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Study of Thermo-Acoustical Parameters in Binary Liquid Mixture Containing Quinoline and Benzene At Temperatures T= (303.15, 308.15, 313.15 and 318.15) K.

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ABSTRACT

Ultrasonic velocities, densities and viscosities have been measured in binary liquid mixture containing quinoline and benzene over the entire mole fraction range of quinoline at temperatures T=(303.15,308.15,313.15 and 318.15)K. From experimentally measured data of ultrasonic velocity, density and viscosity, thermo-acoustical parameters such as adiabatic compressibility (β), intermolecular free length(L_f), acoustical impedance(Z) and internal pressure(π) have been calculated. These results have been explained in terms of molecular interactions between the components of liquid mixture.
Keywords: Ultrasonic velocity, density, viscosity, adiabatic compressibility, internal pressure.

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INTRODUCTION

The study of thermo-acoustical parameters in binary liquid mixture has proved to be useful in elucidating the structural interactions between the components of liquid mixture [1-6]. There are considerable number of recent investigations [7-9] on ultrasonic velocity and their derived parameters are available in this technology with variation of composition and temperature. The temperature dependence of the parameters give important information about the molecular interaction between the components of the mixtures. Study of thermo-acoustical parameters are useful to understand different kinds of association, the molecular packing, physico-chemical behaviour and various types of intermolecular interactions in the liquid mixtures [10]. In the present paper, values of thermo-acoustical parameters and their variations with mole fraction of quinoline in binary liquid mixtures containing quinoline and benzene at temperatures T= (303.15, 308.15, 313.15 and 318.15) K have been reported. Quinoline is a heterocyclic aromatic organic compound with the chemical formula C_9H_7N. Quinoline is a colourless liquid with strong odor and widely useful in manufacturing of dyes, pesticides and solvent for resins and terpenes. Quinoline is often reported as an environmental contaminant associated with facilities processing oil shale or coal and has also been found at legacy wood treatment sites. Benzene is an important organic chemical compound with the chemical formulaC_6H_6 and its molecule is composed of 6 carbon atoms joined in a ring with 1 hydrogen atom attached to each carbon atom. Benzene is a colorless and highly flammable liquid with a sweet smell. Benzene is a natural constituent of crude oil, and is one of the most elementary petrochemicals. Variation of acoustical parameters with mole fraction of quinoline at temperatures T=(303.15, 308.15, 313.15 and 318.15)K is expected to reveal the nature of interactions between the component molecules of the liquid mixtures [11].

MATERIALS AND METHODS

In the present investigation the chemicals used are of AnalaR grade and are obtained from SDFCL chemicals (quinoline) and MERCK chemicals (benzene). The chemicals are purified by standard procedure [12].The different concentrations of the liquid mixture are prepared by varying mole fractions with respect to Job's method of continuous variation. Stoppard conical flasks are used for preserving the prepared mixtures and the flasks are left undisturbed to attain thermal equilibrium. Ultrasonic pulse echo interferometer (Mittal enterprises, India) is used for ultrasonic velocities measurements and all these measurements are done at a fixed frequency of 3MHz. The temperature of the pure liquids or liquid mixtures is done by using temperature controlled water bath by circulating water around the liquid cell which is present in interferometer. Specific gravity bottle is used for the measurement of densities of pure liquids and liquid mixtures. An electronic weighing balance (Shimadzu AUY220, Japan), with a precision of + or - 0.1 mg is used for the measurements of mass of pure liquids or liquid mixtures. Average of 4 to 5 measurements is taken for each sample. Ostwald's viscometer is used for the measurement of viscosity of pure liquids or liquid mixtures .The time of flow of liquid in the viscometer is measured with an electronic stopwatch with a precision of 0.01s.

THEORY AND CALCULATIONS

From the experimentally measured values of ultrasonic velocities, viscosities and densities, thermo-acoustical parameters such as adiabatic compressibility(β),intermolecular freelength(L_f), acoustical impedance(Z) and internal pressure(π) have been calculated by using following relations

ADIABATIC COMPRESSIBILITY (β):

Adiabatic compressibility is a measure of intermolecular association or dissociation or repulsion. It also determines the orientation of the solvent molecules around the liquid molecules. It can be calculated using the equation [13]

$$\beta = 1/(\rho u^2) \quad N^{-1}.m^2 \qquad \text{------(1)}$$

Where, u is the ultrasonic velocity and ρ is the density of the solution.

INTERMOLECULAR FREE LENGTH (L_f)

The free length is the distance between the surfaces of the neighbouring molecules. The intermolecular free length has been calculated using the following formula given by Jacobson [14]

$$L_f = k.\beta^{1/2} \quad Å \quad \text{-------(2)}$$

Where, k is Jacobson's constant.

ACOUSTICAL IMPEDANCE (Z):

Acoustic impedance is important in the determination of acoustic transmission and reflection at the boundary of two materials having different acoustic impedance. It is also useful in the designing of ultrasonic transducers and for assessing absorption of sound in a medium. It is given by the relation

$$Z = u.\,\rho \quad Kg.m^{-2}.s^{-1} \quad \text{-------(3)}$$

INTERNAL PRESSURE (π):

Internal pressure is a fundamental property of a liquid, which provides an excellent basis for examining the solution phenomenon and studying various properties of the liquid state. The internal pressure [15] of the liquid mixture is obtained from the experimental values of ultrasonic velocity, density and viscosity given by

$$\pi = bRT\left[\frac{K\eta}{U}\right]^{1/2}.\left[\frac{\rho^{2/3}}{M_{eff}^{\;7/6}}\right] \quad N.m^{-2} \quad \text{-------(4)}$$

RESULTS AND DISCUSSION

The Comparison of experimentally measured values of densities, ultrasonic velocities and viscosities of pure liquids together with the literature values is given in **Table-1**.

Table 1: The values of densities (ρ), ultrasonic velocities (u) and viscosities (η) of pure liquids together with literature values at temperature T=303.15K.

Liquid	Density ρ(Kg.m^{-3})		Ultrasonic velocity u(m.s^{-1})		Viscosity η (m.Pa.S)	
	Exp	Lit	Exp	Lit	Exp	Lit
Quinoline[16]	1085.45	1085.79	1553.68	1547.00	2.9320	2.9280
Benzene[17]	864.96	866.8	1283.18	1284.44	0.6200	0.6300

The evaluated values of thermo-acoustical parameters such as adiabatic compressibility (β), intermolecular freelength (L_f), acoustical impedance (Z) and internal pressure(π) for the above binary liquid mixture over the entire molefraction range of quinoline at temperatures T=(303.15,308.15,313.15and 318.15)K are given in the **Table-2**. The variations of these thermo-acoustical values with respect to the molefraction of quinoline at temperatures T=(303.15,308.15,313.15and 318.15)K are represented in the figures from **Fig-1** to **Fig-4**.

Table-2: The values of thermo-acoustical parameters such as adiabatic compressibility (β), intermolecular free length (L_f), acoustical impedance (Z) and internal pressure(π) for the above binary liquid mixture over the entire molefraction range of quinoline at temperatures T=(303.15,308.15,313.15 and 318.15)K.

Molefraction (X_1)	Adiabatic compressibility(β) x10^{-11} $N^{-1}.m^2$			
	T=303.15K	T=308.15K	T=313.15K	T=318.15K
0.0000	70.21	72.93	75.48	78.45
0.0779	65.73	68.35	70.84	73.55
0.1596	61.63	64.03	66.31	68.79
0.2457	57.86	60.07	62.16	64.53
0.3362	54.39	56.42	58.35	60.53
0.4318	51.19	52.99	54.76	56.77
0.5327	48.24	49.91	51.47	53.31
0.6394	45.52	46.99	48.43	49.99
0.7524	42.99	44.24	45.44	46.68
0.8724	40.65	41.52	42.25	43.13
1.0000	38.17	38.43	38.72	39.17
	Intermolecular freelength(L_f) Å			
0.0000	0.1661	0.1705	0.1747	0.1794
0.0779	0.1608	0.1651	0.1693	0.1737
0.1596	0.1557	0.1598	0.1638	0.1680
0.2457	0.1508	0.1548	0.1586	0.1627
0.3362	0.1462	0.1500	0.1536	0.1576
0.4318	0.1419	0.1454	0.1488	0.1526
0.5327	0.1377	0.1411	0.1443	0.1479
0.6394	0.1338	0.1369	0.1400	0.1432
0.7524	0.1300	0.1328	0.1356	0.1384
0.8724	0.1264	0.1287	0.1307	0.1330
1.0000	0.1225	0.1238	0.1252	0.1268
	Acoustical impedance(Z) x 10^6 $Kg.m^{-2}.s^{-1}$			
0.0000	1.1099	1.0829	1.0595	1.0343
0.0779	1.1615	1.1343	1.1091	1.0835
0.1596	1.2143	1.1864	1.1607	1.1345
0.2457	1.2682	1.2397	1.2134	1.1857
0.3362	1.3233	1.2941	1.2673	1.2389
0.4318	1.3796	1.3507	1.3233	1.2943
0.5327	1.4370	1.4075	1.3805	1.3509
0.6394	1.4955	1.4665	1.4389	1.4106
0.7524	1.5553	1.5277	1.5015	1.4758
0.8724	1.6162	1.5950	1.5744	1.5517
1.0000	1.6864	1.6780	1.6690	1.6566
	Internal pressure(π)x 10^6 $N.m^{-2}$			
0.0000	126.74	110.26	89.82	64.83
0.0779	140.89	128.11	112.76	95.98
0.1596	150.79	140.20	127.77	114.79
0.2457	157.66	148.64	138.19	127.59
0.3362	162.24	154.43	145.44	136.48
0.4318	165.03	158.13	150.28	142.54
0.5327	166.38	160.27	153.28	146.51
0.6394	166.55	161.04	154.81	148.74
0.7524	165.74	160.68	155.00	149.43
0.8724	164.10	159.54	153.94	148.60
1.0000	162.29	155.78	147.94	144.33

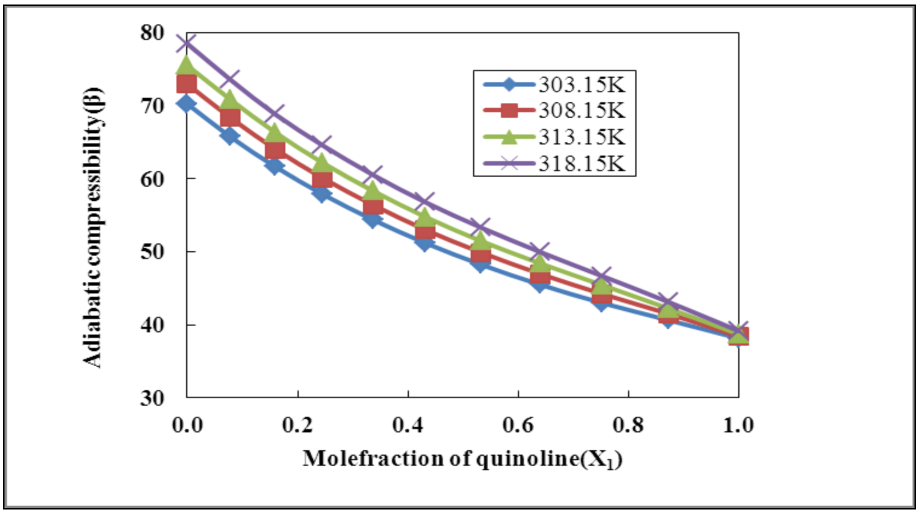

Fig-1: Variation of adiabatic compressibility (β) with molefraction of quinoline(X_1)

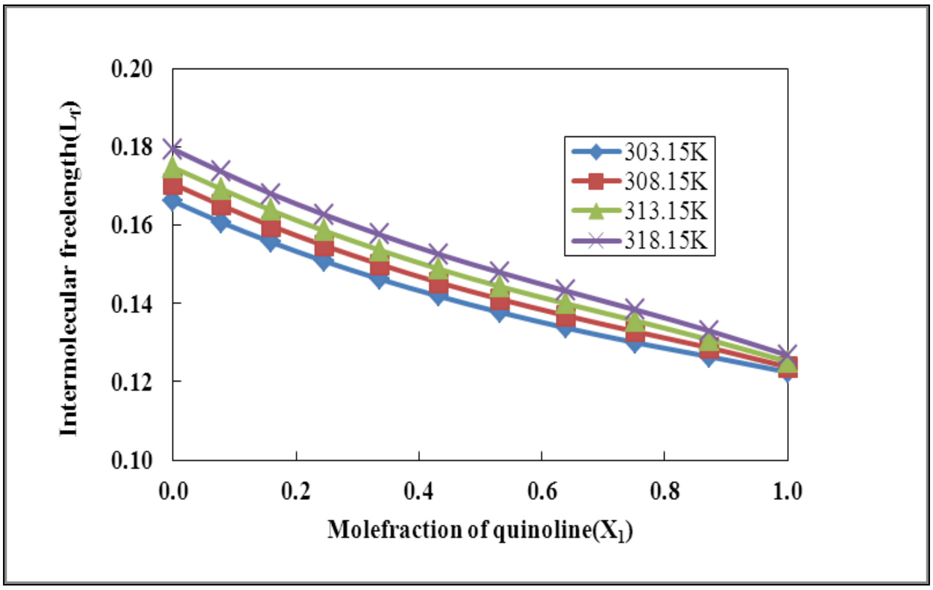

Fig-2: Variation of intermolecular freelength (L_f) with molefraction of quinoline(X_1)

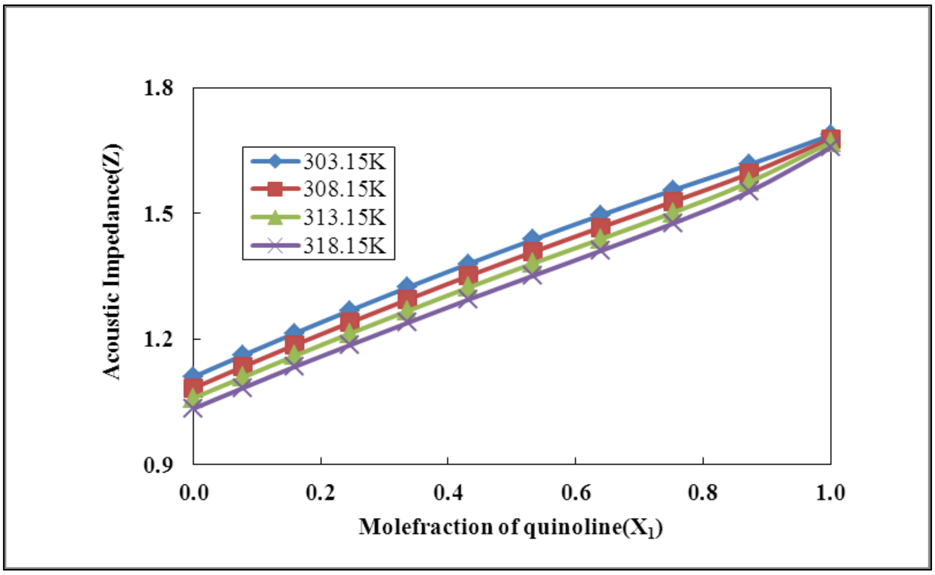

Fig-3: Variation of acoustical impedance (Z)with molefraction of quinoline(X_1)

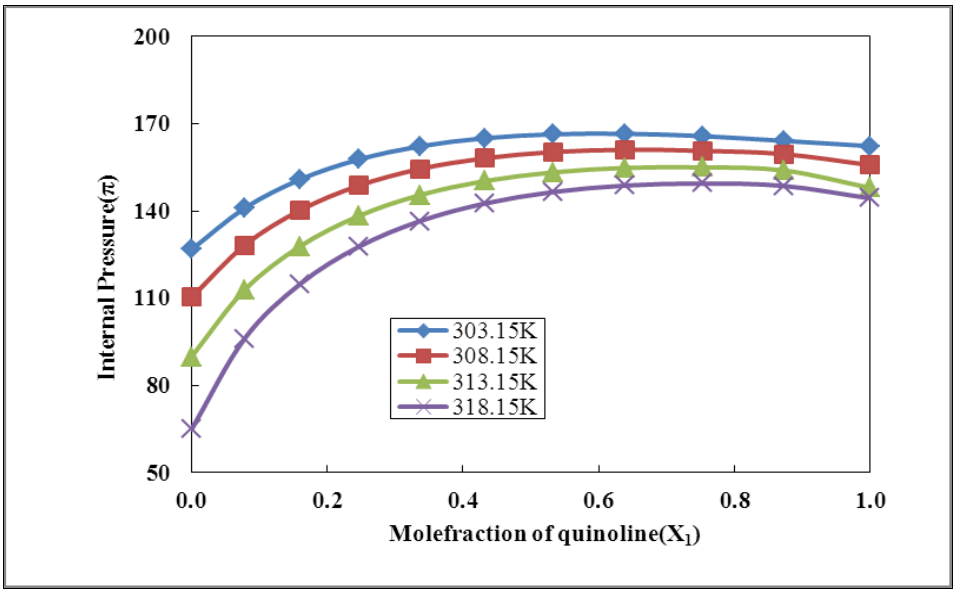

Fig-4: Variation of acoustical impedance (Z) with molefraction of quinoline(X_1)

The variation of adiabatic compressibility(β) with respect to the molefraction of quinoline ranging from 0 to 1 at temperatures T=(303.15,308.15,313.15 and 318.15)K is as shown in Fig-1. From Fig-1, it is observed that the value of adiabatic compressibility decreases with increase in molefraction of quinoline. Also from Fig-1, it is observed that as the temperature increases the adiabatic compressibility value increases in the present binary liquid mixture. Similar observations are made by Ali and Nain [18] in their binary mixtures and reported that the interactions become weaker with increase of temperature.The variation of intermolecular freelength(L_f) with respect to the molefraction of quinoline ranging from 0 to 1 at temperatures T=(303.15,308.15,313.15 and 318.15)K is as shown in Fig-2.From Fig-2, it is observed that the value of intermolecular freelength decreases with increase in molefraction of quinoline. The decrease in intermolecular freelength(L_f)indicates strong intermolecular interactions [19] between the components of the liquid mixture. Also intermolecular freelength increases with the increase of temperature. According to a model proposed by *Eyring Kincaid*, ultrasonic velocity should increase if the intermolecular freelength decreases as a result of mixing components [20]. In the present study, similar results are observed.Fig-3 represents the variation of acoustical impedance (Z) with respect to the molefraction of quinoline at temperatures T=(303.15,308.15,313.15 and 318.15)K.From Fig-3, it is cleared that the value of acoustical impedance increases with the molefraction of quinoline. This supports the strong molecular interactions as suggested by Garcia *et al. [*21], Oswal *et al.[*22]. When an acoustic wave travels in a medium, there is a variation of pressure and instantaneous velocity from particle to particle. This is governed by the inertial and elastic properties of the medium.The variation of internal pressure (π) with respect to molefraction of quinoline ranging from 0 to 1 at temperatures T=(303.15,308.15,313.15 and 318.15)K is as shown in Fig-4.From Fig-4, it is observed that internal pressure value increases with the increase of molefraction of quinoline.The above from Fig-4 results tell that the interactions are increasing [23] with molefraction of quinoline and decreasing with temperature.

CONCLUSIONS

Ultrasonic velocity, density and viscosity values are measured in the binary liquid mixture containing quinoline and benzene at temperatures T=(303.15,308.15,313.15 and 318.15)K. By using these values, thermo-acoustical parameters such as adiabatic compressibility (β), intermolecular freelength(L_f), acoustical impedance(Z) and internal pressure(π) have been calculated over the entire molefraction range of quinoline. An analysis of these results suggests the presence of strong intermolecular interactions between the components of liquid mixture. Also the strength of molecular interactions is observed to be decreased with temperature.

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