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Ultrasonic study of binary mixtures of sesame oil and ethyl ethanoate at different temperatures

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ABSTRACT

The ultrasonic velocity and density are measured in binary mixture of ethyl ethanoate and sesame oil at 298.15K, 303.15K, 308.15K and 313.15K. Acoustical parameters such as isentropic compressibility, intermolecular free length, specific acoustic impedance, molar volume, available volume, volume at absolute zero, Van der waal's constant, Rao's Constant and Wada's Constant have been evaluated. Except isentropic compressibility all the other calculated parameters shows decreasing trend with the increase in concentration of solvent and increase in temperature. The variation of these parameters with temperature and concentration are used to study the intermolecular interaction existing between the components of the mixture.

Introduction

The measurement of speed of sound in liquid mixtures plays important role in determining their physico-chemical behavior and structure of liquids. The ultrasonic velocity gives more details about the bonding between the molecules of the components of the binary mixtures[1-4]. The acoustic and thermodynamic properties are studied for various binary mixtures. But the literature shows scarce results on the study of edible oils with organic solvents which are in great demand for the oil industry. In this work, for the binary mixture of sesame oil and ethyl ethanoate the ultrasonic velocity and density are measured at various temperatures and used to compute the thermo acoustical parameters.

Experimental

The densities of pure liquids, ethyl ethanoate (Merck) and sesame oil and binary mixtures were measured using 25ml relative density bottle with an accuracy of 0.001kg/m^3. The ultrasonic velocities are measured by an ultrasonic interferometer (Mittal) at a frequency of 2 MHz with an accuracy of 0.01m/s. The measurements are made at different temperature of 298.15K, 303.15K, 308.15K and 313.15K, with the help of digitally controlled temperature bath (Raagaa) with an accuracy of 0.01K.

Results and Discussion

Isentropic compressibility (K_s)[5] has been calculated from the equation,

$$K_s = \frac{1}{\rho u^2} \quad ------(1)$$

where ρ and u are density and ultrasonic velocity in liquid mixture.

The intermolecular free length (L_f)[6] is determined using the Jacobson's relation,

$$L_f = \frac{K}{u\rho^{1/2}} \quad ------(2)$$

where K is the temperature Jacobson's constant given by the relation K=(93.875+0.375 T)x10^{-8}.

The specific acoustic impedance (Z)[7] is given by the formula,

$$Z = u.\rho \quad ------(3)$$

The available volume (V_a) is calculated from the following expression.

$$V_a = V_m\left(1 - \frac{u}{u_\infty}\right) \quad ------(4)$$

where, V_m is the molar volume and u_∞ is the limiting ultrasonic velocity.

The Van der Waals constant[8] (b), Rao's constant[9] (R) and Wada's constant[10] (W) are estimated from the following equations.

$$b = \frac{M_{eff}}{\rho} - \frac{RT}{\rho u^2}\left(\sqrt{\frac{1+Mu^2}{3RT}} - 1\right) \quad -----(5)$$

$$R = \frac{M_{eff}\, u^{\frac{1}{3}}}{\rho} \quad ------(6)$$

$$W = V_m K_s^{-1/7} \quad ------(7)$$

where, R is the universal gas constant, T is the temperature and u_∞ is the limiting ultrasonic velocity which is equal to 1600m/s.

The experimentally measured values of ultrasonic velocity along with the computed values of acoustical parameters at different temperatures are presented in Tables 1-4.

The ultrasonic velocity is observed to decrease with increase in concentration of ethyl ethanoate, indicating the

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presence of interactions between the components of the mixtures. The ultrasonic velocity is found to decrease with increase with temperature also.

The intermolecular free length and isentropic compressibility of the binary mixtures shows the opposite trend to that of the velocity.

The increasing trend of free length shows that the distance between surfaces of molecules increases and thereby reducing the ordering of molecules. Eyring and Kinkaid[11] proposed that the free length and compressibility increases with decrease in velocity and vice versa.

The increase in intermolecular free length leads to an increase in compressibility with rise in temperature (Pandey)[12]. An increase in the adiabatic compressibility shows a tendency towards less ordering resulting in a decrease of ultrasonic velocity of the binary mixture (Tabhane and Patki)[13].

Thus the variation of intermolecular free length and adiabatic compressibility with concentration of solvent suggests that molecular arrangement becomes less ordered as the mole fraction increases.

The values of acoustic impedance decrease with the increase in concentration. Van der Waal's constants, Rao's constant and Wada's constant are independent of temperature and the variations of these constants with mole fractions are linear.

Conclusion

The ultrasonic velocity of binary liquid mixture sesame oil and ethyl ethanoate is found to decrease with increase in concentration of the solvent and increase in temperature. The isentropic compressibility and intermolecular free length increases with the increase in concentration and temperature and all the other measured parameters shows decreasing values.

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Table 1 Ultrasonic velocity and acoustic parameters of binary mixture at 298.15K

X1	u(m/s)	L_f (10^{-11} m)	K_s $(TPa)^{-1}$	Z ($10^3 Kg/m^2/s$)	Va (10^{-3} m^3/mol)	b (10^{-3} m^3/mol)	R (10^{-3} m^3/mol)	W (10^{-3} m^3/mol)
0.0494	1452.0	4.6810	517.94	1329.70	84.49	912.82	10343.62	13943.05
0.0994	1450.1	4.6875	519.39	1327.73	81.57	870.00	9854.29	13283.94
0.1958	1448.0	4.6951	521.07	1325.37	74.86	787.40	8914.69	12017.59
0.2986	1440.0	4.7219	527.05	1317.61	69.98	699.24	7902.33	10655.18
0.3986	1428.8	4.7600	535.59	1306.77	65.70	613.51	6915.87	9327.94
0.4984	1416.0	4.8047	545.69	1294.17	60.78	528.00	5934.55	8006.99
0.5996	1400.0	4.8616	558.69	1278.49	55.21	441.22	4940.95	6669.25
0.6990	1376.0	4.9497	579.12	1254.91	49.90	356.04	3964.67	5354.87
0.7996	1344.0	5.0732	608.39	1222.99	43.23	269.85	2981.99	4030.83
0.8999	1276.0	5.3551	677.88	1156.11	37.31	183.91	1998.20	2706.04
0.9498	1226.4	5.5833	736.88	1106.56	33.03	141.16	1514.13	2053.14

Table 2 Ultrasonic velocity and acoustic parameters of binary mixture at 303.15K

X1	U(m/s)	L_f (10^{-11} m)	K_s $(TPa)^{-1}$	Z ($10^3 Kg/m^2/s$)	Va (10^{-3} m^3/mol)	b (10^{-3} m^3/mol)	R (10^{-3} m^3/mol)	W (10^{-3} m^3/mol)
0.0494	1432.1	4.7564	534.78	1305.73	96.28	916.83	10341.4	13940.5
0.0994	1428.6	4.7688	537.57	1302.13	93.69	873.95	9849.9	13278.8
0.1958	1424.0	4.7840	541.00	1298.05	87.04	790.64	8901.7	12002.6
0.2986	1420.4	4.7978	544.11	1293.90	78.90	702.36	7901.5	10654.2
0.3986	1416.0	4.8139	547.79	1289.21	70.93	616.29	6926.4	9340.1
0.4984	1408.0	4.8448	554.84	1280.07	63.75	530.80	5954.8	8030.4
0.5996	1384.0	4.9320	574.99	1256.62	59.97	443.77	4950.5	6680.3
0.6990	1360.0	5.0220	596.17	1233.37	53.77	358.04	3971.5	5362.8
0.7996	1336.0	5.1168	618.88	1209.45	44.82	271.24	2991.4	4041.8
0.8999	1264.0	5.4247	695.62	1137.32	38.96	185.18	2005.8	2714.8
0.9498	1208.0	5.6872	764.54	1082.75	34.89	142.10	1516.5	2055.9

Table 3 Ultrasonic velocity and acoustic parameters of binary mixture at 308.15K

X1	U(m/s)	L_f (10^{-11} m)	K_s $(TPa)^{-1}$	Z ($10^3 Kg/m^2/s$)	Va (10^{-3} m^3/mol)	b (10^{-3} m^3/mol)	R (10^{-3} m^3/mol)	W (10^{-3} m^3/mol)
0.0494	1417.2	4.8123	547.41	1289.00	105.08	919.06	10330.6	13928.0
0.0994	1410.0	4.8390	553.51	1281.32	104.17	876.56	9836.4	13263.3
0.1958	1406.0	4.8541	556.97	1276.99	96.29	793.51	8896.4	11996.4
0.2986	1404.6	4.8597	558.26	1275.29	86.13	704.67	7898.1	10650.3
0.3986	1400.0	4.8764	562.09	1270.77	77.34	618.16	6921.3	9334.2
0.4984	1396.0	4.8944	566.25	1265.04	67.96	532.52	5957.1	8033.1
0.5996	1368.0	4.9964	590.09	1238.78	64.59	444.95	4944.5	6673.4
0.6990	1344.0	5.0897	612.34	1215.10	57.53	359.15	3968.1	5358.8
0.7996	1304.0	5.2537	652.44	1175.39	50.47	272.41	2980.2	4028.8
0.8999	1248.0	5.5054	716.45	1118.41	40.98	185.93	2005.3	2714.3
0.9498	1184.0	5.8126	798.64	1057.54	37.15	142.59	1511.7	2050.3

Table 4 Ultrasonic velocity and acoustic parameters of binary mixture at 313.15K

X1	U(m/s)	L_f (10^{-11} m)	K_s $(TPa)^{-1}$	Z ($10^3 Kg/m^2/s$)	Va (10^{-3} m^3/mol)	b (10^{-3} m^3/mol)	R (10^{-3} m^3/mol)	W (10^{-3} m^3/mol)
0.0494	1400.9	4.8744	561.64	1270.97	114.73	921.37	10316.8	13912.1
0.0994	1397.2	4.8900	565.24	1266.21	111.49	878.97	9833.5	13259.9
0.1958	1400.0	4.8830	563.62	1267.31	99.60	796.16	8913.3	12016.0
0.2986	1394.1	4.9047	568.64	1261.44	91.07	707.08	7905.3	10658.6
0.3986	1387.2	4.9302	574.57	1254.64	82.58	620.38	6924.9	9338.4
0.4984	1384.0	4.9445	577.91	1250.26	72.18	534.18	5958.5	8034.7
0.5996	1352.0	5.0657	606.58	1219.37	69.32	446.74	4945.1	6674.0
0.6990	1328.0	5.1611	629.65	1195.92	61.37	360.56	3967.9	5358.6
0.7996	1288.0	5.3298	671.48	1156.25	53.41	273.51	2980.1	4028.6
0.8999	1212.0	5.6852	764.02	1079.92	45.43	186.99	1997.3	2705.0
0.9498	1168.0	5.9106	825.80	1036.76	38.82	143.48	1514.3	2053.3