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An Ultrasonic Study on Acoustical and Excess Properties of Ternary Liquid Mixtures of 2-Bromoanisole + 1-Butanol + *n*-Hexane at Different Temperatures 303K, 308K and 313K and a Frequency 2MHz

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Summary: The behaviour of liquid mixture of 2-Bromoanisole, 1-Butanol and *n*-Hexane as a function of temperature and composition has been investigated by measuring ultrasonic velocity in conjunction with density and viscosity at 303K, 308K and 318K for frequency 2 MHz using ultrasonic interferometer. With the help of the measured values ultrasonic velocity (u), viscosity (η) and density (ρ), the acoustical parameters like acoustic impedance, adiabatic compressibility, free length, free volume and internal pressure have been calculated. In order to know the molecular interaction between the components in the ternary liquid mixture, nature and strength of molecular interaction in the components of the ternary mixture, the actual values of acoustical parameters were computed in to their excess properties. Excess ultrasonic velocity (U^E), excess acoustic impedance (Z^E), excess intermolecular free length (L^E_f) excess adiabatic compressibility (β^E), excess free volume (V_f^E) and excess internal pressure have been calculated for the ternary liquid mixtures containing 2-bromoanisole, 1-butanol in *n*-hexane at various temperatures 303K, 308K and 313K at fixed frequency 2MHz, for different concentrations ranges from 0.001M to 0.01M and fitted to the Redlich-Kister polynomial equation. The computed excess values of excess ultrasonic velocity, excess acoustic impedance, excess intermolecular free length, excess adiabatic compressibility, excess free volume and excess internal pressure were plotted against the concentration of ternary liquid of the mixture at different temperatures 303K, 308K and 313K at a fixed frequency of 2MHz. A good agreement has been found between the experimental and calculated values of the ultrasonic velocity. The strength and the nature of the interactions between like and unlike molecules have been discussed in terms of dipole-dipole, dipole-induced dipole, and induced dipole-induced dipole interaction through hydrogen bonding. The present study aims to evolve the impact of ultrasonic sound over the molecular interaction of ternary liquid mixture consisting of 2-bromoanisole, 1-butanol in *n*-hexane mixture at different temperature 303K, 308K and 313K.

Keywords: Excess adiabatic compressibility, Excess acoustic impedance, Internal pressure, Molecular interaction, Ternary liquid mixture, Ultrasonic velocity.

Introduction

The measurement of ultrasonic speed in liquid mixture enables accurate determination of some useful acoustical parameters and their excess values which are highly sensitive to molecular interactions in their mixtures. Acoustic and thermodynamic parameters have been used to understand different kinds of association, the molecular packing, molecular motion and various types of intermolecular interactions and their strengths influenced by the size in pure components and in the mixtures [1-5]. Excess parameters play a vital role in assessing the compactness due to molecular arrangement and the extent of molecular interactions in the liquid mixtures through charge transfer, dipole-dipole and dipole induced dipole interactions [6]. The sign and the extent of deviation of these functions from ideality depend on the strength of interactions between unlike molecules [7].The physical (or) chemical nature and the corresponding strength of the molecular interaction between the components of the ternary liquid mixtures have been successfully investigated by the ultrasonic method [8]. The measurement of ultrasonic velocity suggests the accurate determination of some useful acoustical and thermodynamic parameters and their excess functions which are highly sensitive to molecular interactions in liquid mixtures [9, 10]. Thermodynamic and transport properties of binary and ternary mixtures with different organic liquids have been studied by many authors [11, 12]. Although a large number of investigations are carried in liquid mixtures having cyclohexane (or) benzene as one of the components, it is found that no work has been made so for to measure the ultrasonic velocity of the ternary mixtures of 2-bromoanisole, 1-butanol and *n* -hexane.

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For many practical purposes it is necessary to predict the excess properties of a multi component liquid mixture from the properties of the pure components. Investigation into the possible change of the thermodynamic properties of a mixture and their degree of deviation from ideality has been found to be a qualitative and quantitative way to elicit information about the molecular structure and intermolecular forces in liquid mixtures. The measurements of the ultrasonic velocity have been adequately employed for understanding the nature of molecular systems and physico-chemical behaviour in liquid mixtures [13, 14]. A number of empirical, semi-empirical, and statistical theories have been developed by several workers [15].

Molecular interaction is associated with 1-alkanol hybrids, which are one of the most unique components since the alkanol group is very polar nature, because of this, it deeply interacts with other groups that attraction of polar ends. 2-Bromoanisole has methoxy group present second position which is an ortho/para directing, hence it strongly affects the pi electron cloud of benzene ring which renders it more electron rich.

Alcohols are associated organic liquids and are widely used as basic organic compounds for the synthesis of other organic compounds. Branching of the alkyl group attached to the hydroxyl group results in abnormal behaviour of alcohols. The present study reports the excess ultrasonic velocity (U^E), excess acoustic impedance (Z^E), and excess intermolecular free length (L^E_f) for ternary mixture 2- bromoanisole, 1-butanol and *n*-hexane at various temperatures viz., 303K, 308K and 313K at constant frequency 2MHz. With the aim of analyzing the disruption of self association in 1-butanol and the breaking of the dipole-dipole interactions of 2-bromoanisole along with the interaction between the hydroxyl group of alcohol molecule in *n*-hexane is a good non polar solvent. 2-Bromoanisole which is one of the additives used in NCM batteries, while the electrochemical reaction occurring in the NCM batteries, the by-products formed from oxidation-reduction process will influence the total impedance of the NCM batteries [16]. This character of the 2-bromoanisole simulates the author to probe the current study.

Therefore, in continuation of author's earlier study [17], the present study has been taken by the authors to provide useful information regarding the molecular interactions possessed in the system of 2-bromoanisole, 1-butanol in *n*-hexane at different temperatures. The main aim of this investigation is to study the effect of increasing chain length of alkyl group of 1-alkanols on the strength of the H-bonding between an aromatic ether (2-bromoanisole) and aliphatic alcohol (1-butanol).

Experimental

The mixture (2-bromoanisole +1-butanol+*n*-hexane) of various concentrations of equal ratio 1:1 were prepared by taking analytical reagent grade and spectroscopic reagent grade chemicals with minimum assay of 99.9% and obtained from E.Merck Ltd (India). All the component liquids were purified by the standard methods. The density, viscosity, and ultrasonic velocity were measured for various concentrations as prepared above at different temperatures viz 303K, 308K and 313K keeping constant frequency of 2 MHz. Ultrasonic velocity measurements were made using an ultrasonic interferometer (Model F-81, supplied by M/S Mittal Enterprises, New Delhi, India) with the accuracy of ±0.1m·s−1. Water at desired temperature is circulated through the outer jacket of the double-walled measuring cell containing the experimental liquid. The densities of the mixture were measured using a 10-ml specific gravity bottle by relative measurement method with an accuracy of ±0.01 $kg \cdot m^{-3}$. An Oswald viscometer (10 ml) with an accuracy of ±0.001 $Ns \cdot m^{-2}$ was used for the viscosity measurement. The flow time was determined using a digital racer stopwatch with an accuracy of ±0.1s.

Theoretical Aspect

The following acoustical and thermodynamics parameters were calculated:

1. Adiabatic compressibility (β) has been calculated from the ultrasonic velocity (U), and the density (ρ) of the medium using the Newton- Laplace equation [18] as follows:
   $\beta = 1/U^2\rho$ (1)

2. Intermolecular free length (L_f) has been determined as [19] follows:
   $L_f = K_T\beta^{1/2}$ (2)

where K_T is the temperature – dependent constant known as Jacobson's constant ($K_T = 2.131\times10^{-6}$ at 318K), and β is the adiabatic compressibility.

3. Free volume (V_f) in terms of ultrasonic velocity (U) and the viscosity (η) of liquid [20] is as follows:
   $V_f = (M_{eff} U/ k\eta)^{3/2}$ (3)

where M_{eff} is the effective molecular weight of the mixture ($M_{eff} = \Sigma m_i X_i$, where m_i and X_i are the molecular weight and mole fraction of individual constituents, respectively), k is temperature independent constant which is equal to 4.281×10^9 [21] for all liquids.

4. Internal pressure ($\prod_i$) can be calculated using the relation [22] as follows:
$$\prod_I = bRT(k\eta/U)^{1/2} (\rho^{2/3} / M_{eff}^{7/6}) \quad (4)$$

where b stands for cubic packing, which is assumed to be 2 for all liquids, k is a dimensionless constant independent of temperature and nature of the liquids, its values is 4.281×10^9. T is the absolute temperature in Kelvin, M_{eff} is the effective molar weight, R is the universal gas constant, η is the viscosity of the solution in Nsm^{-2}, U is the ultrasonic velocity in ms^{-2} and ρ is the density in kgm^{-3} of solution.

5. The Gibbs free energy can be determined using the relation as follows:
$$\Delta G = k_{B,}T.\ln(k_B.T.\tau/h) \quad (5)$$

where τ is viscous relaxation time, T is the absolute temperature, k_B is Boltzmann's constant, and h is Planck's constant.

6. Acoustic impedance (Z) is given as follows:
$$Z = U.\rho \quad (6)$$

where U and ρ are the ultrasonic velocity and density of the mixture, respectively.

Excess Parameters

In order to study the non-ideality of the liquid mixtures, the difference between the values of acoustic and thermodynamic parameters of real mixtures (A_{exp}) and those corresponding to the ideal mixtures(A_{id}) were computing using the following equation:

$$A^E = A_{exp} - A_{id}$$

where A^E represents Excess parameters, $A_{id} = \Sigma A_i X_i$,i=1 to n , A_i any parameter, X_i mole fraction of the components.

Results and Discussions

The present investigation discusses the applications of ultrasonic velocity to study the type of molecular interaction containing 2-bromoanisole, 1-butanol in *n*-hexane ternary liquid mixture. Ultrasonic velocity along with density and viscosity measurement has been used to determine certain acoustical parameters. A study of excess properties is used to determine more information about the type of interactions.

The experimentally measured values of density, viscosity and ultrasonic velocity for the mixture at 303K, 308K and 313K were presented in Table-1 and their plots against concentration are listed in Fig. 1, Fig. 2 and Fig. 3 respectively, Table-2 ,observed the acoustical parameters of the liquid mixture, and Table-3, represents the excess values of adiabatic compressibility and excess free length and excess ultrasonic velocity, respectively, Similarly Table-4 depicted the excess values of acoustic impedance, free volume and internal pressure for the ternary liquid mixtures.

From the Table-1, it was observed that the ultrasonic velocity of the ternary liquid mixtures decreases with increasing temperature of the mixture with a particular concentration while at the same temperature it is observed that an uneven trend of velocity with respect to increase in concentration of the mixture. However viscosity and density is found to increase with increasing concentration of the mixture.

The nature and the strength of molecular interaction in the mixtures were explained based on the variation of ultrasonic velocity and related acoustical parameters with the change in composition of the component of the pure liquids. In the present study, a linear variation in ultrasonic velocity has been noticed; a linear variation in terms of increase with change in composition of the ternary liquid mixture indicates absence of complex formation which is observed from variation of velocity from Table-1. Increasing velocity results in a decrease in adiabatic compressibility, free length and free volume and increase in internal pressure which is observed in present liquid mixture from Table-2. The observation indicates the closer packing of molecules inside the shield.

In order to understand more about the interaction between the components of liquid mixtures, it is necessary to discuss the same in terms of excess parameters rather than actual values. They can yield an idea about the linearity of the system as association or other type of interactions [23]. It can be seen from Table-2, Table-3 and Table-4.

The variation in excess parameters of the liquid mixture is used to explain the structure making or breaking properties of the liquid mixtures, during

the study the existence of weak, strong complex formation and strength of molecular interaction in the liquid mixture through ultrasonic is discussed. The presence of dispersive force makes a positive contribution to the excess values.

The excess acoustic impedance increase with increase in concentration of the mixture for the same concentration and the same excess acoustic impedance decreases with rise in temperature at particular concentration. This increase in excess acoustic impedance indicates significant interaction between the component molecules. The corresponding plot excess acoustic impedance against concentration is given in Fig. 9. That the excess compressibility increases with increase in concentration at particular temperature and the positive excess values are due to weak interaction between the unlike molecules, the negative excess adiabatic compressibility values has been due to closed packed molecules.

Similar conclusions were also arrived by Islam and Quadri [24]. But when the temperature increases at particular concentration the excess adiabatic compressibility values decreases, this shows that there is stronger interaction due to thermal agitation. The plot of excess adiabatic compressibility is presented in Fig. 4. There is an uneven trend is observed for free volume irrespective of temperatures while the concentration of the mixture increases and at particular concentration increase in temperatures shows once again uneven trend. The values of free volume are decreasing at high temperature, this is found to be in agreement with the statement that the free volume is independent upon the temperature. The decrease in excess free volume shows that the strength of interaction increases gradually with the increase in concentration. It represents that there is weak interaction between the components mixture. Fig.7 indicates the plots of excess free volume.

From the Table-III, Excess free length increases with increase of concentration that predicts the presence of specific molecular interaction between the molecules of the liquid mixture. The adiabatic compressibility and free length are the deciding factors of the ultrasonic velocity in liquid systems. The values of excess inter molecular free length follows the same trend as that of β^E. The values of excess inter molecular free length (Lf^E) are negative.

The negative deviation of excess free length is an indication of the existence of strong interaction between the components. And at the same time for a particular concentration, the free length decreases with increasing in temperature. This also supports the existence of strong interaction between the components; the plot is given in Fig. 5 referred excess free length vs concentration.

The negative contribution to excess adiabatic compressibility (β^E_{ad}) shown in Table-3, excess free length (L^E_f) presented in Table-3, and excess ultrasonic velocity(U^E) (Table-3) and the positive contribution to excess acoustic impedance (Z^E), excess internal pressure (π^E_i), excess free volume (V_f^E) observed in Table-4 respectively indicates the presence strong interaction in the present ternary liquid mixtures. The magnitude and sign of excess adiabatic compressibility (β^E_{ad}) can be used to study the structure making / breaking properties of the liquid mixtures, if more than one type of interaction is present between the interacting components. The negative contribution of excess acoustic compressibility can be attributed to structure making effect in the present investigation.

Bromoanisole is relatively a complex molecule, and its non-ideality in all probability may be due to the polarity arising out of C-O and C-Br bonds. As per as bromo group is concerned, it rotates freely along the C-O axis which is likely to give more flexibility to the interaction arising due to highly polar C-Br bonds.

Both bromoanisole and alkanols are polar in nature which can interact by forming hydrogen bonding through dipole-dipole interaction (O-H-Br^-). Alkanols are liquids associated through hydrogen bonding and in the pure state exhibit equilibrium between monomers and multimers species [25]. In the pure state, halogenated compounds present weak dipole-dipole interaction. When bromoanisole is mixed with alkanols the halogenated solvents can interact with -OH groups [26]. The Aromatic derivatives set up an interaction between the electron cloud and the hydroxyl group [27]. Of course this interaction is of minor intensity compared with hydrogen bonding, but they can lead to formation of intermolecular complexes [28].

n-Hexane belongs to alkane of six carbon atom (hydrocarbon), its highly inert towards an electrophile or nucleophile at ordinary temperature , its being a non-polor solvent is not expected to be involved any strong interaction with the other component present in the liquid mixture.

The Table-3 shows, that the negative excess values of U^E (excess ultrasonic velocity) its presence

of dispersion interaction in the ternary liquid mixture. The Fig.6 shows the gradual decrease of excess ultrasonic velocity. The negative value of excess free length which is present in Table-3, predicts its existence of strong interaction in the ternary liquid mixture due to charge transfer, dipole-induced dipole, dipole-dipole interactions, interstitial accommodation and orientation ordering. The excess adiabatic compressibility is negative in the present ternary liquid mixture at different temperatures as shows in Table-3, Fort and Moore found that the negative excess adiabatic compressibility indicates that the greater interaction between the components of the mixtures. The negative excess values of excess adiabatic compressibility which indicates the highly packed molecules in the mixtures due to their shape and size of the molecules.

Excess adiabatic compressibility shows the negative values in the present study which indicates the formation of strong charge transfer complexes. Normally dispersive force makes a positive excess values and dipole-dipole, dipole-induced dipole, charge transfer interaction and hydrogen bonding between unlike components makes negative contribution. In the present study (2-bromoanisole + 1-butanol in *n*-hexane) excess adiabatic compressibility and excess free length makes negative contribution shows the presence of dipole - dipole and hydrogen bonding between 2-bromoanisole, 1- butanol in *n*-hexane at 303K, 308K and 313K, the presence of -Br group at ortho position decreases the interaction between the components in the liquid mixture, it is confirmed by positive excess values of internal pressure presents in Table-4.

The values of excess free volumes are influenced by (i) the specific interaction between the component molecules and weak physical forces like dipole-dipole (or) dipole-induced dipole interaction (or) Wander waal's forces (ii) the dispersive forces , streric hindrance of component molecules, unfavourable geometric fitting and electrostatic repulsion. The former effect leads to contraction of volume and the latter effect leads to expansion of volume. In the present study the positive value of excess free volume may be interpreted as the expansion of volume. The positive value of excess free volume favourable for the latter effect which is account for the weaker molecular interactions.

The values of excess internal pressure shown in Table-4 is positive in the present ternary system, the positive value of excess internal pressure indicates the existence of strong interaction in the liquid system. The graph between excess internal pressure vs concentration is reflected in Fig. 8. Table-5 indicated the comparison of observed and literature values of density, viscosity and velocity of pure substance presented in the ternary liquid mixture, at different temperature 303K, 308K and 313K.

Table-1: Velocity, Density and Viscosity of 2-bromoanisole, 1-butanol and *n*-hexane at 303K, 308K and 313K.

Concentration 10^{-3}M	Velocity (ms^{-1})			Density Kg/m^3			Viscosity$\times10^{-4}$ Nsm^{-2}		
	Temperature (K)			Temperature(K)			Temperature(K)		
	303	308	313	303	308	313	303	308	313
1	1059.7	1033.6	1015.5	803.0	804.0	952.0	4.8	4.9	4.9
2	1060.7	1034.6	1016.2	803.0	804.0	952.0	4.6	4.7	4.8
3	1061.5	1035.2	1017.4	803.0	804.0	952.0	4.7	4.7	4.8
4	1062.9	1036.3	1018.0	803.0	804.0	953.0	4.7	4.7	4.7
5	1063.9	1036.8	1018.4	803.0	804.0	953.0	4.7	4.7	4.7
6	1064.9	1037.5	1019.2	803.0	804.0	953.0	4.6	4.7	4.6
7	1065.3	1038.2	1020.4	803.0	804.0	954.0	4.7	4.7	4.6
8	1066.6	1039.1	1021.4	803.0	805.0	954.0	4.7	4.7	4.6
9	1067.7	1040.2	1022.2	804.0	805.0	955.0	4.6	4.7	4.6
10	1068.8	1040.4	1022.7	804.0	805.0	955.0	4.6	4.7	4.6

Table-2: Adiabatic Compressibility, Acoustic Impedance, Free Length, Free Volume and Internal Pressure of 2-bromoanisole, 1-butanol in *n*-hexane at 303K, 308K and 313K.

Concentration$\times$ 10^{-3}M	(β) $\times10^{-9}$ $Kg^{-1}ms^2$			(Z)$\times10^5$ $Kgm^{-2}s^{-1}$			(L_f)pm $\times10^{-11}$			(V_f) $\times10^{-7}$ m^3			($\prod_i$) $\times10^8$ atm		
	Temperature (K)			Temperature (K)			Temperature (K)			Temperature (K)			Temperature (K)		
	303	308	313	303	308	313	303	308	313	303	308	313	303	308	313
1	1.1	1.2	1.0	8.5	8.3	9.7	6.6	6.7	6.3	3.7	4.0	2.6	2.8	2.7	3.5
2	1.1	1.2	1.0	8.5	8.3	9.7	6.6	6.7	6.3	3.0	3.0	2.3	3.4	3.4	4.1
3	1.1	1.2	1.0	8.5	8.3	9.7	6.6	6.7	6.3	3.0	3.0	2.3	3.4	3.4	4.1
4	1.1	1.2	1.0	8.5	8.3	9.7	6.6	6.6	6.3	3.0	3.0	2.3	3.4	3.4	4.1
5	1.1	1.2	1.0	8.5	8.4	9.7	6.6	6.6	6.3	3.0	3.0	2.3	3.4	3.4	4.1
6	1.1	1.2	1.0	8.6	8.4	9.7	6.5	6.6	6.3	3.0	3.0	2.3	3.4	3.4	4.1
7	1.1	1.2	1.0	8.6	8.4	9.7	6.5	6.6	6.3	3.0	3.0	2.3	3.4	3.4	4.1
8	1.1	1.2	1.0	8.6	8.4	9.7	6.5	6.6	6.3	3.0	3.0	2.3	3.4	3.4	4.1
9	1.1	1.2	1.0	8.6	8.4	9.7	6.4	6.5	6.3	3.0	3.0	2.3	3.4	3.4	4.2
10	1.1	1.2	1.0	8.6	8.5	9.7	6.4	6.5	6.3	3.0	3.0	2.3	3.4	3.4	4.2

Table-3: Excess Adiabatic Compressibility, Excess Free Length and Excess Ultrasonic Velocity of 2-bromoanisole, 1-butanol, *n*-hexane at 303K,308K and 313K.

Excess Adiabatic Compressibility×10^{-10} Kg^{-1} ms^2				Excess Free Length×10^{-10} m			Excess Ultrasonic Velocity(m/s)		
Temperature(K)				Temperature(K)			Temperature(K)		
Concentration × 10^{-3} M									
10^{-03}M	303	308	313	303	308	313	303	308	313
1	-3.56	-4.14	-6.52	-6.91	-7.13	-7.37	-39.77	-39.50	-34.61
2	-5.57	-6.71	-9.56	-7.14	-7.41	-7.70	-60.46	-55.65	-48.33
3	-7.81	-9.46	-12.81	-7.34	-7.67	-8.00	-79.86	-70.90	-60.49
4	-10.19	-12.52	-16.51	-7.54	-7.92	-8.29	-97.23	-84.65	-72.36
5	-12.85	-15.92	-20.53	-7.73	-8.16	-8.57	-113.68	-97.83	-83.61
6	-15.83	-19.75	-25.05	-7.91	-8.39	-8.83	-129.08	-110.01	-93.68
7	-19.30	-24.17	-30.26	-8.08	-8.61	-9.09	-144.28	-121.55	-102.71
8	-23.14	-29.10	-36.08	-8.25	-8.82	-9.33	-157.24	-132.04	-111.38
9	-27.56	-34.77	-42.78	-8.41	-9.03	-9.57	-169.84	-141.67	-119.59
10	-32.70	-41.36	-50.57	-8.57	-9.22	-9.80	-181.58	-151.58	-125.67

Table-4: Excess Free Volume, Excess Internal Pressure and Excess Acoustic Impedance of 2-bromoanisole, 1- butanol in *n*-hexane at 303K, 308K and 313K.

Excess Free Volume×10^{-7} m^3				Excess Internal Pressure×10^{8} Nm^{-2}			Excess Acoustic Impedance×$10^{5}$$Kgs^{-1}$		
Temperature(K)				Temperature(K)			Temperature (K)		
Concentration×10^{-3} M	303	308	313	303	308	313	303	308	313
1	1.06	1.36	0.03	1.27	1.18	2.02	1.51	1.49	3.01
2	0.97	0.97	0.27	1.35	1.36	2.12	1.55	1.54	3.03
3	0.93	0.93	0.23	1.16	1.17	1.94	1.57	1.55	3.07
4	1.04	1.04	0.24	0.95	0.96	1.77	1.59	1.57	3.10
5	0.95	0.96	0.25	0.78	0.79	1.62	1.62	1.60	3.12
6	0.91	0.91	0.26	0.61	0.62	1.47	1.65	1.62	3.14
7	0.98	0.98	0.28	0.46	0.47	1.33	1.67	1.65	3.18
8	1.00	1.01	0.29	0.32	0.33	1.21	1.70	1.67	3.20
9	0.93	0.83	0.23	0.19	0.19	1.18	1.71	1.70	3.24
10	0.93	0.82	0.23	0.06	0.07	1.08	1.73	1.72	3.26

Table-5: Comparison of observed and literature value velocity, density and viscosity of pure substance in the ternary mixture of 2-bromoanisole, 1-butanol in *n*-hexane at 303K, 308K and 313K.

Name of Component in the ternary mixtures.		Velocity (ms^{-1})			Density Kg/m^3			Viscosity×10^{-4} Nsm^{-2}		
		Temperature (K)			Temperature (K)			Temperature (K)		
		303	308	313	303	308	313	303	308	313
n- Hexane	Observed	1065.1	1054.5	1034.6	0.651	0.648	0.64	0.326	0.31	0.302
	Literature	1058.30 [29]			0.654 [34]			0.296 [35]		
1-Butanol	Observed	1182.5	1180.8	1162.0	0.801	0.798	0.796	1.658	1.516	1.498
	Literature	1198.5 [30]		1189.1 [31]	0.795 [32]		0.787[33]	1.73 [31]		1.381 [32]
2-Bromoanisole	Observed	1267.6	1150.8	1074.9	1.307	1.302	1.30	2.698	2.30	1.994
	Literature	-	-	-	-	-	-	-	-	-

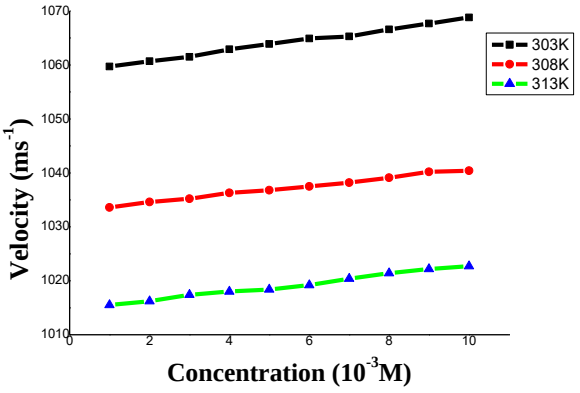

Fig. 1: Plot of concentration vs velocity.

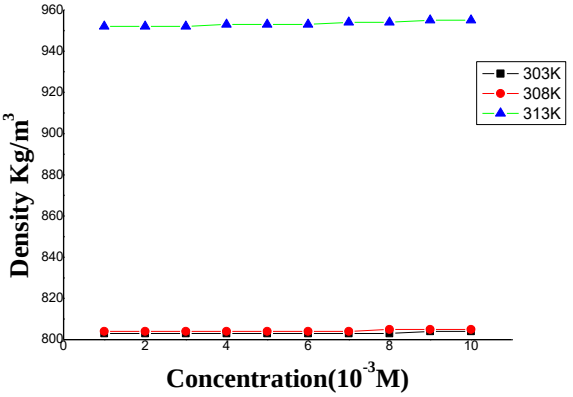

Fig. 2: Plot of concentration vs density.

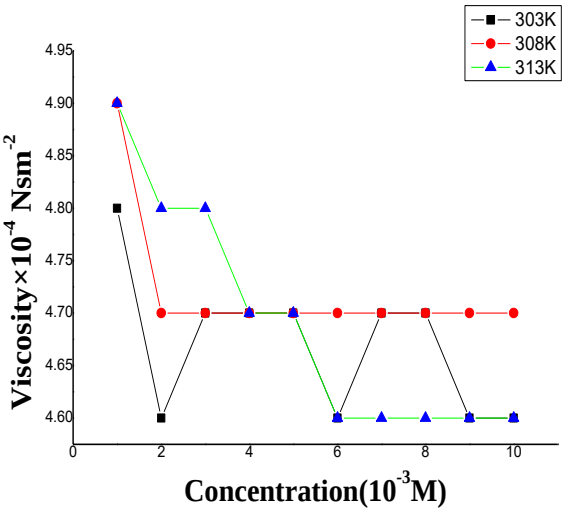

Fig. 3: Plot of concentration vs viscosity.

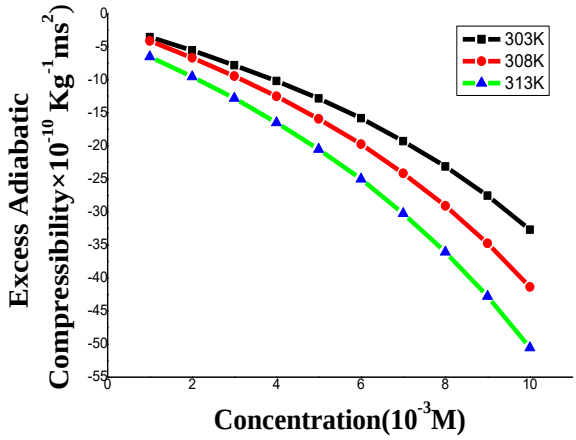

Fig. 4: Plot of concentration vs excess adiabatic compressibility.

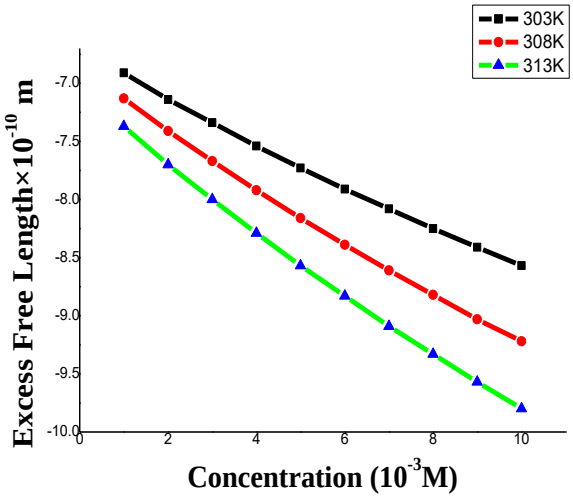

Fig. 5: Plot of concentration vs excess free length.

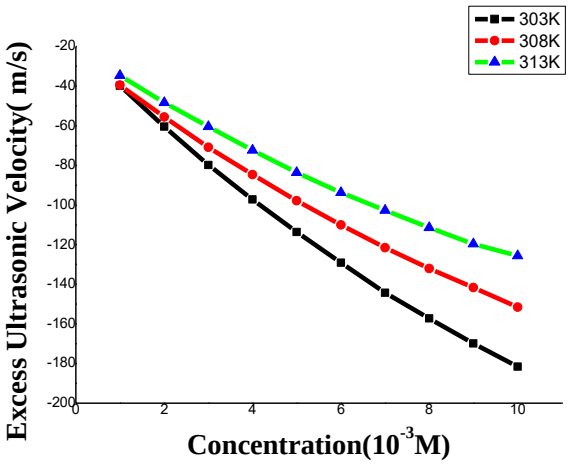

Fig. 6: Plot of concentration vs excess ultrasonic velocity.

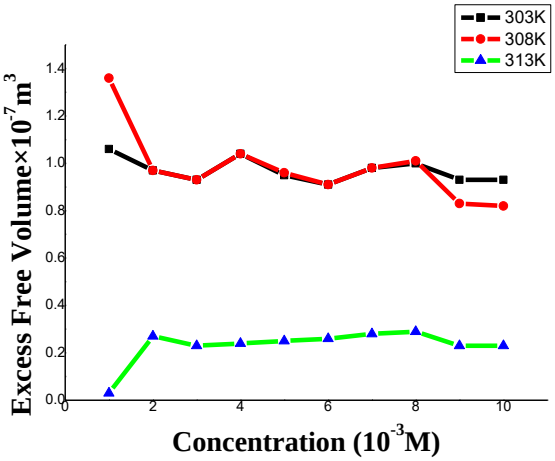

Fig. 7: Plot of concentration vs excess free volume.

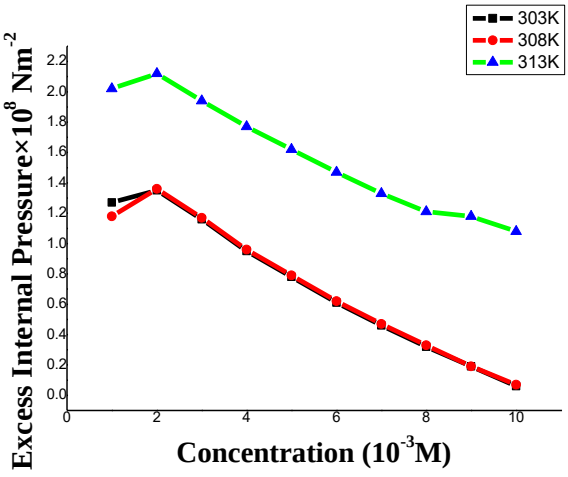

Fig. 8: Plot of concentration vs excess internal pressure.

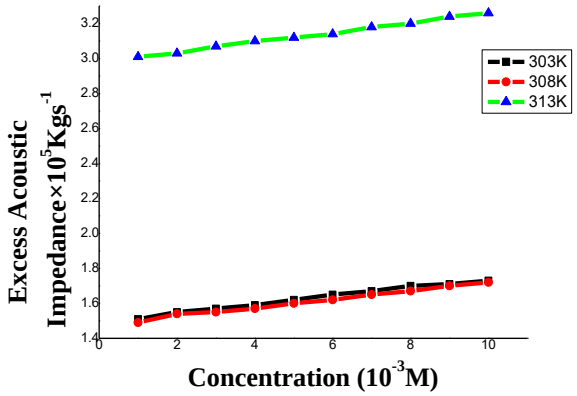

Fig. 9: Plot of concentration vs excess acoustic impedance.

Conclusions

The following conclusions are drawn:

1. The net increase in the concentration of the mixture increases the strong interactions. If the medium also becomes more compact, the speed increases and the continued observance of the systems (2-bromoanisole +1-butanol+*n*-hexane).
2. The increase in temperature due to thermal agitation, resulting in a decrease in ultrasonic velocity. An increase in viscosity with increase in concentration suggests that molecular interactions are increasing in thickness of the liquid mixture and molecular size and shape of the elements that play an equally important role.
3. The adiabatic compressibility suggests that the lack of interaction between unlike molecules that have the minimum declarations.
4. Unlike molecules, weak interactions provide positive higher values, while the dipole-dipole, dipole-induced dipole, charge transfer and hydrogen bonding are unlike the molecules of negative ones. From the magnitude of velocity, there is molecular interactions in the mixture, which are linked to the phenolic group of oxygen atoms, resulting in a weak link between them.
5. The donor-acceptor molecular association arise due to dipole-dipole interaction and the polar nature of different molecular entities in the mixture. The solute solvent association arise due to slightly polar solute and non polar nature of the solvent (*n*-hexane). In this system, molecular association is proposed for nearly equal in ratio of 2-bromoanisole and 1-butanol.

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