

Study of Ultrasonic Velocity in Ternary Liquid Mixtures Using Surface Tension Relations

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Surface tension has been evaluated for the ternary liquid mixtures at 298.15 K. These values have been employed in the prediction of ultrasonic velocity using Auerbach relation. A good agreement between experimental and evaluated values has been reported.

Key Words: Surface tension, Ultrasonic velocity, Ternary liquid mixtures.

INTRODUCTION

The surface tension can be exactly related to the intermolecular forces through statistical thermodynamics. Such an equation was derived by Kirkwood and Buff¹ but it is difficult to use because one must first know how the molecules are distributed through the surface. Kirkwood and Buff⁷ equation is valid only for simple spherical molecules. However, much more several equations have recently been derived which are applicable to more complex molecules. The theories of surface tension reviewed by different investigators^{2–14} are all based to some extent on statistical thermodynamics but they also involve some degree of empirical fittings in most cases. Here, the semi-empirical relation of Brock and Bird¹⁵, designed for the estimation of surface tension of pure liquids have been extended in the case of aforesaid ternary liquid mixtures successfully and the value of surface tension thus obtained has been used to evaluate ultrasonic speed for the above systems.

Brock and Bird¹⁵ have found the following correlation between the critical contents and surface tension.

$$\frac{\sigma}{(P_{c,m}^2 T_{c,m}^2)^{1/9}} = \left(-0.951 + \frac{0.432}{Z_{c,m}} \right) (1 - T_{r,m})^{11/9} \quad (1)$$

where T , $P_{c,m}$, $T_{c,m}$, $Z_{c,m}$ and $T_{r,m}$ are respectively the critical pressure, critical temperature, critical compressibility factor and reduced temperature of ternary liquid mixtures. The values of these parameters are obtained by taking mole fraction averages as

$$P_{c,m} = \sum_1^3 X_1 P_{c,1} \text{ (for ternary system)}$$

$$V_{c,m} = \sum_1^3 X_1 V_{c,1} \text{ (for ternary system)}$$

$$T_{c,m} = \sum_1^3 X_1 T_{c,1} \text{ (for ternary system)}$$

$$Z_{c,m} = \frac{P_{c,m} V_{c,m}}{RT_{c,m}}$$

and

$$T_{r,m} = T/T_{c,m}$$

Thus using pseudo critical constants of mixtures, the values of surface tension can be calculated using equation (1). These values, further, can be used to evaluate ultrasonic speeds in ternary liquid mixtures by the equation¹⁶

$$U = \left(\frac{\sigma}{6.3 \times 10^{-4} \rho} \right)^{2/3} \quad (2)$$

The data necessary for the evaluation of surface tension and ultrasonic speed have been taken from different sources of literature¹⁷⁻²⁰.

RESULTS AND DISCUSSION

The theoretical and experimental values of ultrasonic speed along with the surface tension values of ternary (*n*-hexane + *n*-heptene + toluene, *n*-hexane + cyclohexane + benzene and *n*-pentane + *n*-hexane + benzene at 298.15 K) liquid mixtures are enlisted in Table-1. A perusal of the table indicates a good agreement between predicted and experimental ultrasonic speeds.

The sign of the % deviations plays a vital role in assessing the molecular arrangement and extent of molecular association in ternary liquid mixtures (Table-1). The negative value of deviation is an indication of strong interaction in liquid mixtures. It is due to charge transfer, dipole-induced dipole and dipole-dipole interactions, while positive sign indicates weak interactions and attributed to dispersion forces. In the first set of ternary mixtures, alkane molecules take their position between minimum available space left by two benzene molecules providing an ordered compact structure. Transference of charges due to the partial double bond in benzene is found to be helpful in providing the compact-structural arrangement of the molecules. The other two sets of ternary mixtures have less compact structural arrangements due to large structural spaces. Charge transfer does not play a significant role in mixtures 2 and 3.

TABLE-1
SOUND VELOCITY AND SURFACE TENSION OF TERNARY LIQUID MIXTURES

X_1	X_2	U_{expt}	U_{cal}	σ (dyne/cm)	% dev.
<i>n</i> -Pentane + <i>n</i> -Hexane + Benzene (1)					
0.0966	0.4171	1201.1	1227.4	20.134	2.14
0.1428	0.3739	1197.5	1229.8	20.151	2.62
0.2017	0.3388	1193.2	1229.0	19.980	2.91
0.2590	0.3038	1187.7	1230.5	19.814	3.47
0.2984	0.2877	1177.2	1230.3	19.623	4.31
0.3075	0.2945	1175.2	1226.9	19.480	4.21
0.3420	0.3143	1173.4	1221.3	19.019	3.92
0.3685	0.3523	1170.2	1213.0	18.507	3.52
0.4099	0.3888	1178.4	1201.5	17.943	1.92
0.4082	0.4665	1163.2	1198.8	17.489	2.96
<i>n</i> -Hexane + Cyclohexane + Benzene (2)					
0.0771	0.4315	1278.1	1301.1	23.823	1.76
0.1269	0.4149	1267.5	1292.3	23.225	1.91
0.1795	0.3854	1261.2	1279.2	22.633	1.40
0.2279	0.3501	1251.2	1232.0	21.168	-1.55
0.2616	0.3342	1263.5	1262.6	21.860	-0.0071
0.2812	0.3318	1256.3	1261.3	21.653	0.396
0.3021	0.3643	1260.2	1256.9	21.387	0.026
0.3062	0.3823	1248.4	1257.8	21.315	0.747
0.3448	0.4566	1259.1	1251.5	20.865	-0.607
0.3231	0.4851	1244.2	1256.8	21.008	1.002
<i>n</i> -Hexane + <i>n</i> -Heptane + Toluene (3)					
0.1124	0.3962	1328.8	1338.9	24.262	0.75
0.1761	0.3766	1319.2	1325.7	23.724	0.49
0.2452	0.3379	1317.4	1305.8	23.210	-0.88
0.3027	0.3032	1307.3	1289.8	22.798	-1.35
0.3479	0.2837	1321.5	1275.2	22.449	-3.63
0.3766	0.2895	1318.5	1268.1	22.168	-7.88
0.3907	0.3050	1323.2	1263.4	21.991	-4.75
0.4198	0.3416	1308.2	1261.0	21.636	-3.74
0.4468	0.3796	1321.4	1255.3	21.316	-5.26
0.4525	0.4393	1303.2	1261.1	21.148	-3.33

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