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INTERMOLECULAR INTERACTION IN BINARY LIQUID MIXTURE BY ULTRASONIC MEASUREMENTS

RAJ KUMAR[1] & SINGH Y.P[2]

[1]Department of Chemistry, K.A.P.G College, Kasganj, Uttar Pradesh, India

[2]Department of Chemistry, Sir M.U. Degree College, Sahawar, Uttar Pradesh, India

ABSTRACT

Ultrasonic velocity (*V*). density (ρ) and viscosity (η) measurements for binary liquid mixture of thiophene and 1-propanol at 305.15, 310.15 and 315.15K are determined at atmospheric pressure some thermoacoustical parameters like isentropic compressibility (β_s), molar volume (V_m), specific acoustic impedance (*Z*), intermolecular free length (L_f) and their excess values have been calculated from the experimental data. The results have been used qualitatively to explain the molecular interaction between the components of these binary liquid mixtures.

KEYWORDS : Ultrasonic Velocity, Density, Viscosity, Acoustic Parameters, Thiophene,1-propanol.

INTRODUCTION

The ultrasonic velocity (V), density (ρ) and viscosity (η) measurements find wide applications in characterizing the physico-chemical behaviour of liquid mixture[1-3] and in the study of molecular interactions.[4-5] Properties of liquid-liquid mixtures are thermodynamically very important as a part of studies of thermodynamic and acoustic aspects. This type of study is a powerful model of characterizing the various aspects of physico chemical behaviour of liquid mixtures and studying the interaction between the atoms or molecules of of the components.

Further, ultrasonic velocities, densities, viscosities and derived thermodynamic and acoustical parameters are of considerable interest to understanding the inter molecular interaction in binary liquid mixtures.[6-7]

In view of sprouting interest, in this research articles, an attempt has been made to explain the molecular interaction in the binary mixture of thiophene with 1-propanol at 305.15, 310.15 and 315.15K. Thiophene (or thiofuran) is a hetero cyclic aromatic compound which is used as a solvent, chemical intermediate and its derivatives are used in manufacturing dyes, aroma compounds and pharamaceuticals. 1-propanol is an isomer of 2-propanol and used as a solvent in pharamaceutical industry mainly for resins and cellulose esters. It is also used to manufacture pesticides and suitable to engine fuel usage due to high octane number.

Ultrasonic velocity, density and viscosity of binary liquid mixture have been determined over the entire range of composition in the present research work. The excess functions of some of the acoustical parameters are used to explain the intermolecular interactions.

EXPERIMENTAL DETAILS

All the chemicals used in the present work were analytical reagent (AR) grade. The purity of the chemicals was ascertained by comparing their ultrasonic velocities, densities and viscosities with literature values. The binary liquid mixtures of different known proportions were prepared in stoppard measuring flask. Ultrasonic velocities were measured by using single crystal ultrasonic interferometer (Mittal Enterprises, New Delhi, Model F-81) at a fixed frequency of 2Mhz with an accuracy of $\pm$ 2ms^{-1}. The working of ultrasonic interferometer was checked for its accuracy by measuring ultrasonic velocities of various liquids for which these were available in literature.

Densities of the pure liquids and liquid mixtures were measured by using calibrated double-walled bicapillary pyknometer. The viscosities have been measured by using Ostwals's viscometer. The source of errors and precautions taken has also been mentioned. The temperature was mentioned by circulating water around the liquid cell from thermostatically controlled constant temperature water bath (RAAGA Industries, Madras)

From the experimental data, various thermoacoustic parameters have been calculated using the following standard equation :--

Isentropic compressibility

$$\beta_s = \frac{1}{V^2 \rho} \quad \textbf{(1)}$$

Intermolecular free length

$$L_f = K\sqrt{\beta_s} \quad \textbf{(2)}$$

Where K is the temperature dependent constant.[8]

Molar volume

$$V_m = \frac{\bar{M}}{\rho} \quad \textbf{(3)}$$

and $\bar{M} = X_1 M_1 + X_2 M_2$

Where X_1, X_2 and M_1, M_2 are the mole fraction and molecular weight constituent components respectively.

Specific acoustic impedance

$$Z = V \rho \quad \textbf{(4)}$$

Available volume

$$V_a = V_m - \left(1 - \frac{V}{V_m}\right) \quad \textbf{(5)}$$

Excess values

$$A^E = A_{exp} - A_{ideal} \quad \textbf{(6)}$$

Where *A* represent any thermodynamic function.

These results have been connected to the Redlich-Kister**9** equation, for the determination of binary coefficients of excess values.

RESULTS AND DISCUSSIONS

This research article deals with the study of molecular interaction in binary liquid mixture of thiophene and 1-propanol at 305.15, 310.15 and 315.15K. We have experimentally determined ultrasonic velocity (*V*), density (ρ) and viscosity (η) at different temperatures with the help of these experimental data, the thermodynamic and acoustic properties like isentropic compressibility (β_s), intermolecular free length (L_f), molar volume (V_m), specific acoustic impedance (*Z*) and their excess values have been computed at different temperatures are presented in tables and graphed in figures.

As it can be seen from the tables that ultrasonic velocity increases with increasing mole fraction of thiophene at all temperatures. The increase in velocity suggest the strong molecular interaction between thiophene and 1-propanol.[10] The ultrasonic velocity, density and viscosity decreases with increasing the temperatures.[11-13]

Intermolecular free length is an important fact for determining the variation in ultrasonic velocity of binary liquid mixture, as intermolecular free length increases ultrasonic velocity decreases and vice-versa.[14-15]

Here β_s^E and L_f^E have shown negative values while η^E shows positive deviation at all temperature. The negative value of β_s^E , L_f^E and positive values of η^E at all temperature shows the existence of strong interaction between the components of the mixture attributed to the dipole-dipole interaction. Tresze Zanowies et.al have also reported the similar results on the basis of excess values of isentropic compressibility and free length.[16] The molar volume and their excess value are also observed in supporting trends.[17]

In thiophene, sulphur atom is an electron donor species. Therefore, a strong interaction takes place due to dipole-dipole interaction between thiophene and alcoholic group of 1-propanol. The temperature variation also affect the excess values because negative deviation indicates that the structure making effect is dominate in binary liquid mixtures.

CONCLUSIONS

From the experimental data of ultrasonic velocity (V), density (ρ) and viscosity (η), various thermodynamic acoustical parameters and their excess values of the binary liquid mixture of thiophene and 1-propanol at 305.15, 310.15 and 315.15K were calculated. It is observed that there exist a strong molecular interaction between thiophene at 1-propanol due to dipole-dipole interaction. The magnitude of molecular interaction to be weaker with rise in temperature which may be due to weak intermolecular attractions.

Table 1: Ultrasonic Velocity (V), Density (ρ) and Viscosity (η) of Binary Liquid Mixture at Different Temperature

Mole Fraction (X_1)	V (m/s)			ρ (gm/ml)			η (C.P.)		
	305.15 K	310.15 K	315.15 K	305.15 K	310.15 K	315.15 K	305.15 K	310.15 K	315.15 K
0.0000	1118	1102	1080	0.7826	0.7804	0.7780	1.6498	1.4686	1.1389
0.1066	1149	1128	1102	0.8008	0.8008	0.8002	1.5275	1.3622	1.2193
0.2206	1189	1161	1132	0.8202	0.8206	0.8190	1.3972	1.2484	1.1128
0.3268	1226	1197	1162	0.8406	0.8392	0.8370	1.2761	1.1424	1.0137
0.4302	1254	1227	1187	0.8760	0.8632	0.8598	1.1585	1.0386	0.9169
0.5311	1290	1251	1205	0.8964	0.8919	0.8922	1.0446	0.9364	0.8218
0.6295	1314	1271	1228	0.9262	0.9226	0.9180	0.9345	0.8359	0.7281
0.7255	1337	1292	1247	0.9590	0.9525	0.9472	0.8277	0.7394	0.6360
0.8192	1362	1314	1266	0.9928	0.9845	0.9780	0.7233	0.6413	0.5464
0.9106	1395	1344	1292	1.0198	1.0138	1.0048	0.6214	0.5674	0.4594
1.0000	1424	1370	1316	1.0527	1.0426	1.0325	0.5220	0.4560	0.3740

Table 2: Excess Values of Isentropic Compressibility (β_s^E), Intermolecular Free Length (L_f^E) and Viscosities (η^E) of Binary Liquid Mixture at Different Temperature

Mole Fraction (X_1)	β_s^E (cm^2/dyne.10^{12})			L_f^E (A°)			η^E (C.P.)		
	305.15 K	310.15 K	315.15 K	305.15 K	310.15 K	315.15 K	305.15 K	310.15 K	315.15 K
0.0000	0.00	0.00	0.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.1066	–1.77	–1.58	–1.38	-0.0025	-0.0021	-0.0018	0.0021	0.0016	0.0011
0.2206	–3.77	–3.11	–2.98	-0.0065	-0.0048	-0.0044	0.0038	0.0032	0.0024
0.3268	–4.99	–4.56	–3.97	-0.0093	-0.0084	-0.0068	0.0051	0.0047	0.0036
0.4302	–5.81	–5.16	–4.30	-0.0124	-0.0100	-0.0073	0.0061	0.0057	0.0045
0.5311	–5.78	–4.97	–4.31	-0.0119	-0.0099	-0.0072	0.0062	0.0055	0.0048
0.6295	–4.83	–4.17	–3.79	-0.0093	-0.0073	-0.0063	0.0053	0.0047	0.0040
0.7255	–3.71	–3.17	–2.93	-0.0066	-0.0057	-0.0043	0.0039	0.0055	0.0027
0.8192	–2.55	–2.11	–1.94	-0.0041	-0.0028	-0.0024	0.0026	0.0022	0.0016
0.9106	–1.40	–1.35	–1.14	-0.0024	-0.0023	-0.0016	0.0014	0.0009	0.0007
1.0000	0.00	0.00	0.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table 3: Specific Acoustic Impedance (*Z*), and Excess Values of Molar Volume (V_m^E) of Binary Liquid Mixture at Different Temperature

Mole Fraction (X_1)	*Z* x 10^{-5} (C.G.S. Unit)			V_m^E (ml/mole)		
	305.15 K	310.15 K	315.15 K	305.15 K	310.15 K	315.15 K
0.0000	0.8749	0.8600	0.8402	0.00	0.00	0.00
0.1066	0.9201	0.9033	0.8818	1.12	0.82	0.60
0.2206	0.9752	0.9527	0.9271	2.25	1.88	1.67
0.3268	1.0306	1.0045	0.9726	3.02	2.75	2.55
0.4302	1.0985	1.0591	1.0206	3.28	3.00	2.86
0.5311	1.1563	1.1157	1.0751	2.83	2.72	2.54
0.6295	1.2170	1.1726	1.1273	2.48	2.21	2.03
0.7255	1.2822	1.2306	1.1811	1.86	1.70	1.51
0.8192	1.3522	1.2936	1.2381	1.02	1.02	0.87
0.9106	1.4226	1.3625	1.2982	0.75	0.50	0.48
1.0000	1.4992	1.4284	1.3588	0.00	0.00	0.00

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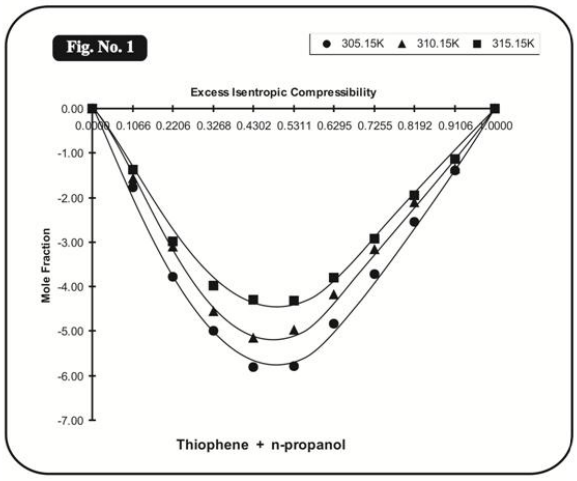

Figure 1

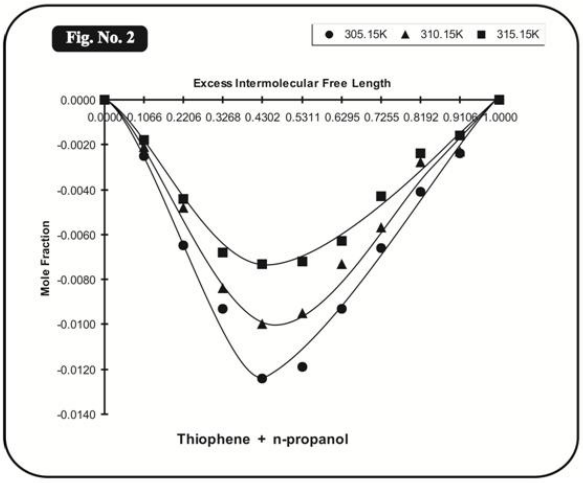

Figure 2

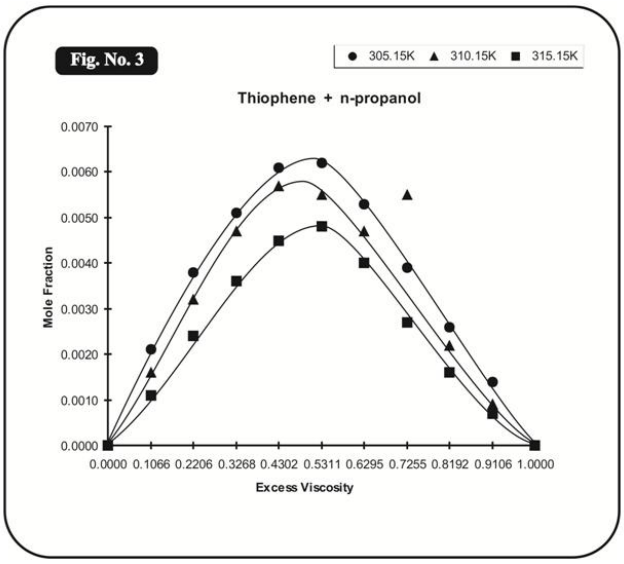

Figure 3