EXCESS THERMODYNAMIC AND OTHER ALLIED PARAMETERS IN THE BINARY MIXTURES OF 2-PHENOXY ETHANOL WITH BENZYL BENZOATE AS COMMON COMPONENT

[1,2]J.Nageswara Rao, [1,3]P.V.Sairam, [1,3]G.Srinivasa Rao
[1]Krishna University, Machilipatnam
[2]Department of Physics, Government Degree College, Chintalapudi, W.G.Dist
[3]Department of Physics Andhra Loyola College, Vijayawada.

Abstract: Density, viscosity and Ultrasonic velocity have been measured in binary mixture of 2-Phenoxy Ethanol with benzyl benzoate as common component at deferent Temperatures 30^0C, 40^0C and 50^0C. From the measured data, computed excess Thermodynamic parameters like Adiabatic Compressibility, Internal Pressure, molar Volume, Free length, enthalpy and Gibbs activation energy and the intermolecular interactions are estimated in the light of the excess parameters. Also theoretical velocities are evaluated from a knowledge of the five theories FLT, CFT, NOMOTO, VANDAEL and JUNJIE. FLT, CFT, NOMOTO and JUNJIE appear to agree well with the experimental results. In the mixture of 2-Phenoxy Ethanol with Benzyl benzoate Strong interactions are suggested.

IndexTerms **- Binary mixtures, 2-Phenoxy Ethanol, Benzyl benzoate; Velocity; Molecular interactions.**

I. INTRODUCTION

Ultrasonic methods has been accepted as an important tool in predicting the molecular interactions in the binary mixtures and these techniques are comparable to other techniques like Infrared spectroscopy, NMR spectroscopy and Dielectric relaxation studies etc. Though several binary mixtures have been studied, the binary mixtures with at least one component as 2-Phenoxyethanol or benzyl benzoate have been referred [1-14] owing to the nature of the liquids in our present investigation. In the present investigation, the binary mixtures of the three cresols with benzyl benzoate as common component have been chosen owing to their importance in medicine and chemistry. Benzyl benzoate is used as an anti parasitic insecticide, as a food additive in artificial flavor, and as a solubilizing agent in the preparation of oily injections and also a good solvent for various chemical reactions. 2-Phenoxyethanol is a compound having a faint rose like aromatic odor. 2-Phenoxyethanol used as solvent in ballpoint inks, resins and inorganic synthesis. It is also used as an antiseptic, an insect repellent and cosmetics and repellants. Ultrasonic velocity, density and viscosity have been measured in the binary mixtures of benzyl benzoate with 2-Phenoxyethanol at 30ºC, 40ºC and 50ºC. From the thermodynamic and other parameters computed from the measured data, excess parameters have been calculated and the inter molecular interactions have been estimated. Theoretical evaluation of velocities has also been made and FLT,VANDEAL, CFT, NOMOTO and JUNJIE have been found to be better.

II. EXPERIMENTTAL METHODS

The chemicals used in the present investigation Benzylbenzoate and 2- Phenoxyethanol are extra puregrade from LOBA Chemie Private Limoted.The binary mixture was prepared by mixing the weighted quantities of pure liquids. Density of binary mixture has been measured using a double stem capillary type pychnometer with an accuracy of 2 parts in 10^5. Weighta are taken using an Digital balance with an accuracy of ±0.001 mg. Viscosity has been measured using Ostwald Viscometer with an accuracy of ±0.1%. Ultrasonic velocity has been measured usong a single crystal Interferometer working at frequency 2MHz with an accuracy of ±0.05%. Above all devices Pychnometer, Viscometer and Interferometer are standardized with triply distilled water as reference liquid before carrying out all the measurements in test liquids.

III. THEORETICAL ASPECTS

A formula for evaluating ultrasonic velocity theoretically ,developed by schaaffs based on the collision factors of the molecules.

Ultrasonic velocity $$U = U_\infty S r_f \quad \text{----1.1}$$

$$U = \frac{U_\infty S B}{V_T} \quad \text{----1.2}$$

Where collision factor $$S = \frac{U_{exp}}{U_\infty \left(\frac{B}{V_T} \right)} \quad \text{----1.3}$$

According to Nomoto's theory, theoretical ultrasonic velocity can be written as

$$U_{NOMOTO} = \left(\frac{R}{V}\right)^3 = \left[\frac{(X_A R_A + X_B R_B)}{(X_A V_A + X_B V_B)}\right]^3 \quad \text{----1.4}$$

The theoretical ulatrasonic velocity in binary liquid mixtures according to Junjie's theory[7] is given by

$$U_{JUNJIE} = \frac{\frac{X_A M_A}{\rho_A} + \frac{X_B M_B}{\rho_B}}{\left[(X_A M_A + X_B M_B)\left(\frac{X_A M_A}{V_A^2 \rho_A} + \frac{X_B M_B}{V_B^2 \rho_B}\right)\right]^{1/2}} \quad \text{----1.5}$$

The ultrasonic velocity in binary liquid mixtures according to VANDAEL'S theory [8] is given by

$$U_{VANDAEL} = \frac{1}{\left[(X_A M_A + X_B M_B)\left(\frac{X_A}{M_A U_A^2} + \frac{X_B}{M_B U_B}\right)\right]^{1/2}} \quad \text{----1.6}$$

If ρ_{mix} is the density of the liquid mixture, then theoretical velocity in the mixture U_{mix} can be evaluate by using the relation

$$U_{FLT} = \frac{K}{L_{mix}\, \rho_{mix}^{1/2}} \quad \text{----1.7}$$

Nutsch –Kuhnkies[3] extended this theory to binary mixtures also. Thus ultrasonic velocity in binary mixture is

$$UCFT = \frac{U_\infty S_{mix} B_{mix}}{V_T^M} \quad \text{----1.8}$$

If the measured ultrasonic velocity (U_{exp}) and density (ρ_{exp}) are known , then adiabatic compressibility of a liquid can be calculated using the relation

$$\beta = \frac{1}{U_{exp}^2 \rho_{exp}} \quad \text{----1.9}$$

The difference between the experimentally observed compressibility β^{exp} and that of an ideal solution β^{ideal} is equal to the excess adiabatic compressibility β^E is given by

$$\beta^E = \beta^{exp} - \beta^{ideal} \quad \text{----1.10}$$

The internal pressure π and free volume V_f can be calculated using Suryanarayana and Kuppusamy relations[9] for pure components at any particular temperature given by

$$\pi = bRT\left[\frac{K\eta}{U}\right]^{1/2} \frac{\rho^{2/3}}{M^{7/6}} \quad \text{------1.11}$$

Excess internal pressure

$$\pi^E = \pi^{exp} - \pi^{ideal} \quad \text{----1.12}$$

Enthalpy is computed with the help of molar volume and internal pressure . The excess enthalpy is given by

$$H^E = H^{exp} - H^{ideal} \quad \text{------1.13}$$

$$= \pi V - \left[\pi_A V_A X_A + \pi_B V_B X_B\right] \quad \text{------1.14}$$

Activation energy [12] of Gibb's is given by

$$G = RT\left[\ln \eta V_M\right] \quad \text{----1.15}$$

And excess activation energy is given by

$$G^E = RT\left[\ln(\eta V_M) - \left\{X_A \ln\left(\eta^A V_M^A\right) + X_B \ln\left(\eta^B V_M^B\right)\right\}\right] \quad \text{----1.16}$$

The equation for molar volume of the ideal mixture is given by

$$V^{ideal} = X_A V_A + X_B V_B \quad \text{----1.17}$$

The excess molar volume of the given binary mixture is given by

$$V^E = V_M^{exp} - V_M^{ideal} \quad \text{----1.18}$$

The viscosity of a binary liquid mixture can be calculated by employing the measured values of density of a liquid and time of flow of the liquid of the system at any temperature.

$$\text{Viscosity} \qquad \eta = \frac{\rho t}{\rho^1 t^1}\eta^1 \quad \text{----1.19}$$

The difference between experimental viscosity and ideal viscosity of the liquid is called the excess viscosity and is given by

$$\eta^E = \eta^{exp} - \eta^{ideal} \quad \text{----1.20}$$

Excess free length can be difined as the difference between experimental free length and ideal free length .and is given by the relation

$$L_f^E = L_f^{exp} - L_f^{ideal} \quad \text{-----1.21}$$

$$= L_f^{exp} - \left(L_f^A X_A + L_f^B X_B\right) \quad \text{----1.22}$$

Classical absorption (α/f^2), relaxation time (τ) and relaxation strengths (α_R) are computed by using the following relations.

Classical absorption $\alpha/f^2 = 8\pi^2\eta/3\rho U^2$ ----1.23

Relaxation Time $\tau = 4\eta/3\rho U^2$ ----1.24

Relaxation strength $\alpha_R = 1-(U_{exp}^2/U_\infty^2)$ ----1.25

IV. Results and Discussion

BINARY MIXTURES OF BENZYL BENZOATE WITH 2-PHENOXYETHANOL

Ultrasonic velocity, density and viscosity have been measured in the binary mixtures of benzyl benzoate with 2-Phenoxyethanol over the entire compositions range of benzyl benzoate at 30ºC,40ºC and 50ºC presented in Table 1.1. As observed from Table 1.1, the velocity decreases from 2-Phenoxyethanol to Benzyl benzoate at all temperatures 30º C,40ºC and 50ºC. The percentage deviations w.r.t. the five theories in the binary mixture have been presented in Table 1.2. Maximum percentage deviations at all three temperatures with 2-Phenoxyethanol for all the five theories CFT, FLT, VANDAEL, JUNJIE and NOMOTO are -0.68(<1), 0.32(<1), -1.29, 0.42(<1) and 0.45(<1) ; 1.53, 0.45(<1), 1.27, 0.44(<1), 0.48(<1) and 0.17 and 0.90(<1), 0.75(<1), -1.29, 0.64(<1) and 0.65(<1) respectively.. From the above values, it may be envisaged that except in VANDAEL, most of the % deviations are less than unity i.e, for the system of 2-Phenoxtethanol, all the other four theories have a sharp edge.

Table 1.1 Ultrasonic velocity, density and viscosity in the mixtures of 2-Phenoxy Ethanol

Mole fraction of Benzyl benzoate	Velocity (ms^{-1})	Density (kgm^3)	Viscosity (mill.Pa.s)
Benzyl benzoate + **2-Phenoxy Ethanol at 30ºC**			
0.0000	1568.03	1096.76	15.5601
0.0690	1556.31	1096.95	13.9843
0.1430	1548.35	1097.13	12.3107
0.2224	1543.41	1097.43	10.5415
0.3079	1537.87	1097.83	9.8919
0.4003	1531.82	1098.68	9.0719
0.5003	1527.54	1099.35	8.5934
0.6089	1522.13	1101.63	7.9523
0.7275	1518.05	1103.39	7.1281
0.8573	1512.11	1106.87	6.8851
1.0000	1506.90	1119.35	6.5325
Benzyl benzoate + **2-Phenoxy Ethanol at 40ºC**			
0.0000	1528.51	1080.44	8.8999
0.0690	1521.25	1081.05	8.5128
0.1430	1514.98	1082.75	7.8420
0.2224	1508.98	1084.15	7.1695
0.3079	1500.84	1086.63	6.7021
0.4003	1492.55	1087.99	6.3256
0.5003	1489.22	1090.55	5.9818
0.6089	1485.55	1093.48	5.5196
0.7275	1481.55	1095.47	5.3642
0.8573	1477.40	1098.91	5.1916
1.000	1471.44	1109.75	5.0210
Benzyl benzoate + **2-Phenoxy Ethanol at 50ºC**			
0.0000	1490.85	1078.67	6.4209
0.0690	1476.17	1078.99	6.0819
0.1430	1471.09	1079.34	5.7638
0.2224	1468.06	1080.14	5.5225
0.3079	1464.32	1080.59	5.2354
0.4003	1459.32	1081.59	4.9222

0.5003	1455.45	1083.84	4.7560
0.6089	1451.82	1086.45	4.5513
0.7275	1446.34	1087.91	4.3584
0.8573	1443.92	1091.75	4.2860
1.0000	1440.0	1107.09	4.2983

Table 1.2 Percentage Deviations in Theoretical Velocities

Mole fraction of Benzyl benzoate	$\%U_{CFT}$	$\%U_{FLT}$	$\%U_{VANDAEL}$	$\%U_{JUNJIE}$	$\%U_{NOMOTO}$
2-Phenoxy Ethanol at 30ºC					
0.0000	-------	----------	------	---------	-------
0.0690	0.29185298	0.02566307	-0.04	0.32849101	0.346013
0.1430	0.32443495	0.00936405	-0.28	0.42565526	0.456666
0.2224	0.15381244	-0.0811784	-0.67	0.33237176	0.372815
0.3079	0.00852582	-0.0508513	-0.95	0.28339133	0.329339
0.4003	0.09038368	0.05438026	-1.11	0.27247459	0.320074
0.5003	0.34929958	0.09661037	-1.29	0.15024014	0.195635
0.6089	0.42322626	0.17604115	-1.27	0.10774766	0.147239
0.7275	0.66936096	0.21725627	-1.18	-0.0182295	0.011661-
0.8573	-0.6864006	0.32569802	-0.74	-0.0173186	0.000594
1.0000	----------	----------	----------	----------	----------
2-Phenoxy Ethanol at 40ºC					
0.0000	----------	----------	------	---------	----------
0.0690	0.2377	0.0420	-0.30	0.0828	0.0982
0.1430	0.4957	0.0245	-0.63	0.1055	0.1329
0.2224	0.6883	0.0494	-0.92	0.1153	0.1511
0.3079	1.1039	0.2051	-1.0	0.2722	0.3131
0.4003	1.4008	0.4567	-0.99	0.4450	0.4874
0.5003	1.4443	0.3460	-1.21	0.2883	0.3288
0.6089	1.5114	0.2649	-1.27	0.1590	0.1942
0.7275	1.4743	0.2680	-1.14	0.0549	0.0816
0.8573	1.5347	0.2321	-0.78	0.0358	-0.0209
1.0000	----------	----------	---------	---------	----------
2-Phenoxy Ethanol at 50ºC					
0.0000	--------	-------	------	---------	--------
0.0690	0.5213	0.6753	0.24	0.6425	0.6557
0.1430	0.3823	0.7281	-0.14	0.6309	0.6539
0.2224	0.1274	06427	-0.60	0.4825	0.5125
0.3079	01311	0.6422	-0.95	0.3858	0.4200
0.4003	0.2752	0.7207	-1.12	0.3788	0.4142
0.5003	0.4077	0.6800	-1.27	0.2973	03312
0.6089	0.5532	0.6233	-1.29	0.2023	0.2319
0.7275	07119	0.7567	-1.01	0.2387	0.2611
0.8573	0.9027	0.5818	-0.71	0.0660	0.0785
1.0000	--------	----------	---------	--------	----------

The thermodynamic, acoustic and other related parameters computed from the standard relations are presented in table 1.3 In Binary mixture of Benzyl Benzoate and 2-Phenoxyethanol adiabatic compressibility, Molar Volume and Free length increases with concentration of Benzyl benzoate while Internal Pressure, enthalpy and Activation energy decreases with the increase in concentration of BB.

Table 1.3: Thermodynamic Parameters in the Mixtures of 2-Phenoxyethanol

Mole fraction of Benzyl benzoate	Adiabatic compressibility (10^{-11} N^{-1} cm^2)	Internal pressure (atms)	Molar volume (ml.mole^{-1})	Free length (A^0)	Enthalpy (KJ.mole^{-1})	Activation energy (RT units)
2-Phenoxy Ethanol at 30ºC						
0.0000	3.71	9768.32	125.9766	0.384256	1230.580	19106
0.0690	3.76	8910.44	130.6161	0.387112	1163.848	18928
0.1430	3.80	8023.52	135.5898	0.389073	1087.907	18701
0.2224	3.83	7108.80	140.9133	0.390264	1001.725	18407
0.3079	3.85	6584.60	146.632	0.391599	965.513	18347
0.4003	3.88	6021.84	152.7464	0.392995	919.815	18232
0.5003	3.90	5582.87	159.392	0.393973	889.866	18203
0.6089	3.92	5112.44	166.3722	0.394968	850.569	18115
0.7275	3.93	4594.15	174.0636	0.395712	799.674	17953
0.8573	3.95	4282.36	182.2038	0.396641	780.262	17981
1.0000	3.93	3966.161	189.619	0.395788	752.059	17949
2-Phenoxy Ethanol at 40ºC						
0.0000	3.96	7408.16	127.88	0.4040	947.34	17736.3
0.0690	4.00	6963.59	132.53	0.4058	922.24	17744.43
0.1430	4.02	6417.25	137.38	0.4072	881.66	17598.15
0.2224	4.05	5881.18	142.63	0.4086	838.88	17466.72
0.3079	4.09	5449.02	148.14	0.4103	807.23	17392.21
0.4003	4.13	5061.05	154.24	0.4123	780.65	17348.25
0.5003	4.13	4692.27	160.67	0.4128	753.94	17310.40
0.6089	4.14	4290.13	167.61	0.4132	719.04	17214.16
0.7275	4.16	4014.84	175.32	0.4140	703.89	17255.53
0.8573	4.17	3743.98	183.52	0.4145	687.11	17288.37
1.0000	4.16	3498.69	191.25	0.4141	669.15	17308.21
2-Phenoxy Ethanol at 50ºC						
0.0000	4.17	6364.41	128.08	0.4210	815.21	16917.5
0.0690	4.25	5967.54	132.79	04252	792.43	16871.7
0.1430	4.28	5571.38	137.82	0.4266	767.87	16830.1
0.2224	4.30	5220.14	143.16	0.4273	747.36	16818.2
0.3079	4.32	4857.60	148.97	0.4283	723.64	16783.8
0.4003	4.34	4497.28	155.15	0.4296	697.79	16730.8
0.5003	4.36	4214.84	161.67	0.4302	681.42	16747.9
0.6089	4.37	3923.77	168.69	0.4308	661.92	16744.2
0.7275	4.39	3645.85	176.54	0.4321	643.64	16749.6
0.8573	4.39	3426.04	184.72	0.4321	632.88	16821.6
1.0000	4.36	3267.02	191.71	0.4303	626.35	16922.5

All the excess parameters are computed at all three temperatures with concentration of Benzyl benzoate and are presented in table 1.4 to estimate the molecular interactions in the binary system. From the table 1.4 it is noticed that excessive adiabatic compressibility (β^E) is negative at 40ºC and 50ºC and positive at 30ºC. Excessive internal pressure is more negative at 30ºC and positive at 40^{O}C and 50ºC. Excessive enthalpy and excessive Gibbs activation energy are negative at all three temperatures. Excessive free length (L^F) is positive at all three temperatures. From these excess parameters it may be suggested strong interactions in 2-Phenoxyehanol system.

From the variation of excessive Gibbs activation energy (G^E) which is negative at all three temperatures, it may be that exothermic type of chemical reaction.

Table 1.4: Excess parameters in the Mixtures of 2-Phenoxyethanol

Mole fraction of Benzyl benzoate	Adiabatic compressibility (10^{-12} N^{-1} cm^2)	Internal pressure (atms)	Molar volume (ml.mole^{-1})	Free length (A^0)	Enthalpy (KJ.mole^{-1})	Activation energy (RT units)
2-Phenoxy Ethanol at 30ºC						

0.0000	-----	--------	------	---------	----------	------
0.0690	0.327	-457.32	0.25	0.00206001	-33.697	-98.08
0.1430	0.484	-915.15	0.51	0.00316817	-74.248	-239.61
0.2224	0.491	-1369.06	0.7 8	0.0034427	-122.426	-441.69
0.3079	0.527	-1397.09	1.06	0.0037911	-117.717	-402.82
0.4003	0.576	-1424.10	1.30	0.00412251	-119.230	-411.13
0.5003	0.544	-1282.79	1.58	0.00394721	-101.323	-324.67
0.6089	0.515	-1122.63	1.64	0.00368853	-88.613	-286.33
0.7275	0.467	-953.17	1.79	0.00306477	-82.786	-311.07
0.8573	0.396	-511.92	1.67	0.00249696	-40.092	-133.15
1.0000	--------	--------	----	----------	---------	---------
2-Phenoxy Ethanol at 40ºC						
0.0000	-0.166	0	0	0	0	0
0.0690	-0.145	174.66	0.28	0.00111	-5199.8	7.6761
0.1430	-0.126	431.88	0.45	0.00172	25904	-76.93
0.2224	-0.106	657.47	0.66	0.00228	-46587	-174.37
0.3079	-0.860	755.31	0.75	0.00316	54449	-212.27
0.4003	-0.652	782.29	1.00	0.00425	55347	-216.70
0.5003	-0.476	760.08	1.09	0.00368	54229	-211.74
0.6089	-0.298	737.34	1.14	0.00305	58868	-261.45
0.7275	-0.116	549.22	1.33	0.00259	41076	-169.34
0.8573	0.624	312.69	1.31	0.00179	21752	-80.94
1.0000	0.223	0	0	0	0	0
2-Phenoxy Ethanol at 50ºC						
0.0000	-0.145	0	0	0	0	0
0.0690	-0.120	-183.03	0.31	0.00348	9735.90	-46.20
0.1430	-0.100	350.12	0.64	0.00420	-20335.74	-88.17
0.2224	-8.18	455.37	0.93	0.00419	-25841.77	-100.47
0.3079	-6.30	553.04	1.29	0.00440	-33407.04	-135.30
0.4003	-4.37	627.35	1.60	0.00481	-41823.49	-188.70
0.5003	-2.55	600.02	1.75	0.00459	-39301.42	-172.08
0.6089	-7.56	554.46	1.86	0.00414	-38282.84	-176.38
0.7275	1.20	465.24	2.16	0.00439	-34174.39	-171.50
0.8573	2.87	283.053	2.09	0.00315	-20423.69	-100.16
1.0000	4.17 .	0	0	0	0	0

Computed other parameters like Relaxation strength, Relaxation time and classical absorption and presented in table 1.5. Relaxation strength shows increasing trend with concentration of Benzyl benzoate. The behavior of relaxation time and classical absorption decreses with concentration of benzylbenzoate.

Table 1.5: Variation of relaxation strength, relaxation time and classical absorption in mixtures of 2-Phenoxyethanol

Mole fraction of benzyl benzoate	Relaxation strength	Relaxation time (10^{-6}) sec	Classical Absorption (10^{-6})
0.0000	0.039566435	7.6936	151.71
0.0690	0.053862005	7.0177	138.38
0.1430	0.063520421	6.2406	123.06
0.2224	0.069485346	5.3765	106.02
0.3079	0.076158238	5.0797	100.16
0.4003	0.083411568	4.6919	92.52
0.5003	0.088519269	4.4666	88.07
0.6089	0.094974799	4.1543	81.91
0.7275	0.09982007	3.7377	73.70
0.8573	0.106846239	3.6273	71.52
1.0000	0.112990392	3.4267	67.57

0.0000	0.08736	4.70	92.69
0.0690	0.09600	4.53	89.46
0.1430	0.10344	4.20	82.96
0.2224	0.11053	3.87	76.35
0.3079	0.12011	3.65	71.99
0.4003	0.12980	3.47	68.62
0.5003	0.13367	3.29	65.02
0.6089	0.13795	3.04	60.13
0.7275	0.14258	2.97	58.65
0.8573	0.14737	2.88	56.90
1.0000	0.15424	2.78	54.94
0.0000	0.13178	3.57	70.41
0.0690	0.14879	3.44	68.01
0.1430	0.15464	3.29	64.87
0.2224	0.15812	3.13	62.37
0.3079	0.16240	3.01	59.40
0.4003	0.16811	2.84	56.18
0.5003	0.17252	2.76	54.46
0.6089	0.17664	2.64	52.25
0.7275	0.18285	2.55	50.35
0.8573	0.18558	2.51	49.50
1.0000	0.19000	2.49	49.22

REFERENCES:

[1] Siva Sankar J. Geetalakshmi, Naidu P.S, and Ravindra Prasad; J. Pure Appl. Ultrason. 29 (2007) 82
[2] Geetalakshmi, M., Naidu P.S and Ravindra Prasad K; J. Pure Appl. Ultrason. 30 (2008) 18
[3] Sk Md Nayeema and D.Krishna Rao ; International Journal of Pharma Research & Review, Feb 2014; 3(2):65-78 4.
[4] Jaya Madhuri, N., Naidu P.S. and Ravindra Prasad K;Presented at National Conference on emerging materials (ncem) at Vidyanagar (AP) 11-19 July 2009.
[5] Jayamadhuri, N.,Glory, J., Naidu P. S. and Ravindra Prasad K; Proceedings of the XVIII National Symposium on Ultrasonics (XVIII NSU) 21-23 Dec. 2009 at VITS UNIVERSITY, Vellore (Tamila Nadu).
[6] Sk. Md Nayeema, Sk. Nyamathullab, Imran Khanc, D. Krishna Rao; Journal of Molecular Liquids; Volume 218, June 2016, Pages 676–685.
[7] Ramesh P,Geeta Lakshmi M,JayaMadhuri N,Naidu P S and Ravindra Prasad K; v Invertis Journal of Science&Technology.2011;4: 14-30.
[8] Mallikarjuna P, Jaya Madhuri N and Ravindra Prasad K.; J Pure ApplUltrason. 2010;32: 59-69.
[9] NageswaraRao J, Jayamadhuri N, Glory J, Naidu P S and Ravindra Prasad K.;Physical Chemistry an Indian Journal, 9(3), 2014 [81-91]
[10] Jaya Madhuri N, Naidu P S, Glory J and Ravindra Prasad K.;.E-Journal of Chemistry.2011;89(1):457-469.
[11] Jaya Madhuri N, Glory J,Naidu P S and Ravindra Prasad K.; J Pure ApplUltrason.2011;33: 63-70.
[12] Jayamadhuri N, Glory J, Naidu P S and Ravindra Prasad K. ;Proceedings of Eighteenth National Symposium on Ultrasonics. Pr°Ceedings of Eighteenth National Symposium on Ultrasonics, NSU – XVIII VIT University, Vellore. 2009;December21-23:405- 408.
[13] Sk Md Nayeema and D.Krishna Rao; International Journal of Pharma Research & Review, Feb 2014; 3(2):65-78
[14] Shashi Singh,Isht Vibhu, Manisha Guptha, and J.P.Shukla ;Chinese Journal of Physics, August 2007;Vol 45, No.4