

EVALUATION OF ULTRASONIC VELOCITY AND PERCENTAGE DEVIATION OF TERNARY MIXTURES AT DIFFERENT TEMPERATURES

J.Thennarasu¹ and G. Meenakshi²

¹Department of Physics, Sri Aravindar Engineering College, Villupuram

²Department of Physics, KMCPGS Lawspet, Pondicherry University, Pondicherry.

*E-mail:thennarasu_30@rediffmail.com

ABSTRACT

Investigation based on the behavior of propagation of ultrasonic waves in Solids and liquid system are now rather well established as an effective means for examining certain physical properties of the materials. The data obtained from ultrasonic propagation parameters such as ultrasonic velocity, adiabatic compressibility, molar volume, free length etc; and their variation with concentration of one of the component of the medium are useful in understanding the nature of molecular interaction in terms of physical parameters. Owing to the sensitivity to very low population densities at high energy states, ultrasonic methods have been preferred and are reported to be complementary to other technique like dielectric relaxation, I.R spectroscopy, N.M.R etc. A Thorough study of literature reveals that the ternary liquids and liquid mixtures were studied and reported by different scientists. They reported on the nature of forces involved in the formation of the hydrogen bonds. The research work on benzene with ethyl methyl ketone and acetophenone at 293k, 298k, and 303k system is scanty, and one of the reasons for the same is that weak complex formations arise in the hydrogen bonds. In the study of molecular interactions, the O-H finds an important role as it is highly polar and associates with any other group in a molecule having some degree of polar attraction. The present investigation has been undertaken to study the nature of interaction between benzene with ethyl methyl ketone and Acetophenone at 293k, 298k, and 303k.

Keywords: Ultrasonic velocity, adiabatic compressibility, Nomoto's relation, Vandael ideal mixing relation, Schaff's collision factor theory, Molecular interactions.

© 2011 RASĀYAN. All rights reserved.

INTRODUCTION

Densities and ultrasonic velocity of ternary mixtures of Benzene with Ethyl methyl ketone and Acetophenone at 293k, 298k, and 303k were measured over the entire composition range. Ultrasonic velocities theoretically evaluated using nomoto's relation; vandael ideal mixing relation and schaff's collision factor theory are compared with experimental values to check applicability of these equations to the system studied.

Ultrasonic velocity of sound waves in a medium is fundamentally related to the binding forces between the molecules. Ultrasonic velocities of the liquid mixtures consisting of polar and non-polar components are of considerable importance in understanding intermolecular interaction between components molecules and find application in several industrial and technological processes. Ultrasonic velocity measurements have been employed extensively to detect and assess weak and strong molecular interactions in binary mixtures, because mixed solvents find practical applications in many chemical and industrial processes. Increasing use of benzene and acetophenone in many industrial processes have greatly stimulated the need for extensive information on the acoustic and transport properties of these liquids and their mixtures. The parameters such as ultrasonic velocity (U), density (ρ), and derived parameters provide better insight into intermolecular interactions. The investigation is carried out to study of molecular interactions in the ternary liquid mixtures of benzene + ethyl methyl ketone + acetophenone.

EXPERIMENTAL

During the recent years considerable interest has been developed in the ultrasonic studies of ternary liquid mixtures. Kannappan and V.Rajendiran¹ measured the ultrasonic velocity in three ternary liquid mixtures of benzene, ethyl methyl ketone and acetophenone at 293k, 298k, and 303k and also compared the relative merits for theoretical evaluation of sound velocity in the liquid mixtures.

Nomoto's empirical formula for sound velocity in ternary liquid mixtures in terms of polar sound velocity R_{mix} and molar volume V_{mix} as-

$$U_{\text{mix}} = (R_{\text{mix}}/V_{\text{mix}})^3 \quad (1)$$

$$U_{\text{mix}} = \{(X_1 R_1 + X_2 R_2 + X_3 R_3) / (X_1 V_1 + X_2 V_2 + X_3 V_3)\}^3 \quad (2)$$

where,

$$R = (M/\rho) U^{1/3} \quad (3)$$

The symbols have the usual meaning as already discussed. Vandael's expression for sound velocity in ternary liquid mixtures is

$$(1/X_1 M_1 + X_2 M_2 + X_3 M_3) (1/U_{\text{im}}^2) = X_1/M_1 U_1^2 + X_2/M_2 U_2^2 + X_3/M_3 U_3^2 \quad (4)$$

Schaff's and nutsch-kunhkies expression for sound velocity in ternary liquid mixture is

$$U_{\text{mix}} = U \alpha (X_1 S_1 + X_2 S_2 + X_3 S_3) (X_1 B_1 + X_2 B_2 + X_3 B_3) / V_m \quad (5)$$

where,

$$U \alpha = 1600 \text{ ms}^{-1}$$

S_1, S_2, S_3 & B_1, B_2, B_3 are the collision factors and actual volumes of the molecules per mole of the first and second components respectively.

Table-1: Ultrasonic velocity and density of Ternary Liquid Mixtures

S.No.	Substances	293.15k		298.15k		303.15k	
		Density(ρ) $\times 10^3 \text{ Kgm}^{-3}$	Ultrasonic velocity (U) ms^{-1}	Density (ρ) $\times 10^3 \text{ Kgm}^{-3}$	Ultrasonic velocity (U) ms^{-1}	Density(ρ) $\times 10^3 \text{ Kgm}^{-3}$	Ultrasonic velocity (U) ms^{-1}
1.	Benzene	868.42	1321.6	864.74	1304.1	861.1	1289
2.	Ethyl methyl Ketone	796.18	1230.7	792.13	1214.3	788.14	1129.6
3.	Acetophenone	477.53	1468.8	246.23	1464.7	146.72	1460.1

Table-2: Ultrasonic velocity of Ternary Mixture (Benzene + Ethylmethyl Ketone + Acetophenone) at 293K

S.No.	Mole fraction		Density $\rho \text{ Kgm}^{-3}$	Molar Sound Velocity R_{mix}	ULTRASONIC VELOCITY(U)			
	X_1	X_3			$U_{\text{expt}} \text{ ms}^{-1}$	$U_{(\text{mix})\text{nomoto}} \text{ ms}^{-1}$	$U_{\text{im vandael}} \text{ ms}^{-1}$	$U_{\text{im CFT}} \text{ ms}^{-1}$
1.	0.074004	0.657395	995.236	1.467705	1388.360	1389.465	1384.993	1379.99
2.	0.147932	0.580504	975.365	1.465665	1387.525	1384.971	1379.981	1377.562
3.	0.221784	0.504619	965.998	1.464528	1382.236	1380.381	1374.969	1375.134
4.	0.295562	0.42972	923.201	1.464273	1379.858	1375.699	1369.957	1372.706
5.	0.369265	0.355788	898.250	1.464884	1375.556	1370.934	1364.945	1370.278
6.	0.442892	0.282804	853.633	1.466342	1370.010	1366.092	1359.933	1367.85
7.	0.516445	0.210751	829.231	1.468629	1365.239	1361.182	1354.921	1365.422
8.	0.589923	0.139611	789.952	1.471729	1359.369	1356.211	1349.909	1362.994
9.	0.663327	0.069366	770.010	1.475624	1353.292	1351.188	1344.897	1360.566

RESULTS AND DISCUSSION

Ultrasonic velocity and density²⁻⁶ for the pure components of benzene, ethyl methyl ketone and acetophenone at 293K, 298 K , and 303 K are given in the table.

Ultrasonic velocity of ternary liquid mixtures benzene, ethyl methyl ketone and acetophenone at 293k, 298k, and 303k are evaluated and are given in tables respectively. The variation of ultrasonic velocity with concentration of benzene, ethyl methyl ketone and acetophenone at 293k, 298k, and 303k are theoretically calculated. The percentage deviations of theoretically calculated ultrasonic velocity from the experimental results are also given in the table. The values of ultrasonic velocity have been evaluated theoretically using three different methods namely, nomoto, vandael and collision factor method.

The selected mixtures can be analyzed with polar solute in polar solvent. In all the three methods the increase of mole fractions in the solution decreases the ultrasonic velocity with respect to the experimental values. It may be due to the fact that the benzene which is having high density than ethyl methyl ketone and acetophenone. In all the three temperatures namely 293k, 298k, and 303k only nomoto, vandael shows positive deviation whereas the CFT method shows negative deviation⁷. The result shows, among all the above mentioned methods, nomoto shows better agreement with the experimental values followed by vandael. For nomoto method, the percentage deviation increases first and then decreases with increase in molar fraction at all the selected temperatures. In the case of vandael, the percentage deviation^{8, 9} increases with the increases in the mole fraction at all selected temperatures. In the case of CFT, the percentage deviation decreases with the increases in the mole fraction at all selected temperatures.

Based on the theoretical values of ultrasonic velocity, it is worthwhile to state that nomoto method yield the best result in all the cases. The CFT method also shows good results. Whereas the results obtained from the vandael method are not found to be satisfactory¹⁰. The percentage deviation can be studied on the basis of interaction between the components of the mixture.

Table-3: Ultrasonic velocity of Ternary Mixture (Benzene + Ethylmethyl Ketone + Acetophenone) at 298K

S.No.	Mole fraction		Density	Molar Sound Velocity	ULTRASONIC VELOCITY(U)			
	X ₁	X ₃	ρ Kgm ⁻³	R _{mix}	U _{expt} ms ⁻¹	U _{(mix)nomoto} ms ⁻¹	U _{im vandael} ms ⁻¹	U _{im CFT} ms ⁻¹
1.	0.074004	0.657395	993.06	1.68437	1384.223	1364.8882	1359.963	1360.068
2.	0.147932	0.580504	974.239	1.68134	1386.889	1359.018	1357.428	1357.999
3.	0.221784	0.504619	964.989	1.67952	1381.019	1353.0212	1354.893	1355.93
4.	0.295562	0.42972	921.023	1.67885	1378.555	1346.9099	1352.358	1353.861
5.	0.369265	0.355788	897.029	1.67931	1374.598	1340.698	1349.823	1351.792
6.	0.442892	0.282804	851.028	1.68089	1368.909	1334.402	1347.288	1349.723
7.	0.516445	0.210751	827.779	1.68354	1366.668	1328.037	1344.753	1347.654
8.	0.589923	0.139611	784.036	1.68725	1358.806	1321.6209	1342.218	1345.585
9.	0.663327	0.069366	768.883	1.69199	1352.368	1315.169	1339.683	1343.516

Table-4: Ultrasonic velocity of Ternary Mixture (Benzene + Ethylmethyl Ketone + Acetophenone) at 303K

S.No.	Mole fraction		Density	Molar Sound Velocity	ULTRASONIC VELOCITY(U)			
	X ₁	X ₃	ρ Kgm ⁻³	R _{mix}	U _{expt} ms ⁻¹	U _{(mix)nomoto} ms ⁻¹	U _{im vandael} ms ⁻¹	U _{im CFT} ms ⁻¹
1.	0.074004	0.657395	975.069	1.117666	1382.300	1359.632	1343.556	1352.252

2.	0.147932	0.580504	968.898	1.118127	1381.069	1354.454	1341.229	1348.889
3.	0.221784	0.504619	944.445	1.119879	1377.206	1349.276	1338.902	1345.526
4.	0.295562	0.42972	898.862	1.122888	1374.002	1344.098	1336.575	1342.163
5.	0.369265	0.355788	845.658	1.127121	1369.658	1338.92	1334.248	1338.8
6.	0.442892	0.282804	822.201	1.132546	1360.001	1333.742	1331.921	1335.437
7.	0.516445	0.210751	798.869	1.139131	1354.259	1328.564	1329.594	1332.074
8.	0.589923	0.139611	776.329	1.146848	1347.778	1323.386	1327.267	1328.711
9.	0.663327	0.069366	755.598	1.155666	1339.963	1318.208	1324.94	1325.348

Table-5: Percentage Deviation of Ternary Mixture (Benzene + Ethylmethyl Ketone + Acetophenone) at 293K

S. No.	Mole fraction		Density	Molar Sound Velocity	% DEVIATION		
	X ₁	X ₃	ρ Kgm ⁻³	Rmix	U _{(mix)nomoto} ms ⁻¹	U _{im vandeal} ms ⁻¹	U _{im CFT} ms ⁻¹
1.	0.074004	0.657395	995.236	1.467705	-0.07	0.24	0.66
2.	0.147932	0.580504	975.365	1.465665	0.18	0.54	0.71
3.	0.221784	0.504619	965.998	1.464528	0.13	0.52	0.51
4.	0.295562	0.42972	923.201	1.464273	0.30	0.71	0.51
5.	0.369265	0.355788	898.250	1.464884	0.33	0.77	0.38
6.	0.442892	0.282804	853.633	1.466342	0.28	0.73	0.15
7.	0.516445	0.210751	829.231	1.468629	0.29	0.75	-0.01
8.	0.589923	0.139611	789.952	1.471729	0.23	0.69	-0.26
9.	0.663327	0.069366	770.010	1.475624	0.15	0.62	-0.51

Table-6: Percentage Deviation of Ternary Mixture (Benzene + Ethylmethyl Ketone + Acetophenone) at 298K

S. No.	Mole fraction		Density	Molar Sound Velocity	% DEVIATION		
	X ₁	X ₃	ρ Kgm ⁻³	Rmix	U _{(mix)nomoto} ms ⁻¹	U _{im vandeal} ms ⁻¹	U _{im CFT} ms ⁻¹
1.	0.074004	0.657395	993.06	1.68437	1.39	1.77	1.74
2.	0.147932	0.580504	974.239	1.68134	2.00	2.12	2.08
3.	0.221784	0.504619	964.989	1.67952	2.02	1.89	1.81
4.	0.295562	0.42972	921.023	1.67885	2.29	1.90	1.79
5.	0.369265	0.355788	897.029	1.67931	2.46	1.80	1.65
6.	0.442892	0.282804	851.028	1.68089	2.52	1.57	1.40
7.	0.516445	0.210751	827.779	1.68354	2.82	1.60	1.39
8.	0.589923	0.139611	784.036	1.68725	2.75	1.22	0.97
9.	0.663327	0.069366	768.883	1.69199	2.73	0.93	0.65

Table-7: Percentage Deviation of Ternary Mixture (Benzene + Ethylmethyl Ketone + Acetophenone) at 303K

S. No.	Mole fraction		Density	Molar Sound Velocity	% DEVIATION		
	X ₁	X ₃	ρ Kgm ⁻³	Rmix	U _{(mix)nomoto} ms ⁻¹	U _{im vandeal} ms ⁻¹	U _{im CFT} ms ⁻¹
1.	0.074004	0.657395	975.069	1.117666	1.63	2.80	2.17

2.	0.147932	0.580504	968.898	1.118127	1.92	2.88	2.33
3.	0.221784	0.504619	944.445	1.119879	2.02	2.78	2.30
4.	0.295562	0.42972	898.862	1.122888	2.17	2.72	2.31
5.	0.369265	0.355788	845.658	1.127121	2.24	2.58	2.25
6.	0.442892	0.282804	822.201	1.132546	1.93	2.06	1.80
7.	0.516445	0.210751	798.869	1.139131	1.89	1.82	1.63
8.	0.589923	0.139611	776.329	1.146848	1.80	1.52	1.47
9.	0.663327	0.069366	755.598	1.155666	1.62	1.12	1.09

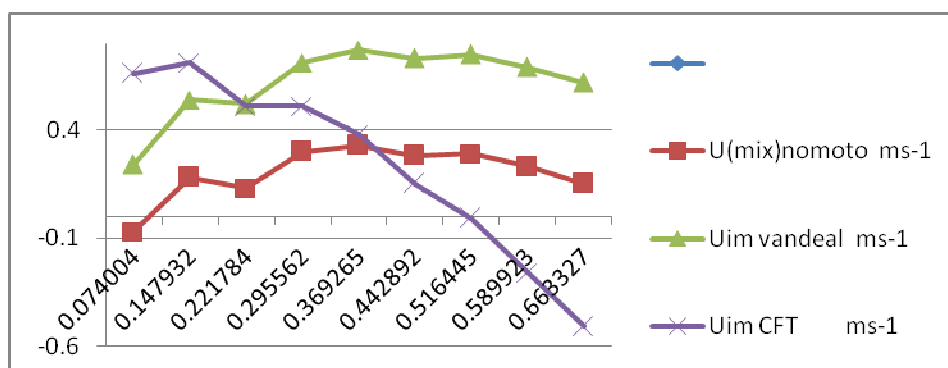


Fig.-1: Percentage Deviation of Ternary Mixture (Benzene + Ethylmethyl Ketone + Acetophenone) at 293K

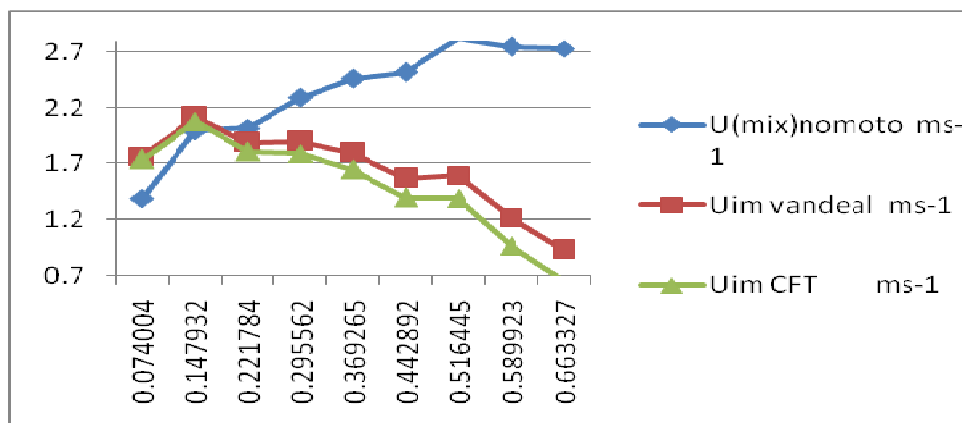


Fig.-2: Percentage Deviation of Ternary Mixture (Benzene + Ethylmethyl Ketone + Acetophenone) at 298K

CONCLUSION

Ultrasonic method is a powerful probe for characterizing the physio-chemical¹¹ properties and existence of molecular interaction in the liquid mixtures. In addition, the density, ultrasonic velocity and the percentage deviation provide evidence of confirmation. It is concluded that the weak molecular interaction exists between the mixing components which may be due to the dominance of dispersion and dipolar forces. Further the strength of interaction tends to be weaker with rise in temperature due to weak intermolecular forces and thermal dispersive forces. From the magnitude of derived parameters the existence of molecular interaction in the mixture is in the order-

Benzene >Ethyl methyl ketone>Acetophenone

Further to confirm the molecular interaction effect may be studied with nomoto¹² method having higher density medium in comparison with the liquid like benzene.

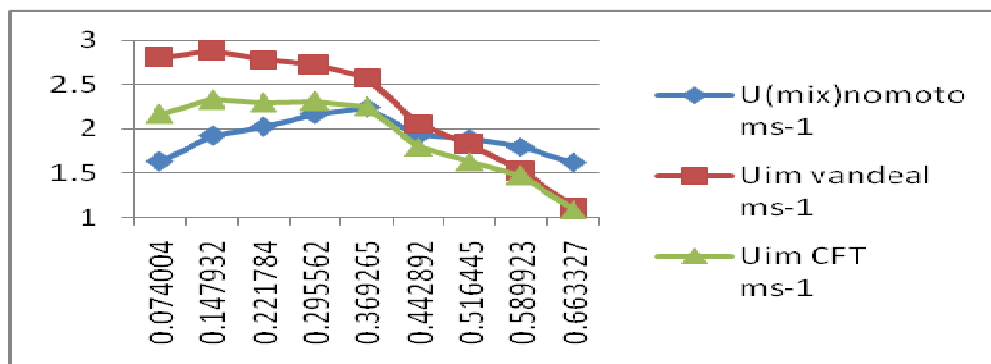


Fig.-3: Percentage Deviation of Ternary Mixture (Benzene + Ethylmethyl Ketone + Acetophenone) at 303K

REFERENCES

1. A.N.Kannappan and V.Rajendiran, *Ind.J.Pure Appl.Phy.* **30**,240-252(1992).
2. U .Srinivasoly and P.R. Naidu, *J.Pure Appl. Ultrasonics*, **43** ,123(1995)
3. R.T.Fort and W.R.Moore, *Tranfarady Soc.(GB)*, **61** ,2102(1965)
4. G . Arul, *Phys. Ultrasonic*, **34** ,898(1989)
5. R . Prigogine, *The Molecular theory of solutions(North-Holand, Amsterdam)*,**4**,487(1957)
6. T.M. Letcher and J.A .Nevine, *J.Chem. Thermodynamics*, **26** ,697(1994)
7. V .Rajendiran and R .Christopher, *Newton Benny Acoustics letters*, **17**,2(1993)
8. L.Palaniappan, Ph.d.,*Thesis, Annamalai University*, **1**(1998) 276-287
9. Eigen and Meyer, *In Technique of Organic*, **8** (1963)859
10. R.P .Acoust, *Lett*, **6**(1983)53
11. W .Scaff's, *Phys.*, **4**,69,110,114,115(1975)
12. Nomoto, *J. Phys. Soc.*,**13**,1528(1958)

[RJC-833/2011]

Water: Research & Development

[Water R&D]

www.waterrnd.com

ISSN: 2249-2003

[Abstracted in : Chemical Abstracts Service, USA and CAB(I) , UK]

WaterR&D is an international Research Journal, dedicated to 'Water'. It is a truly interdisciplinary journal on water science and technology. It'll showcase the latest research related to Water in the field of chemistry, physics, biology, agricultural, food, pharmaceutical science, and environmental, oceanographic, and atmospheric science. It includes publication of reviews, regular research papers, case studies, communications and short notes.

Manuscript Categories: Full-length paper, Review Articles, Short/Rapid Communications.

Manuscripts should be addressed to:

E-mail: waterrd@gmail.com