Research Article

Acoustical Behavior of Molecular Interactions in Binary Liquid Mixture Containing 1-Butanol and Hexane at Temperatures 298.15K, 303.15K and 308.15K

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ABSTRACT
Ultrasonic velocity (u), density (ρ), and viscosity (η) values have been measured experimentally in the binary liquid mixture containing 1-butanol and hexane at different temperatures 298.15K, 303.15K and 308.15K, over the entire range of composition. This experimental data have been used to calculate the acoustical parameters such as adiabatic compressibility (β), free length (L_f), molar volume (V_m) and acoustic impedance (z). The results have been qualitatively used to explain the molecular interactions between the components of the liquid mixture.

Keywords: Ultrasonic velocity, 1-butanol, hexane, acoustic impedance, molar volume.

1. INTRODUCTION

The Knowledge of acoustical parameters is of great importance in studying the molecular interactions and physicochemical behaviour in binary liquid mixtures[1,2].The study of molecular interactions in the liquid mixtures is of considerable in the elucidation of the structural properties of the molecules. The intermolecular interactions influence the structural arrangement along with the shape of the molecules. In the recent years, ultrasonic technique has been found to be one of the most powerful techniques for studying the nature of molecular interactions in liquid mixtures. Acoustical parameters are used to understand different kinds of association, the molecular packing, molecular motion, physico-chemical behaviour and various types of intermolecular interactions and their strengths, influenced by the size in pure components and in the mixtures. As a part of today's progressive and ongoing research[3,4] on thermodynamic and acoustic properties of binary liquid mixtures, we report here the results of study on binary mixture of 1-butanol and hexane over the entire range of composition at T= 298.15K, 303.15K, and 308.15K. By using the these experimental values of ultrasonic velocity (u), density (ρ) and viscosity (η), acoustical parameters such as adiabatic compressibility (β), free length (L_f), molar volume (V_m) and acoustic impedance (z) have been estimated using standard relations.

2. EXPERIMENTAL DETAILS

All the liquids used were purified by standard procedure[5]. Job's method of continuous variation was used to prepare the mixtures in the required proportions. Job's method of continuous variation was used to prepare the mixtures of required proportions. The various concentrations are prepared by varying mole fractions. The prepared mixtures were preserved in well-Stoppard conical flasks. After mixing the liquids thoroughly, the flasks were left undisturbed to allow them to attain thermal equilibrium. The ultrasonic velocities were measured by using single crystal ultrasonic pulse echo interferometer (Mittal enterprises, India; Model: F-80X). It consists of a high frequency generator and a measuring cell. The measurements of ultrasonic velocities were made at a fixed frequency of 3MHz. The capacity of the measuring cell is 12ml. The ultrasonic velocity has an accuracy of ± 0.5 m/s The temperature was controlled by circulating water around the liquid cell from thermostatically controlled constant temperature water bath (accuracy ± 0.01K).The densities of pure liquids and liquid mixtures were measured by using a specific gravity bottle with an accuracy of ± 0.5%. An electronic balance (Shimadzu AUY220, Japan), with a precision of ±0.1 mg was used for the mass measurements. Averages of 4 to 5 measurements were taken for each sample. Viscosities were measured at the desired temperature using Ostwald's viscometer, which was calibrated using water and benzene. The flow time has been measured after the attainment of bath temperature by each mixture. The flow measurements were made with an electronic stopwatch with a precision of 0.01 s. The viscosities η, were obtained from the following relation:

$$\eta = k \cdot \rho \cdot t \qquad (1)$$

where k, ρ and t, are viscometric constant, density of liquid and time of efflux for a constant volume of liquid respectively. For all pure compounds and mixtures, 4 to 5 measurements were performed and the average of these values was used in all calculations. The values are accurate to ± 0.001cP. The experimentally measured values of pure components are compared with the literature[6, 7] values and are given in (Table 1).

Table 1: Experimental and literature values of density and ultrasonic velocity of pure liquids at 303.15K

Liquids	Density (ρ) kgm^{-3}		Ultrasonic velocity (u) ms^{-1}	
	Experimental	Literature	Experimental	Literature
1-butanol	1227.4	1228.8[*6]	801.7	801.8[*7]
hexane	1058.2	1057.0[*8]	650.1	649.3[*9]

Table 2: Densities (ρ), viscosities (η) and ultrasonic velocities (u) of liquid mixture at T = 298.15K, 303.15K and 308.15K

Mole fraction of 1-butanol (x)	U ms^{-1}	ρ Kgm^{-3}	η $X10^{-3}$ Nsm^{-2}
T=298.15K			
0.0000	1076.0	657.1	0.0355
0.1364	1090.0	675.3	0.0510
0.2623	1109.0	692.6	0.0686
0.3791	1130.7	710.8	0.0837
0.4871	1152.5	729.3	0.1010
0.5875	1171.0	747.4	0.1210
0.6812	1190.0	764.6	0.1370
0.7688	1207.0	778.6	0.1520
0.8507	1222.0	790.2	0.1670
0.9277	1234.0	800.0	0.1810
1.0000	1246.1	806.8	0.1960

Table 3: Densities (ρ), viscosities (η) and ultrasonic velocities (u) of liquid mixture at T = 298.15K, 303.15K and 308.15K

Mole fraction of 1-butanol (x)	U ms^{-1}	ρ Kgm^{-3}	η $X10^{-3}$ Nsm^{-2}
T=303.15K			
0.0000	1058.2	650.1	0.0335
0.1364	1073.0	668.6	0.0473
0.2623	1091.0	686.0	0.0640
0.3791	1112.0	704.0	0.0780
0.4871	1133.6	722.9	0.0950
0.5875	1152.5	740.0	0.1140
0.6812	1171.4	757.1	0.1320
0.7688	1188.4	771.2	0.1460
0.8507	1204.0	783.4	0.1610
0.9277	1218.0	793.9	0.1750
1.0000	1227.4	801.7	0.1900
T=308.15K			
0.0000	1038.5	644.7	0.0305
0.1364	1054.0	663.0	0.0424
0.2623	1074.0	678.6	0.0590
0.3791	1095.0	696.8	0.0724
0.4871	1116.0	716.6	0.0890
0.5875	1135.0	733.2	0.1080
0.6812	1154.0	751.4	0.1240
0.7688	1171.0	765.4	0.1400
0.8507	1187.5	777.0	0.1550
0.9277	1201.0	787.4	0.1680
1.0000	1211.7	798.5	0.1820

Table 4: Adiabatic compressibility (β), Free length (L_f), molar volume (V_m) and acoustic impedance (Z) of liquid mixture at T = 298.15K, 303.15K and 308.15K

Mole fraction of 1-butanol (x)	β_{ad} 10^{-10} m^2N^{-1}	L_f 10^{-11} m	V_m 10^{-7} m^3	Z 10^6 $m^{-2}s^{-1}$
T=298.15K				
0.0000	**13.1445**	**7.5250**	**1.3115**	**0.7070**
0.1364	12.4638	7.3276	1.2518	0.7361
0.2623	11.7396	7.1115	1.1986	0.7681
0.3791	11.0042	6.8852	1.1481	0.8037
0.4871	10.3231	6.6687	1.1011	0.8405
0.5875	9.7574	6.4834	1.0583	0.8752
0.6812	9.2357	6.3077	0.1019	0.9099
0.7688	8.8160	6.1627	0.9878	0.9398
0.8507	8.4746	6.0422	0.9607	0.9656
0.9277	8.2088	5.9467	0.9374	0.9872
1.0000	7.9823	5.8641	0.9186	1.0054
T=303.15K				
0.0000	13.7368	7.6927	1.3256	0.6879
0.1364	12.9907	7.4809	1.2644	0.7174
0.2623	12.2469	7.2636	1.2102	0.7484
0.3791	11.4873	7.0347	1.1592	0.7828
0.4871	10.7647	6.8098	1.1109	0.8195
0.5875	10.1739	6.6203	1.0688	0.8529
0.6812	9.6258	6.4395	1.0298	0.8869
0.7688	9.1814	6.2891	0.9972	0.9165
0.8507	8.8057	6.1591	0.9691	0.9432
0.9277	8.4906	6.0479	0.9446	0.9670
1.0000	8.2797	5.9723	0.9245	0.9840
T=308.15K				
0.0000	14.3823	7.9425	1.3367	0.6695
0.1364	13.5770	7.7169	1.2750	0.6988
0.2623	12.7755	7.4857	1.2234	0.7288
0.3791	11.9692	7.2456	1.1712	0.7630
0.4871	11.2046	7.0103	1.1206	0.7997
0.5875	10.5873	6.8145	1.0788	0.8322
0.6812	9.9935	6.6206	1.0376	0.8671
0.7688	9.5279	6.4646	1.0048	0.8963
0.8507	9.1267	6.3270	0.9771	0.9227
0.9277	8.8048	6.2144	0.9524	0.9457
1.0000	8.5297	6.1166	0.9282	0.9675

3. RESULTS AND DISCUSSION

The experimental values of density (ρ), viscosity (η) and ultrasonic velocity (u) for the binary liquid mixture over the entire range of composition at different temperatures 298.15K, 303.15K and 308.15K are presented in Table-2 . From Table-2 it is observed that the ultrasonic velocity increases with increase in mole fraction of 1-butanol. This may be due to association of a very strong dipole-induced dipole interaction between the component molecules. The calculated thermo acoustical parameters such as adiabatic compressibility (β), free length (L_f), molar volume (V_m) and acoustic impedance (z) and their variations are given in Table-3**.** Adiabatic compressibility is a measure of intermolecular association or dissociation or repulsion. It is independent of temperature and pressure for un-associated and weakly associated molecules. It also determines the orientation of the solvent molecules around the liquid molecules. The structural arrangement of the molecule affects the adiabatic compressibility. From Table-3 and it is observed that adiabatic compressibility decreases with increase in mole fraction of 1-butanol in the mixture taken up for study. As adiabatic compressibility is inversely proportional to ultrasonic velocity, since ultrasonic velocity increases with mole fraction, so that adiabatic compressibility decreases with mole fraction of 1-butanol.The free length is the distance between the surfaces of the neighbouring molecules. Generally, when the ultrasonic velocity increases, the value of the free length decreases. The observed increase in ultrasonic velocity and corresponding decrease in free length with mole fraction of 1-butanol in the binary liquid mixture is in accordance with the proposed by theory[10]. From Table-3, it is studied that the values of adiabatic compressibility and free length increases with increase in temperatures, it clearly reveals that interaction become stronger at lower temperatures. Similar variations are observed in case of molar volume given in Table-3. Also it is observed from Table-3, that acoustic impedance increases with increase in mole fraction of 1-butanol.

4. CONCLUSION

It is very obvious from values of ultrasonic velocity, density, viscosity and calculated acoustical parameter of the binary liquid mixture containing 1-butanol and hexane at 298.15K, 303.15K and 308.15K that there exists a strong molecular association between the components of the liquid mixture.

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