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Research Article

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Study of ultrasonic parameters in binary liquid mixture containing quinoline and o-xylene at different temperatures

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ABSTRACT

Density (ρ),Ultrasonic velocity (u), and viscosity (η) values have been measured in the binary system containing quinoline and o-xylene at different temperatures 303.15K, 308.15K, 313.15K and 318.15K over the entire range of composition. The experimental data have been used to calculate the ultrasonic parameters such as adiabatic compressibility (β), free length (L_f), free volume (V_f) and internal pressure (π). The results have been qualitatively used to explain the molecular interaction between the components of the mixture.

Key Words: Density, Ultrasonicvelocity, Viscosity, Quinoline, Free length,o-xylene.

INTRODUCTION

In the recent years ,ultrasonic technique has been found to be one of the most powerful technique for studying the nature of molecular interactions in liquid mixtures. The study of molecular interaction 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. Acoustic and thermodynamic 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. Xylene is widely used in the areas of application include printing, rubber, and leather industries with sweet smelling.Similarly it is a cleaning agent.Quinoline is a colourless liquid with strong odor and widely used in manufacturing of dyes, pesticides and solvent for resins and terpenes. As a part of today's progressive and ongoing research [1-4] on thermodynamic and acoustic properties of binary liquid mixtures, we report here the results of study on binary mixture of quinoline and o-xylene over the entire range of composition at T= 303.15K, 308.15K, 313.15K and 318.15K. Using the experimental values of ultrasonic velocity (u), density (ρ) and viscosity (η), ultrasonic parameters such as adiabatic compressibility, free length, free volume and internal pressure have been estimated using standard relations.

EXPERIMENTAL SECTION

The various concentrations are prepared by varying mole fractions. 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 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 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 4-5 measurements were taken for each sample. 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. Purity of the sample checked with previous investigation[6]. The ultrasonic velocity has an accuracy of ± 0.5 $m.s^{-1}$. The temperature was controlled by circulating water around the liquid cell from thermostatically controlled constant temperature water bath (accuracy ± 0.01K).

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:

$$\eta = k \cdot \rho \cdot t \qquad \text{---} \qquad (1)$$

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, 3-5 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 [7,8] values and are given in Table 1.

THEORY

From the experimentally measured values of ultrasonic velocity (u), density (ρ) and viscosity (η), various ultrasonic derivable parameters such as adiabatic compressibility (β), free length (L_f), free volume (V_f) and internal pressure (π) are calculated using the following equations:

$$\beta = 1/\rho u^2 \qquad \text{---} \qquad (2)$$
$$L_f = K_T \beta^{1/2} \qquad \text{---} \qquad (3)$$
$$V_f = M_{eff}\, u/\eta K \qquad \text{---} \qquad (4)$$
$$\pi = bRT\,(K\eta/u)(\rho^{2/3}/M^{7/6}) \qquad \text{---} \qquad (5)$$

where K_T is the temperature dependent constant, M is the effective molecular weight of the solution, K is the temperature independent constant ($K = 4.28 \times 10^9$), b a constant which is 2 for cubic packing, R the gas constant and T is the temperature in K.

RESULTS AND DISCUSSION

The experimentally calculated values of density, viscosity and ultrasonic velocity for the binary system over the entire range of composition and at temperatures 303.15K, 308.15K, 313.15K and 318.15K are presented in Table 2. Ultrasonic Parameters such as adiabatic compressibility, free length, free volume and internal pressure have been estimated using standard relations and are given in Table 3. From Table 2 it is observed that the ultrasonic velocity increases with increase in mole fraction of quinoline. This may be due to association of a very strong dipole-induced dipole interaction between the component molecules.

Adiabatic compressibility is a measure of intermolecular association or dissociation or repulsion. It is independent of temperature and pressure for unassociated 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 the table 3 it is observed that adiabatic compressibility decreases with increase in mole fraction of quinoline 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 quinoline. From table 3 it is also observed that, the values of L_f and β increases with increase in temperatures, it clearly reveals that interaction become weaker at higher temperatures.

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 decrease in intermolecular free length indicates the interaction between the solute and solvent molecules due to which the structural arrangement in the neighbourhood of constituent ions or molecules gets affected considerably.From table 3 it is observed that, the intermolecular free length L_f decreases with increase in mole fraction of quinoline which shows that the dipole-induced dipole interaction becomes stronger which makes the system less compressible as evident from the values of adiabatic compressibility. The observed increase in ultrasonic velocity and corresponding decrease in L_f with mole fraction of quinoline in all the mixtures is in accordance with the proposed by Eyring and kincard [9] . From table 3 it is observed that, free volume first decreases and then increases with increase in mole fraction of quinoline.

Free volume is defined as the average volume in which the centre of the molecules can move inside the hypothetical cell due to the repulsion of surrounding molecules.

Also it is observed from table 3 that internal pressure increases with increase in mole fraction of quinoline.

Internal pressure is a fundamental property of a liquid, which provides an excellent basis for examining the solution phenomenon and studying various properties of the liquid state. It is a measure of the change in the internal energy of liquid or liquid mixtures, as it undergoes a very small isothermal change. It is a measure of cohesive or binding forces between the solute and solvent molecules.

Table 1 Experimental and literature values of density and ultrasonic velocity of pure liquids.

Liquids	ρ / (kg.m^{-3})		U / (m.s^{-1})	
	Expt	Lit	Expt	Lit
Quinoline	1085.45	1085.79[7]	1553.68	1547[7]
o-Xylene	870.70	870.73[8]	1338.75	1328.30[8]

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[8] *Jaseem et al.*

Table 2 Values of density (ρ), viscosity (η) and ultrasonic velocity (u) of liquid mixture at T = 303.15K, 308.15K, 313.15K and 318.15K

X1	ρ kgm^{-3}	ηX10^{-3} Nsm^{-2}	u ms^{-1}	ρ kgm^{-3}	ηX10^{-3} Nsm^{-2}	u ms^{-1}
Quinoline+O-xylene						
	T=303.15K			**T=308.15K**		
0	870.70	0.7050	1338.75	869.4000	0.6652	1315.00
0.1022	901.40	0.8420	1376.84	896.7850	0.7616	1364.21
0.2039	922.99	0.9360	1408.42	919.0240	0.8545	1398.95
0.3051	942.22	1.1050	1424.21	936.5920	0.9835	1417.89
0.4058	961.85	1.2320	1446.32	956.6990	1.1211	1436.84
0.5060	981.69	1.4060	1465.26	977.9230	1.2604	1458.95
0.6058	1001.73	1.6430	1496.84	998.6390	1.4624	1487.37
0.7050	1027.16	1.9870	1509.47	1021.9956	1.7827	1506.32
0.8038	1047.92	2.1700	1531.58	1042.7120	1.9573	1518.95
0.9021	1067.14	2.6010	1544.21	1063.2250	2.3254	1528.42
1.0000	1085.45	2.9320	1553.68	1082.1100	2.7072	1550.68
	T=313.15K			**T=318.15K**		
0	867.70	0.6210	1297.50	865.9000	0.5690	1278.15
0.1022	893.69	0.6910	1357.89	891.3140	0.6890	1348.42
0.2039	915.51	0.7610	1376.84	911.4970	0.7520	1364.21
0.3051	932.06	0.8790	1408.42	929.8550	0.8580	1398.95
0.4058	952.25	1.0180	1430.53	948.1110	0.9850	1421.02
0.5060	974.98	1.1160	1455.79	967.2810	1.0890	1443.16
0.6058	995.28	1.3160	1481.05	990.7100	1.2880	1468.42
0.7050	1018.22	1.5710	1500.00	1013.2260	1.4960	1481.05
0.8038	1039.33	1.7280	1509.47	1036.8570	1.7130	1493.68
0.9021	1058.07	2.0540	1518.95	1054.6070	2.0030	1512.63
1.0000	1078.60	2.4470	1547.37	1074.9900	2.4300	1541.05

Table 3 Values of adiabatic compressibility, inter molecular free length, free volume and internal pressure of liquid mixture at T = 303.15K, 308.15K, 313.15K and 318.15K

X1	β X10^{-11} Kg^{-1} m s^{2}	L_f A^{O}	V_fX10^{-7} m^{3}	π X10^{6} atm	β X10^{-11} Kg^{-1} m s^{2}	L_f A^{O}	V_fX10^{-7} m^{3}	π X10^{6} Atm
Quinoline+O-xylene								
	T=303.15K				**T=308.15K**			
0.0000	64.0815	0.0159	3.2245	294.34	66.5164	0.0163	3.4257	288.17
0.1022	58.5213	0.0152	2.6643	316.34	59.9169	0.0155	3.0538	301.24
0.2039	54.6182	0.0147	2.4268	326.84	55.5995	0.0149	2.7550	312.41
0.3051	52.3240	0.0143	1.9843	349.49	53.1083	0.0146	2.3490	329.06
0.4058	49.7011	0.0140	1.7792	362.51	50.6299	0.0142	2.0297	345.70
0.5060	47.4455	0.0137	1.5337	381.06	48.0415	0.0138	1.7946	360.70
0.6058	44.5551	0.0132	1.2904	403.88	45.2642	0.0134	1.5215	381.52
0.7050	42.7277	0.0130	1.0100	440.07	43.1240	0.0131	1.1852	415.82
0.8038	40.6814	0.0126	0.9303	452.78	41.5672	0.0129	1.0724	430.39
0.9021	39.2975	0.0124	0.7370	489.38	40.2614	0.0127	0.8588	463.93
1.0000	38.1650	0.0122	0.6384	513.20	38.4310	0.0124	0.7173	492.61
	T=313.15K				**T=318.15K**			
0.0000	68.4567	0.0166	3.7214	279.96	70.6917	0.0170	4.1484	269.63
0.1022	60.6848	0.0157	3.5070	287.00	61.7047	0.0159	3.4898	286.96
0.2039	57.6193	0.0153	3.2012	296.41	58.9498	0.0156	3.2123	295.20
0.3051	54.0871	0.0148	2.7501	311.20	54.9518	0.0150	2.8239	307.98
0.4058	51.3165	0.0144	2.3295	329.15	52.2324	0.0146	2.4246	323.85
0.5060	48.3956	0.0140	2.1468	339.10	49.6386	0.0143	2.1983	334.65
0.6058	45.8051	0.0136	1.7712	361.86	46.8115	0.0139	1.8053	358.47
0.7050	43.6493	0.0133	1.4242	390.16	44.9938	0.0136	1.5036	381.92
0.8038	42.2277	0.0131	1.2811	404.74	43.2279	0.0133	1.2774	404.50
0.9021	40.9638	0.0129	1.0248	435.96	41.4422	0.0130	1.0576	430.47
1.0000	38.7214	0.0125	0.8321	467.82	39.1708	0.0127	0.8355	466.14

CONCLUSION

It is very obvious from values of ultrasonic velocity, density and viscosity, and related ultrasonic parameters values for the binary liquid mixture of quinoline and o-xylene at 303.15K, 308.15K, 313.15K and 318.15K, that there exists a strong molecular association between the components of the liquid mixture.

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