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A Discussion of Acoustical Parameters in Binary Mixtures at different Temperatures: An Ultrasonic Study

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ABSTRACT

In this analysis, the ultrasonic velocity, density and viscosity of DMSO were measured at different temperatures of 308K, 313K, 318K, 323K, 328K and 333K with butanol. Acoustical parameters such asacoustic impedance (Z), adiabatic compressibility (β_a), Intermolecular freelength (L_f), relaxation time (τ), internal pressure (π_i) have been determined from these. The variety of derived parameters was used to analyze the form and scope of interactions between the binary molecules.

Keywords : Ultrasonic velocity, DMSO, Alcohol, Acoustical parameters, free length, adiabatic compressibility

I. INTRODUCTION

In understanding the nature of the molecular interaction between them, thermodynamic and acoustical research on binary/ternary liquid mixtures play a vital role [1,2]. Ultrasonic studies are commonly used in the food industry, the pharmaceutical sector and the automotive industry [3-5]. Ultrasonic techniques have clarified the essence of the bonding, the frequency of the interactions, the properties and the composition of the binary and ternary liquid mixtures.

Butanol is used to raise octane and oxygenate as a solvent, ethanol denaturant, paint remover component and gasoline. To minimize pain and accelerate the healing of wounds, burns, and muscle and skeletal injuries, DMSO is used topically. To treat painful conditions such as headache, inflammation, osteoarthritis, rheumatoid arthritis and extreme facial pain called tic douloureux, DMSO is often used topically. The present study records the acoustical parameters of the DMSO binary system with butanol at different temperatures.

II. Materials and Methods

AR graded samples of DMSO and butanol were purchased from chempure pvt. Ltd. and used without purification. Ultrasonic interferometer (Model F-81, Mittal Enterprises) is used to measure ultrasonic velocity at 2MHz frequency. The temperature can be varied and maintained constant by

an electronically digital operated variable temperature bath. Density of pure and binary liquid mixtures is determined by using 5ml specific gravity bottle by relative measurement method. Viscosity is measured by Oswald viscometer with water sample as reference. The measurement of velocities, densities and viscosities for all liquid mixtures has been studied at 303K, 308K, 313K,318K, 323K and 328K.

From these measured data, various acoustical parameters are computed using the standard relations:

Adiabatic compressibility (β_a) = $\frac{1}{U^2 \rho}$ ------(1)

Acoustic impedance (Z) = Uρ ------(2)

Relaxation time (τ) = 4/3 β_a η ------(3)

Free length(L_f) $= K_T \beta_a^{1/2}$ ------(4)

Internal pressure (π_i) $= bRT \left(\frac{K\eta}{V}\right)^{1/2} (\rho^{2/3}/{M_{eff}}^{7/6})$ ------(5)

DMSO+ Butanol at 308K

Mole fraction		U ms^{-1}	ρ 10^{-3} Nsm^{-2}	η 10^{-3} Nsm^{-2}	β_a 10^{-10} ms^2kg^{-1}	z 10^6 $kgm^{-2}s^{-1}$	L_f 10^{-10} m	τ 10^{-13} s	π_i 10^8 Nm^{-2}
X_1	X_2								
1.000	0.000	1455.6	1072.6	1.152	4.400	1.561	0.478	0.676	6.114
0.814	0.186	1380.4	1020.2	1.543	5.144	1.408	0.517	1.059	7.108
0.622	0.378	1290.6	946.6	1.540	6.342	1.222	0.574	1.302	7.068
0.385	0.615	1206.0	874.2	1.697	7.865	1.054	0.639	1.779	7.385
0.192	0.808	1142.4	816.4	2.110	9.386	0.933	0.698	2.642	8.182
0.000	1.000	1090.0	759.8	1.906	11.078	0.828	0.758	2.816	7.679

DMSO+ Butanol at 313K

Mole fraction		U ms^{-1}	ρ 10^{-3} Nsm^{-2}	η 10^{-3} Nsm^{-2}	β_a 10^{-10} ms^2kg^{-1}	z 10^6 $kgm^{-2}s^{-1}$	L_f 10^{-10} m	τ 10^{-13} s	π_i 10^8 Nm^{-2}
X_1	X_2								
1.000	0.000	1431.6	1072.4	1.110	4.549	1.535	0.491	0.673	6.149
0.814	0.186	1349.2	1020	1.447	5.386	1.376	0.534	1.039	7.073
0.622	0.378	1262.8	946.4	1.447	6.626	1.195	0.592	1.279	7.039
0.385	0.615	1170.8	874.2	1.575	8.345	1.024	0.665	1.753	7.338
0.192	0.808	1123.2	816.2	1.939	9.712	0.917	0.717	2.512	8.038
0.000	1.000	1049.2	758.6	1.598	11.975	0.796	0.796	2.553	7.278

DMSO+ Butanol at 318K

Mole fraction		U ms^{-1}	ρ 10^{-3} Nsm^{-2}	η 10^{-3} Nsm^{-2}	β_a 10^{-10} ms^2kg^{-1}	z 10^6 $kgm^{-2}s^{-1}$	L_f 10^{-10} m	τ 10^{-13} s	π_i 10^8 Nm^{-2}
X_1	X_2								
1.000	0.000	1422.8	1072.2	1.061	4.607	1.526	0.498	0.651	6.127
0.814	0.186	1332.8	1019.8	1.418	5.520	1.359	0.545	1.044	7.157
0.622	0.378	1254.0	946.2	1.401	6.721	1.187	0.602	1.255	7.059
0.385	0.615	1148.4	874.0	1.512	8.676	1.004	0.684	1.749	7.375
0.192	0.808	1114.4	816.0	1.857	9.868	0.909	0.729	2.444	8.021
0.000	1.000	1030.0	757.2	1.484	12.448	0.780	0.819	2.468	7.182

DMSO+Butanol at 323K

Mole fraction		U ms^{-1}	ρ 10^{-3} Nsm^{-2}	η 10^{-3} Nsm^{-2}	β_a 10^{-10} ms^2kg^{-1}	z 10^6 $kgm^{-2}s^{-1}$	L_f 10^{-10} m	τ 10^{-13} s	π_i 10^8 Nm^{-2}
X_1	X_2								
1.000	0.000	1406.0	1072.0	1.040	4.718	1.507	0.509	0.654	6.195
0.814	0.186	1317.8	1019.8	1.363	5.647	1.344	0.557	1.026	7.168
0.622	0.378	1238.8	946.0	1.360	6.888	1.172	0.615	1.249	7.106
0.385	0.615	1143.6	874.0	1.477	8.749	1.000	0.693	1.723	7.419
0.192	0.808	1092	815.8	1.758	1.0279	0.891	0.751	2.410	8.007
0.000	1.000	1017.6	755.2	1.324	12.787	0.768	0.838	2.258	6.921

DMSO+ Butanol at 328K

Mole fraction		U ms^{-1}	ρ 10^{-3} Nsm^{-2}	η 10^{-3} Nsm^{-2}	β_a 10^{-10} ms^2kg^{-1}	z 10^6 $kgm^{-2}s^{-1}$	L_f 10^{-10} m	τ 10^{-13} s	π_i 10^8 Nm^{-2}
X_1	X_2								
1.000	0.000	1385.6	1071.8	1.022	4.859	1.485	0.521	0.662	6.283
0.814	0.186	1305.2	1019.8	1.343	5.756	1.331	0.566	1.031	7.260
0.622	0.378	1226.4	946.0	1.317	7.028	1.160	0.627	1.234	7.137
0.385	0.615	1127.2	873.8	1.418	9.007	0.985	0.709	1.704	7.435
0.192	0.808	1074.6	815.6	1.672	10.626	0.877	0.771	2.367	7.991
0.000	1.000	990.0	754.2	1.197	13.528	0.747	0.870	2.159	6.768

DMSO+ Butanol at 333K

Mole fraction		U ms^{-1}	ρ 10^{-3} Nsm^{-2}	η 10^{-3} Nsm^{-2}	β_a 10^{-10} ms^2kg^{-1}	z 10^6 $kgm^{-2}s^{-1}$	L_f 10^{-10} m	τ 10^{-13} s	π_i 10^8 Nm^{-2}
X_1	X_2								
1.000	0.000	1374.4	1071.6	0.992	4.940	1.473	0.530	0.653	6.309
0.814	0.186	1285.6	1019.8	1.310	5.933	1.311	0.581	1.037	7.335
0.622	0.378	1213.2	946	1.286	7.182	1.148	0.639	1.231	7.199
0.385	0.615	1108.0	873.8	1.334	9.322	0.968	0.729	1.659	7.385
0.192	0.808	1060.0	815.4	1.568	10.915	0.864	0.789	2.283	7.910
0.000	1.000	974.8	751.8	1.058	13.998	0.733	0.893	1.975	6.496

III. RESULTS AND DISCUSSION

The table clearly shows that the ultrasonic velocity decreases at temperatures of 303K, 308K, 313K, 318K, 323K and 328K with the rising concentration of butanol and DMSO. The decline in cohesive forces due to poor molecular interactions was followed by a linear decrease in density and ultrasonic velocity with increased solute concentration. Ultrasonic speed in the solutions relies on the length of the intermolecular free path. Figure 1 shows that with changes in concentration, adiabatic compressibility increases. The rise in adiabatic compressibility in these binary mixtures indicates that less hydrogen bonding is produced, indicating a weak intermolecular interaction between solvent and solute. It is also known that the interactions are lower at a higher temperature than at a lower temperature [6].

The velocity decreases as the temperature increases, suggesting more spacing between the molecules. Compared to the ultrasonic velocity in the mixtures.The adiabatic compressibility and Intermolecular free length indicate an inverse behavior. Intermolecular free length, which relies on the adiabatic compressibility and shows a behavior close to that of compressibility. The change in free length also implies that due to which structural rearrangement is also impacted, there is a major interaction between solvent and solute molecule [7].

With the rise in the mole fraction, the relaxation time increases because of the structural relaxation mechanism [8] and in a situation in which the molecules are rearranged due to the cooperative process. A measure of inter-molecular attraction between the components is the internal pressure in a binary mixtures. When the concentration of butanol increases, the internal pressure increases, implying heavy intermolecular bonding of hydrogen due to the polarity of butanol [9].

IV. CONCLUSION

In conclusion, the molecular interaction of DMSO binary mixtures with butanol across the entire composition range has been studied at atmospheric pressure and at temperatures of 303K, 308K, 313K, 318K, 323K and 328K. Acoustical parameters such as acoustic impedance (Z), adiabatic compressibility (β_a), Intermolecular free length

(L_f), relaxation time (τ), internal pressure (π_i) have been determined and the results are interpreted and the observed results will definitely help the researchers for their further research work.

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