.0242	0.6020	1.6286	0.0210	3.3430
0.1913	0.8404	5.8531	1363	0.2706	0.0230	0.5684	1.899	0.0219	2.9025
0.2942	0.8504	4.4022	1359	0.2726	0.0218	0.5347	2.6620	0.0226	9.5609
0.3963	0.8692	3.1558	1355	0.2774	0.0205	0.5014	3.9924	0.0234	-1.0268
0.4959	0.8844	2.3340	1352	0.2813	0.0191	0.4697	5.7014	0.0240	-1.6349
0.6050	0.9092	1.7321	1349	0.2883	0.0175	0.4354	7.9725	0.0246	-1.8802
0.6947	0.9332	1.3334	1346	0.2949	0.0162	0.4072	10.6902	0.0252	-2.8731
0.7993	0.9648	0.9642	1343	0.3039	0.0146	0.3744	15.3683	0.0258	-3.2951
0.9013	1.0084	0.8031	1340	0.3165	0.0130	0.3402	17.3683	0.0262	-3.8191
1	1.0616	0.5885	1340	0.3332	0.0113	0.3135	24.7413	0.0264	0.0000
1,3-Dioxolane + Decanol									
0	0.8292	11.8027	1378	0.2714	0.0264	0.6990	0.8971	0.0192	0.0000
0.0881	0.8364	8.5615	1374	0.2726	0.0254	0.6634	1.3454	0.0199	-0.9486
0.191	0.8396	7.8207	1370	0.2724	0.0243	0.6226	1.4040	0.0206	-1.0823
0.2921	0.8560	5.5340	1366	0.2765	0.0228	0.5827	2.1400	0.0213	-1.3167
0.3937	0.8672	4.2319	1362	0.2789	0.0214	0.5429	2.8863	0.0221	-1.5245
0.4956	0.8824	3.4173	1358	0.2826	0.0199	0.5035	3.5598	0.0228	-1.7167
0.604	0.9076	2.5370	1353	0.2890	0.0182	0.4615	4.8971	0.0238	-3.0204
0.7129	0.9308	1.5262	1348	0.2948	0.0166	0.4198	9.1301	0.0248	-4.3032
0.7983	0.9616	1.1637	1344	0.3032	0.0151	0.3871	12.1810	0.0256	-5.4310
0.8971	1.0040	0.8623	1340	0.3151	0.0133	0.3505	16.4668	0.0260	-5.8106

Mole fraction 1,3-Dioxolane (x_1)	Density (ρ) / g. cm ⁻³	Viscosity (η) / mPas	Sound velocity (u) / ms ⁻¹	Surface Ten- sion (S) $\times 10^3$ / N. m ⁻¹	Available volume (V_a) $\times$ 10^{-3} / m ³ mol ⁻¹	Enthalpy (H) J / mol $\times 10^6$	Free Volume (V_f) $\times 10^{-7}$ M ³ mol ⁻¹	Relaxation Strength (r)	Interaction parameter (χ) $\times 10^{-3}$
1	1.0616	0.5885	1340	0.3332	0.0113	0.3135	24.7413	0.0264	0.0000

The excess parameters such as excess surface tension (S^E), excess available volume (V_a^E), excess relaxation strength (r^E), excess enthalpy (H^E) and excess free volume (V_f^E) have been calculated using the following equations.

Surface Tension

$$S = 6.4 \times 10^{-3} \cdot \rho \cdot u^{1/2} \quad (1)$$

Available volume

$$V_a = (M / \rho) [1 - (U / U_\infty)] \quad (2)$$

Where M is the molecular weight of the solution which can be calculated according to the equation $[M = M_1X_1 + M_2X_2]$ and $U_\infty = 1600$ m/s.

Free Volume

$$V_f = (M U / k \eta)^{3/2} \quad (3)$$

Relaxation strength

$$r = 1 - (U / U_\infty)^2 \quad (4)$$

Enthalpy

$$H = V_m \times P_i \quad (5)$$

Interaction parameter

$$\chi = (u_{\text{exp}}^2 / u_{\text{idl}}^2) - 1 \quad (6)$$

$$Y^E = Y_{\text{exp}} - (X_1 Y_1 + X_2 Y_2) \quad (7)$$

Y^E refer to (S^E), (V_a^E), (r^E), (H^E) and (V_f^E) whereas Y_{exp} is measured property. Y_1 , Y_2 , are any acoustic parameter, X_1 and X_2 are mole fraction of 1,3-Dioxolane and 1-alkanol.

A perusal of table 2 shows the mole fraction (X_1) of 1,3-Dioxolane increases, density and ultrasonic velocity increase, while viscosity decreases. This trend can be explained by molecular interactions in the system [25]. When 1,3-Dioxolane is added, it likely leads to closer packing of molecules due to molecular interactions, such as dipole-induced dipole forces.

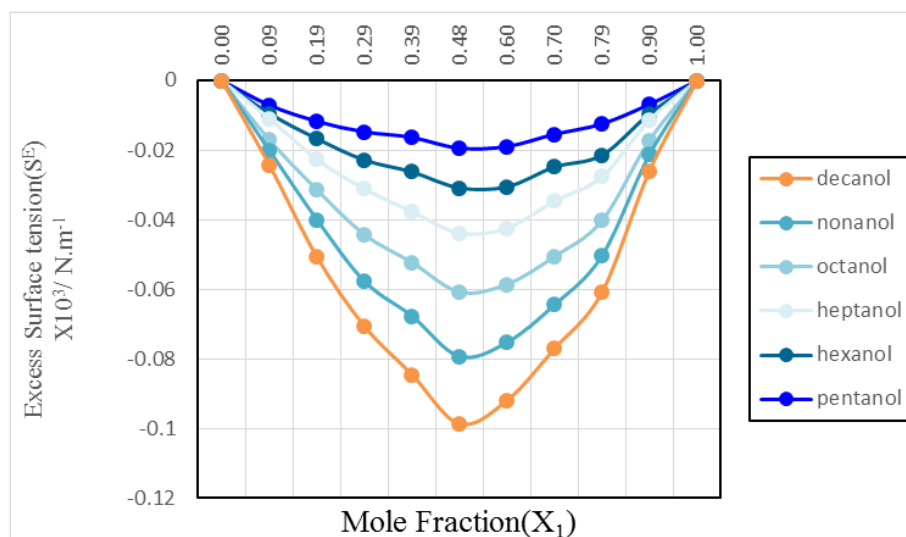


Figure 1. Variation of excess surface tension (S^E) with mole fraction (x_1) of 1,3-dioxolane with 1-alkanols at 298.15K.

The calculated excess surface tension (S^E), values for the binary liquid mixture listed in Figure 1. A perusal of curves in

figure 1 indicate the values of excess surface tension (S^E), data for binary mixtures of 1,3-Dioxolane with 1-alkanols

are negative. The excess surface tension (S^E), values are negative over the entire mole fraction range and become more negative with increasing the mole fraction of second component for all binary mixtures. These results can be explained in term of molecular interactions and structured effects. Excess values of surface tension are negative over the entire composition range at 298.15K, indicating weak interaction between the components of the mixture. In all the cases surface tension increases with increase in mole fraction of 1,3-Dioxolane, which indicate reduction in the intermolecular interactions. For all studied systems, excess surface tension (S^E), were negative over the entire mole fraction range of 1,3-Dioxolane at 298.15K. Among the six systems, 1,3-Dioxolane with 1-alkanols containing system showed more negative.

The available volume is the parameter related molecular interactions of the medium and calculated by using the expression (2). The nature and type of interactions in binary organic liquid mixtures have been studied in terms of mixing parameters such as excess available volume. This parameter can be calculated from direct measurement of density (ρ) and sound velocity (u). Such data are useful in process engineer-

ing, design applications and other related areas. Figure 2 depicts the variation of the excess available volume (V_a) of the chosen system. We clearly see from figure 2 that the non-linear variation of excess available volume (V_a) with mole fraction of 1,3-dioxolane. The negative deviation of excess available volume (V_a) reaching a minimum at 0.48 mole fraction of 1,3-dioxolane shows the molecular interactions between the molecules [26]. It is evident from figure 2 that the value of excess available volume (V_a^E) are negative for all binary liquid system at 298.15K. The value of V_a^E are plotted against the mole fraction of 1,3- dioxolane and are shown in Figure 2. Similarly results were also obtained by D. Bala Karuna Kumar et al [27] for binary mixtures of N-methyl-2-pyrrolidone. The depolymerisation of hydrogen bonded alcohols aggregates and decrease in dipolar association of component molecules leads to expansion of volume dominating interstitial accommodation which causes negative value of excess available volume (V_a^E) but it is compensated by charge transfer complex formation between hydrogen of alcohols and oxygen of 1,3- dioxolane. From the plots of (V_a^E) Vs X_1 (Figure 2) it may seen that excess available volume are negative over the whole mole fraction.

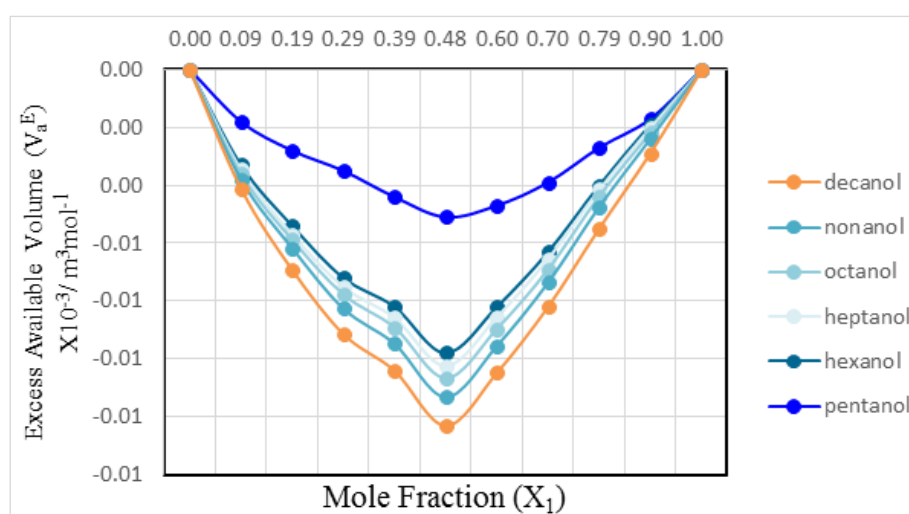


Figure 2. Variation of excess available volume (V_a^E) with mole fraction (x_1) of 1,3-dioxolane with 1-alkanols at 298.15K.

From table 2 show that the values of interaction parameter (χ) are positive for the system 1,3-dioxolane + pentanol, 1,3-dioxolane + hexanol, 1,3-dioxolane + heptanol and 1,3-dioxolane + octanol. The positive values of interaction parameter (χ) indicate the existence of strong interactions in the binary liquid mixture. The values of interaction parameter (χ) are negative for the system 1,3-dioxolane + nonanol and 1,3-dioxolane + decanol. This indicating the weak interactions in these binary liquid mixtures [28].

The term relaxation denotes the process of establishment of statistic equilibrium in a physical or physicochemical system and its rate depends upon the probability of transition of system from one stage of equilibrium to another. The term re-

laxation Strength (r) describes several processes by which nuclear magnetization prepared in non-equilibrium state returns to the equilibrium distribution. The term relaxation Strength (r) is useful in prediction of molecular properties of liquid mixtures. The relaxation strength (r) decreases with increases in concentration of 1,3-dioxolane (X_1). Figure 3 shows the variation of excess relaxation strength (r^E) with mole fraction of 1,3-dioxolane at the temperature 298.15K For the binary system 1,3-dioxolane with 1-alkanols, the excess relaxation strength (r^E) values are negative and decreasing with the increase in mole fraction of 1,3-dioxolane up to the mole fraction (0.5) and the increase with increase in mole fraction. We clearly see from figure 3 that the non-linear

variation of excess relaxation strength (r^E) with mole fraction of 1,3-dioxolane. The negative deviation of excess relaxation strength (r^E) reaching a minimum at 0.48 mole fraction of 1,3-dioxolane shows the molecular interactions between the molecules. The structural changes take place due to the variation in relaxation strength (r) of the system. The excess relaxation strength (r^E) (shown in figure 3) decrease with in-

crease in the composition of 1,3-dioxolane till 0.48 mole fraction, reaches minimum at 0.48 mole fraction and beyond 0.48 mole fraction, it again increases. The existence of minimum relaxation strength (r) indicates the squeezing of molecules in the system. The presence of minimum relaxation strength (r) suggests that the molecules in the system are being squeezed more closely together.

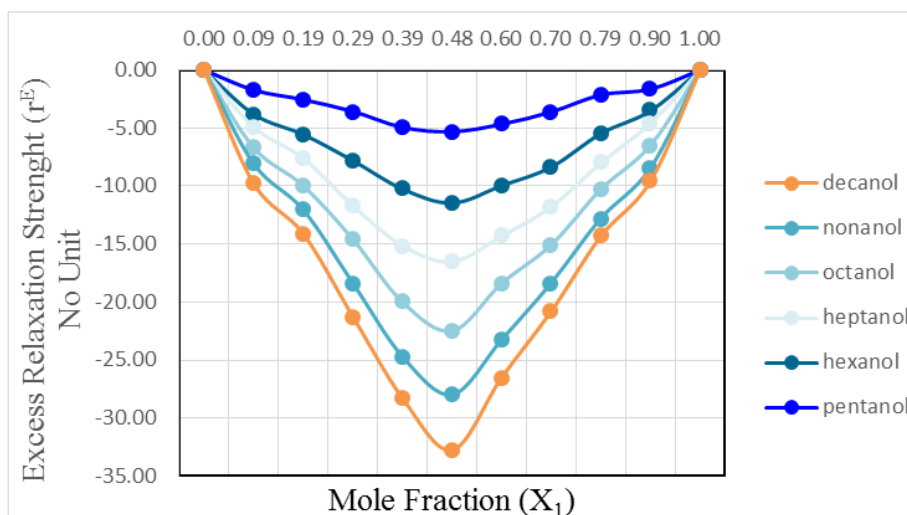


Figure 3. Variation of excess relaxation Strength (r^E) with mole fraction (x_1) of 1,3-dioxolane with 1-alkanols at 298.15K.

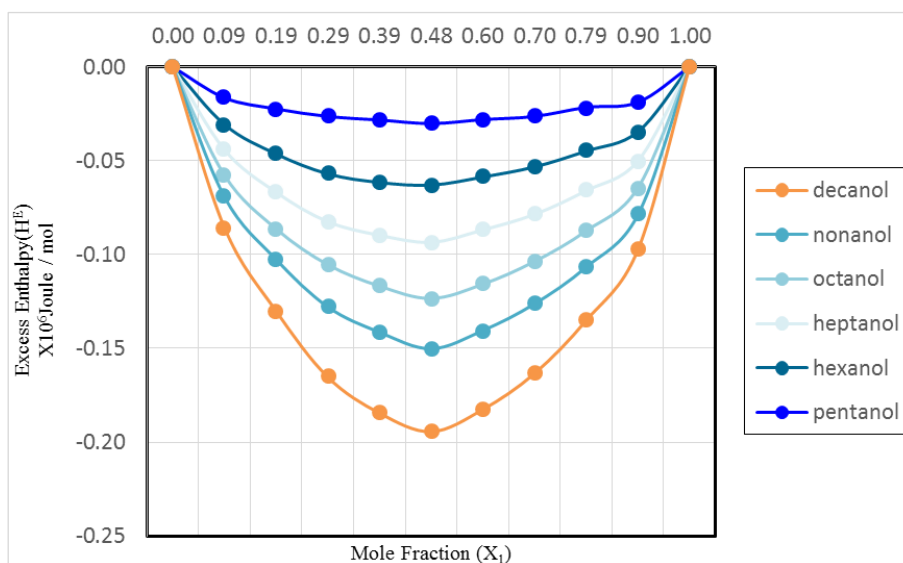


Figure 4. Variation of excess enthalpy (H^E) with mole fraction (x_1) of 1,3-dioxolane with 1-alkanols at 298.15K.

Figure 4 shows the variation of excess enthalpy (H^E) with mole fraction of 1,3-dioxolane at the temperature 298.15K. For the binary system 1,3-dioxolane with 1-alkanols, the excess enthalpy (H^E) values are negative and decreasing with the increase in mole fraction of 1,3-dioxolane up to the mole fraction (0.5) and the increase with increase in mole fraction. In the present investigation for the six binary systems it is observe that, as the mole fraction of 1,3-dioxolane increase,

the excess enthalpy (H^E) values decreases. This situation is observed for all six binary system under study and can be viewed from plots Figure 5. This suggests that dipole and dispersive force are operative in these systems, when the 1,3-dioxolane concentration low. When the concentration of 1,3-dioxolane increased, the corresponding decrease in concentration of 1,3-dioxolane leads to specific interactions i.e., the interactions move from weak to strong which supports

the above arguments is case of other parameters. As a result, the free dipoles released from the alkanols in association with 1,3-dioxolane molecules forming strong hydrogen bonds, hence stronger molecular association existing between the 1,3-dioxolane with 1-alkanols molecules through hydrogen bonding [29].

Free volume is defined as the space within a liquid that is not occupied by molecules, allowing for particle movement and interactions. It is characterized by fluctuations as moving particles expand their cells while adjacent cells compress, leading to a regular distribution of free volume. The concept of free volume is an extension of the idea that each molecule is enclosed by its neighbor in a cell. The free volume per molecules may be regarded as the effective volume accessible to the centers of a molecule in a liquid. It is however, evident from the consideration of the liquid state theories that the concept of free volume varies with the specific model chosen for the liquid. A perusal of Figure 6 shows that the value of excess Free Volume(V_f^E), are negative for the all

binary liquid system 1,3-dioxolane with 1-alkanols at 298.15K. In the present investigation the negative excess free volume(V_f^E), for binary mixtures of 1,3-dioxolane with 1-alkanols may be attributed to hydrogen bond formation through dipole-dipole interaction between 1-alkanol and 1,3-dioxolane molecule or to structural contributions arising from the geometrical fitting of 1-alkanol into the 1,3-dioxolane due to difference in the free volume between components. The interactions of alcohols with organic liquids are interesting due to its acetic nature. The O-H bond in alcohols is polar and allows the release of hydrogen atom as proton (H^+). The order of acidity in alcohols is: 1^0 -alcohol $> 2^0$ -alcohol $> 3^0$ -alcohol. This order is due to +I effect while the interacting ability of alcohols is well established no such opinion is suggested from literature [30, 31] with regards to 1,3-dioxolane with 1-alkanols were selected to study their molecular interactions through their acoustical behavior.

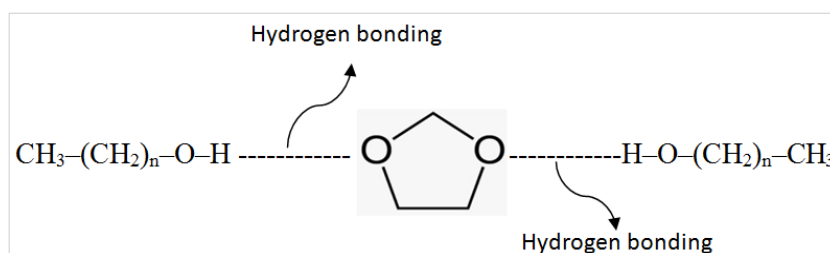


Figure 5. Hydrogen bonding present in 1,3-dioxolane - n-alkanols.

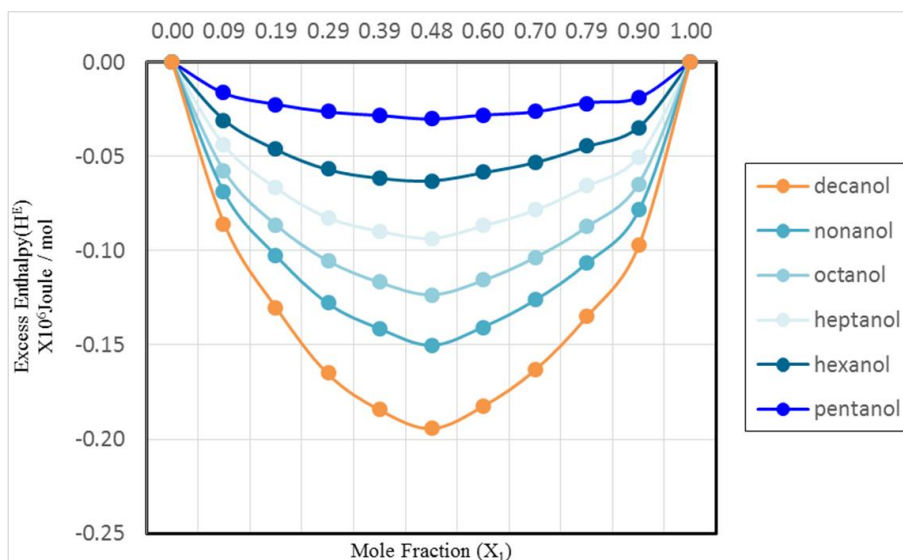


Figure 6. Variation of excess Free Volume(V_f^E), with mole fraction (x_1) of 1,3-dioxolane with 1-alkanols at 298.15K.

The negative values of excess free volume(V_f^E), indicate the presence of strong molecular interaction. We may conclude that 1-alkanols, is disrupted. It is also concluded that

Suryanarayana approach for estimating free volume thermodynamic considerations is very well applicable in the present case.

4. Conclusion

This research article report experimental study of sound velocity, viscosity and density and its derived excess parameters. The existence of molecular interactions in solute-solvent is favoured in the system, confirmed from the ultrasonic velocity (u), viscosity (η), density (ρ), surface tension (S), available volume (V_a), relaxation strength (r), interaction parameter (χ), enthalpy (H) and Free Volume (V_f). We are concluded that there exist a molecular interaction between 1,3-dioxolane and 1-alkanols due to Hydrogen bonding and degree of complexation.

Abbreviations

PCP	Physico-chemical Properties
MI	Molecular Interaction
BLM	Binary Liquid Mixtures
EP	Excess Parameters
SSI	Solute-solvent Interactions
CDT	Cyclic Diether
CDH	Central Drug House
ρ	Densities of Liquid
u	Ultrasonic Velocity
η	Viscosity
X_1	Mole Fraction of 1,3-Dioxolane
T	Temperature
S	Surface Tension

S^E	Excess Surface Tension
(V_a)	Available Volume
(V_a^E)	Excess Available Volume
(r)	Relaxation Strength
(χ)	Interaction Parameter
(H)	Enthalpy
(H^E)	Excess Enthalpy
(V_f)	Free Volume
(V_f^E)	Excess Free Volume
Y^E	Thermodynamic Excess Function

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Author Contributions

Dhirendra Kumar Sharma: Supervision, Writing - original draft, Writing - review & editing

Anand Kumar Trivedi: Data Curation, Investigation

Chandra Pal Prajapati: Software, Validation

Conflicts of Interest

The authors declare no conflicts of interest.

Appendix

Graphical abstract

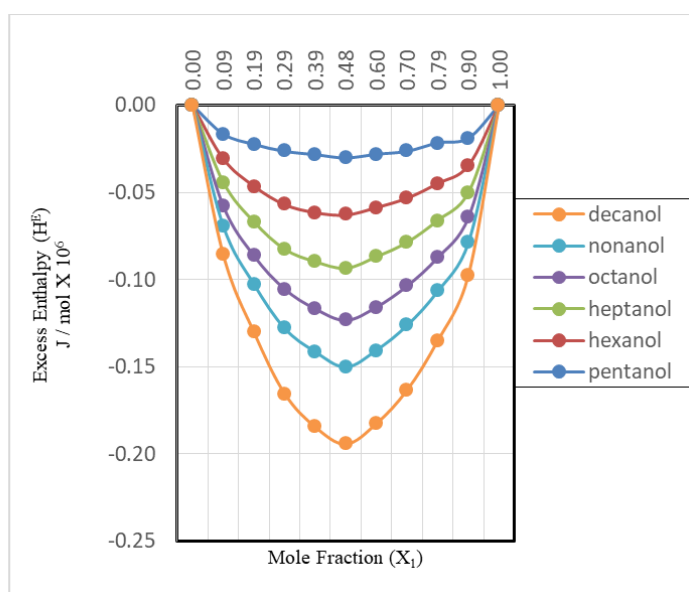
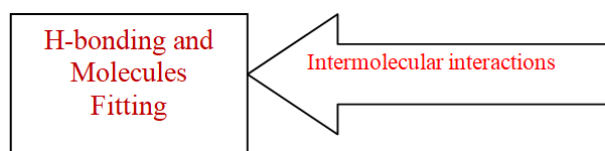


Figure A1. Schematic representation of intermolecular interaction by hydrogen bonding.

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