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Acoustical Studies On Binary Liquid Mixtures Of Some Benzene Sulphonyl Chloride with Hydrocarbons at 303.15 K

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Abstract

In the present study ultrasonic velocity (u) and density (ρ) have been measured at frequency 1 MHz in the binary mixture of benzene sulphonyl chloride in hydrocarbon at 303.15k using ultrasonic interferometer technique. The measured value of ultrasonic velocity(u) and density(ρ) have been used to estimate the acoustical parameter namely free length (L_f), adiabatic compressibility (β_s), acoustic impedance(Z), and Wada's constant (W) with a view to investigate the nature and the strength of molecular interactions. The results are analyzed in the site of molecular interaction between the components. The interaction resulting in the interstitial accommodation of benzene sulphonyl chloride into hydrocarbon are predominant factor over dipole -dipole interaction.

Keywords Acoustical properties, ultrasonic velocity, density, free length, Wada constant, acoustic impedance.

INTRODUCTION

The ultrasonic study of liquid and liquid mixtures is useful in understanding the nature of molecular interactions in pure liquids and in liquid mixtures. Ultrasonic waves are high frequency mechanical waves. Ultrasonic wave propagation affects the physical properties of the medium and hence can provide information about molecular interactions of the pure liquids and liquid mixtures. Ultrasonic offer the most exciting

and fascinating field of scientific research among the researcher. Since the ultrasonic and other related thermo acoustic parameters provide useful information regarding the structure of molecules, molecular order, molecular packing, inter and intra -molecular interaction [1-2] etc. Ultrasonic study of liquid and liquid mixture has gained much importance during the last two decades in assessing the nature of molecular interaction and investigating the physiochemical behavior of system [3-4]. Molecular interaction in liquid mixtures has been extensively studied using ultrasonic technique by many workers [5], because mixed solvents find practical applications in many chemical, biological and industrial processes. The measured ultrasonic parameters are being extensively useful to study intermolecular processes in liquid systems [6-7]. The sign and magnitude of the non-linear deviations from ideal values of sound velocities and adiabatic compressibility of liquid mixtures with composition are related to the difference in molecular size and strength of interaction between unlike molecules. In the present study the chemicals used are Benzene sulphonyl chloride, pentane, hexane and heptane.

In the present work, density and ultrasonic velocity of Benzene sulphonyl chloride, pentane, hexane and heptane binary mixture have been measured and used to compute the acoustic parameters such as adiabatic compressibility (β_s), free length (L_f), Wada's constant (W) and acoustic impedance (Z). In addition to these thermo-acoustic parameters excess parameters were computed. These are excess intermolecular free length (L_f^E), excess adiabatic compressibility (β_s^E), excess wada constant (W^E) and excess acoustic impedance (Z^E). Behavior of these parameters has been used to interpret the intermolecular interaction in this binary mixture for entire mole fraction range.

EXPERIMENTAL

Materials

The chemicals used in the present work were high purity laboratory reagent grade samples of Benzene Sulphonyl chloride, n-pentane, n-hexane and n-heptane were purchased from Merck Chem. Ltd India. All chemicals was stored over sodium hydroxide pellets for several days and fractionally distilled twice (Perrin, et al, 1988) [8]. All chemicals was purified by the method described by Zhao et al (2000) [8] benzene sulphonyl chloride was dried over K_2CO_3, filtered and distilled were discarded. All the chemicals were stored in dark bottles over freshly activated molecular sieve to minimize absorption of moisture. The purity of the solvent was ascertained by comparing the measured density and sound velocity of the pure component at 303.15K, as shown in Table 1. The reported experimental values of density (ρ) and ultrasonic velocity (u) conform closely to their corresponding literature values,

Measurements

Three binary system viz. Benzene sulphonyl chloride + n-pentane, Benzene sulphonyl chloride + n-hexane and Benzene sulphonyl chloride + n-heptane were studied. Each sample mixture was prepared, on mass basis, by mixing the calculated volume of liquid components in specially designed glass stopper bottles. All binary mixture were prepared by weight covering the entire mole fraction range. The components of binary

mixtures were injected by means of syringe in to the glass vials of sealed with rubber stopper in order to check evaporation losses during sample preparation. The mass measurements were carried out using an single pan analytical balance (Model K-15 Deluxe, K Roy Instruments Pvt. Ltd.) with an accuracy of $\pm 0.00001 \times 10^{-3}$ kg as described elsewhere (R.R. Yadava, et al 1994) [9]. The possible error in the mole fraction was estimated to be less than $1x10^{-4}$. Five samples were prepared for one system, and their density and sound velocity were measured on the same day.

Density

Densities of pure liquids and their binary mixtures were determined by using a double-arm pycnometer (Sathyanarayan, et al 2007) [10] with a bulb of 25 cm^3 and a capillary of an internal diameter of about 1 mm is used to measure the densities (ρ) of pure liquids and binary mixtures. The pycnometer is calibrated by using conductivity water (having specific conductance less than 1×10^6 ohm^{-1}) with 0.9970 and 0.9940 gm as its densities at T = 303.15 K, respectively. The pycnometer filled with air bubbles free liquids is kept in a thermostate water both (MSI Goyal Scientific, Meerut, India) controlled with a thermal equilibrium. The precision of the density measurements was estimated to be ± 0.0002 g cm^3. The observed values of densities of pure Benzene sulphonyl chloride, n-pentane, n-hexane and n-heptane, at 303.15K were 1.3901, 0.6134, 0.6632 and 0.6529 g /cm^3 which compare well with corresponding literature values of respectively.

Sound velocity

The ultrasonic velocities were measured using a multifrequency ultrasonic interferometer (Model F-80D, Mittal Enterprise, New Delhi, India) working at 1 M.Hz. The meter was calibrated with water and benzene at 303.15K. The measured values of ultrasonic velocities of pure n-pentane, n-hexane and n-heptane 303.15K were 1220, 960, 1065 and 1120 $m.s^{-1}$ respectively, which compare well with the corresponding literature values.

Table 1: Value of Sound velocity (U) and Density (ρ) of pure organic liquids at 303.15K

Liquids	**Sound Velocity Experimental (U_{exp}) ms^{-1}**	**Sound Velocity Literature (U_{exp}) ms^{-1}**	**Density Experimental (ρ_{exp})gm/cm^3**	**Density Literature (ρ_{exp}) gm/cm^3**
Benzene Sulphonyl Chloride	1220	1233	1.3901	1.3901
n- Pantane	960	975	0.6134	0.6132
n-Hexane	1065	1095	0.6632	0.6632
n-Heptane	1120	1131	0.6529	0.6529

THEORATICAL BACKGROUND

For the measurement of ultrasonic absorption by interferometer technique, the experimental liquid is placed in the cell of the ultrasonic interferometer. Then the distance between the crystal and the reflector is slowly varied by the micrometer screw. The current in the anode circuit of the oscillator undergoes cyclic variation giving rise to alternate maxima and minima. The distance between consecutive alternate maxima and minima corresponds to half wavelength in the liquid medium. The ultrasonic velocity is found using the average values of minima and maxima. The standard equations utilized for computation of different thermo-acoustic parameters are explained below.

1. **Ultrasonic Velocity**: It is the velocity of the sound waves propagating through the binary liquid mixture. λ is the wavelength of the sound waves inside the binary or ternary liquid mixture.

$$U = n \lambda \text{ m/s} \quad (1)$$

2. **Intermolecular Free Length**: It is the distance covered by sound wave between the surfaces of the neighboring molecules. It is measure of intermolecular attractions between the components in a binary or ternary liquid mixture.

$$L_f = K.\beta_{ad}^{1/2} \text{ m} \quad (2)$$

K is a constant known as Jacobson's constant given by
$K = (93.875 + 0.375 \text{ T in degree Kelvin}) \times 10^{-8}$

3. **Adiabatic compressibility**: β_s, is the adiabatic compressibility, which is given by the relation

$$\beta_s = u^{-2} \rho^{-1} \quad (3)$$

Where ρ is the density of liquid.

3. **Wada's Constant**: It is required in the study of acoustical properties of pure liquids & liquid mixtures. It is also known as molar compressibility. Its value depends on the structure of pure liquid or liquid mixtures. Variations in Wada's constant with mole fraction of the solute provide evidence of molecular interaction between the components of binary or ternary system.

$$W = \frac{M}{\rho} \cdot \frac{1}{\beta^{1/7}} \text{ J/mol} \quad (4)$$

4. **Specific Acoustic Impedance**: When an acoustic wave travels in a medium there is variation of pressure from particle to particle. The ratio of instantaneous pressure excess at any particle of the medium to the instantaneous velocity of that particle is known as specific acoustic impedance of that medium.

$$Z = U.\ \rho\ Kg\ /m^2.s \qquad (5)$$

5. Excess Parameters: The general relation for evaluating various excess parameters is

$$A^E = A_{expt.} - A_{ideal} \qquad (6)$$

where $A_{expt.}$ is the experimentally determined values of any acoustical parameters and $A_{ideal} = \Sigma\ A_i\ X_i$, A_i is any acoustical parameters & X_i the mole fraction of that liquid component. The nature and degree of molecular interaction between the component molecules of the liquid mixture have been speculated through the size and extent of deviation of the excess parameters. There will be positive deviation if size of the solvent molecule is increased and if it is decreased then the deviation is negative. A stronger molecular interaction may be due to charge transfer, dipole-induced dipole and dipole-dipole interactions. It leads to more compact structure of binary or ternary liquid mixtures. Weak molecular interactions may cause expansion in the volume of the liquid mixture.

RESULTS AND DISCUSSION

The experimentally measured values of density (ρ) and ultrasonic velocity (u) and compared values of adiabatic compressibility (β_s), and inter molecular free length (L_f) with respect to concentration of Benzene sulphonyl chloride in pentane, hexane and heptane are present in table – 2. Evaluation of all these parameter is done at the constant temperature 303.15 K and at fixed ultrasonic frequency 1 MHz. These parameters play very important role in explaining the nature and degree of association or dissociation among the constituents of the binary mixture of Benzene sulphonyl chloride in pentane, hexane and heptane that discussion of result obtained from these parameter is made below.

Table 2: The acoustic parameters density, sound velocity, adiabatic compressibility and intermolecular free length at 303.15 K.

Mole Fraction (x_1)	Density (ρ) gm.cm^{-3}	Ultrasonic Velocity (u) ms^{-1}	Adiabatic Compressibility (β_s)X10^6 (Pa)$^{-1}$	Free length (L_f)X10^6 (m)
Benzene suplhonyl chloride + pentane				
0.0000	0.6135	975	1.7146	0.8262
0.2012	0.6576	1020	1.4602	0.7456
0.3618	0.7056	1060	1.2613	0.6842
0.4928	0.8129	1090	1.0354	0.6297
0.6018	0.8746	1115	0.9196	0.5887
0.6939	0.9056	1140	0.8493	0.5486
0.7728	0.9789	1160	0.7584	0.5191
0.8411	1.0696	1175	0.6771	0.4986
0.9006	1.1783	1190	0.5993	0.4696
0.9892	1.3796	1210	0.4950	0.4439
1.0000	1.3901	1220	0.4833	0.4386
Benzene suplhonyl chloride + hexane				
0.0000	0.6632	1065	1.3294	0.7275
0.2012	0.6901	1070	1.2656	0.7098
0.3618	0.7801	1075	1.1092	0.6645
0.4928	0.9012	1085	0.9425	0.6125
0.6018	0.9881	1100	0.8363	0.5769
0.6939	1.1001	1110	0.7377	0.5419
0.7728	1.3094	1125	0.6034	0.4900
0.8411	1.3499	1140	0.5700	0.4763
0.9006	1.3601	1160	0.5464	0.4663
0.9892	1.3701	1190	0.5154	0.4529
1.0000	1.3901	1220	0.4833	0.4386
Benzene suplhonyl chloride + heptane				
0.0000	0.6529	1120	1.2210	0.6971
0.2012	0.7289	1122	1.0897	0.6586
0.3618	0.7710	1125	1.0248	0.6387
0.4928	0.8712	1130	0.8989	0.5982
0.6018	0.9014	1140	0.8536	0.5829
0.6939	0.9901	1150	0.7637	0.5513
0.7728	1.0912	1160	0.6810	0.5207
0.8411	1.2610	1170	0.5793	0.4802
0.9006	1.3212	1180	0.5435	0.4651
0.9892	1.3701	1200	0.5068	0.4491
1.0000	1.3901	1220	0.4833	0.4386

The variation of the above mention parameters with rise in mole fraction of Benzene sulphonyl chloride in pentane, hexane and heptane is illustrated in figure 1 to 4 as shown below

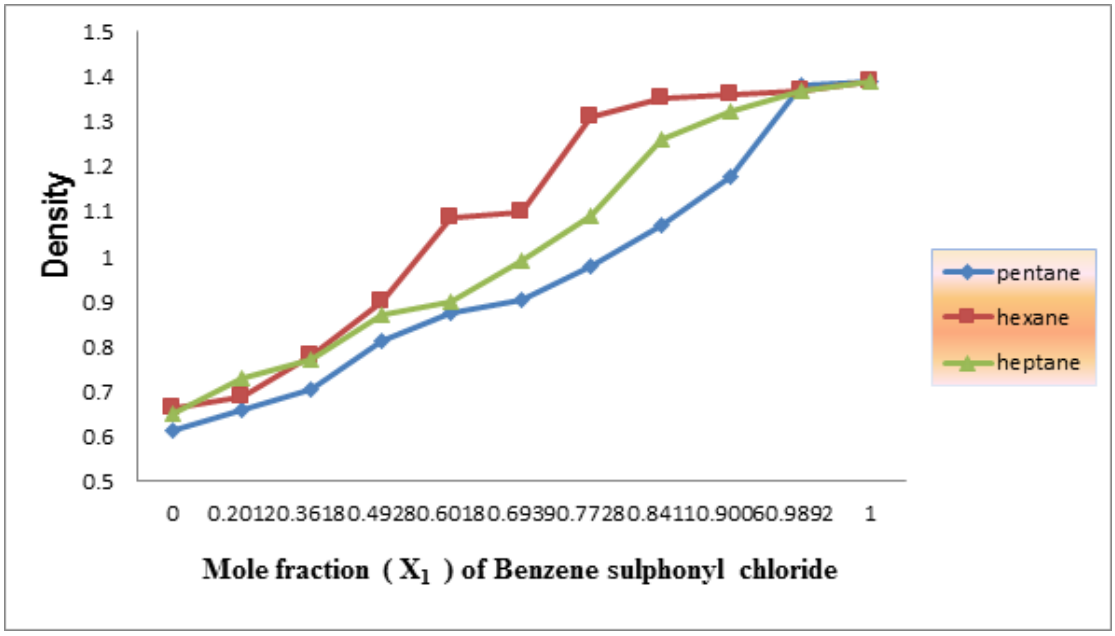

Figure 1: Plots of density (ρ) with mole fraction (X_1) for the binary mixture of benzene sulphonyl chloride with pentane, hexane and heptane at 303.15 K

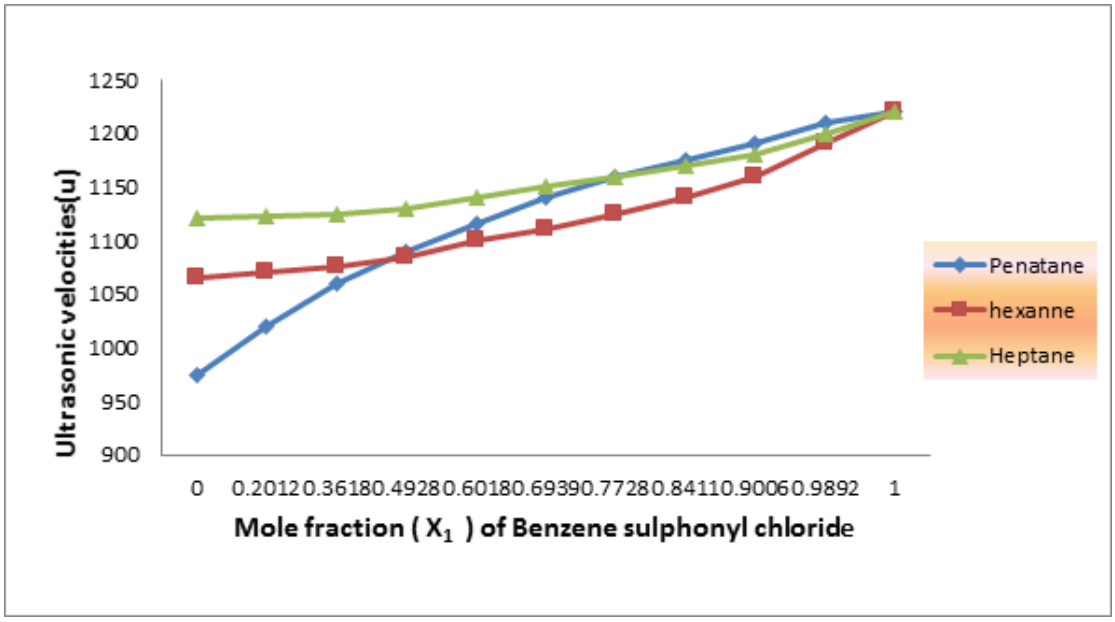

Figure 2: Plots of ultrasonic velocity (u) with mole fraction (X_1) for the binary mixture of benzene sulphonyl chloride with pentane, hexane and heptanes at 303.15 K

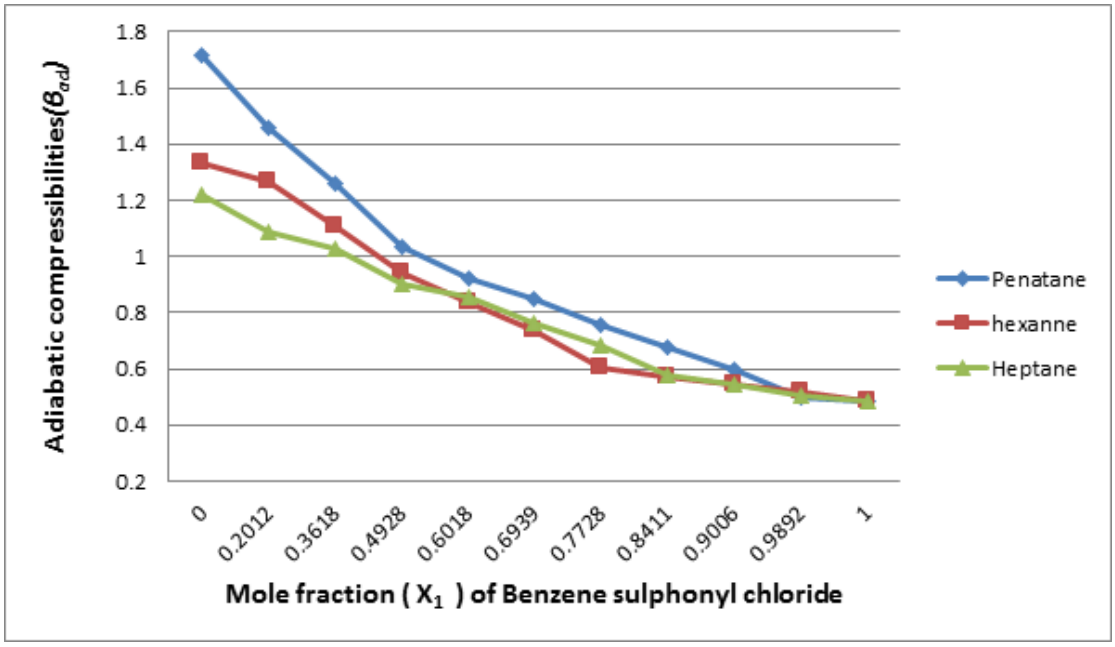

Figure 3: Plots of adiabatic compressibility (β_s) with mole fraction (X_1) for the binary mixture of benzene sulphonyl chloride with pentane, hexane and heptanes at 303.15 K

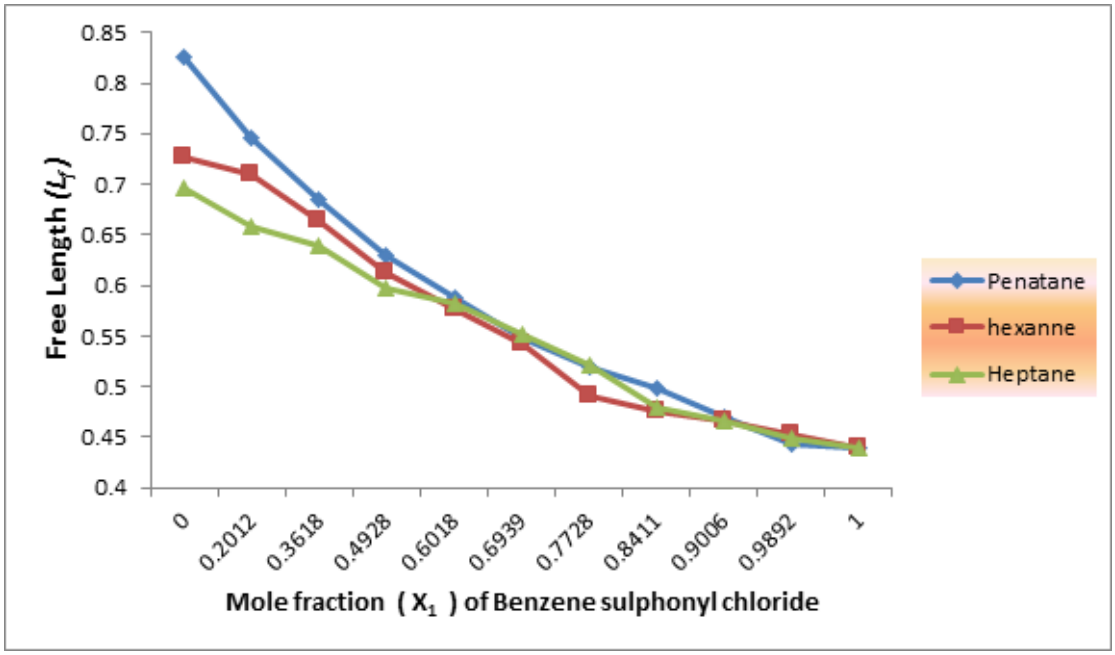

Figure 4: Plots of free Length (L_f) with mole fraction (X_1) for the binary mixture of benzene sulphonyl chloride with pentane, hexane and heptanes at 303.15 K

The variation of density of the binary mixture with rise in mole fraction of Benzene sulphonyl chloride and pentane, hexane and heptane is depicted in figure -1. Perusal of figure -1 illustrate that the density is increasing with increase in concentration of Benzene sulphonyl chloride in pentane, hexane and heptanes. The density Rise is due to shrinkage in volume and increases in cohesive force in the binary system. It means that there is contraction in volume of the Binary System with increase in concentration of Benzene sulphonyl chloride in pentane, hexane and heptane. It indicates strong molecular interaction between the unlike molecules of the system [11].

The variation of ultrasonic velocity of the binary mixture with rise in mole fraction of Benzene sulphonyl chloride in pentane, hexane and heptane is depicted in figure -2. Perusal of figure -2 illustrate that the ultrasonic velocity in increasing non-linearly with increase in concentration of Benzene sulphonyl chloride in pentane, hexane and heptanes. This non-linear increase in ultrasonic velocity with increase in concentration of Benzene sulphonyl chloride in pentane, hexane and heptane maybe due to complex formation. The increase in ultrasonic velocity depends on the behavior of intermolecular free length. It is always reverse to that behavior of intermolecular free length. The increase in ultrasonic velocity with the concentration of solute supports strong interaction between the unlike molecules of mixture. This suggest that dipole - induced dipole attraction is stronger than induced dipole - induce dipole attraction where linear plots are normally obtained [12].

The variations of adiabatic compressibility of the binary mixture with rise in mole fraction of Benzene sulphonyl chloride in pentane, hexane and heptane is depicted in figure 3. Perusal of figure 3 illustrate that the adiabatic compressibility is decreasing non linearly with increase in concentration of Benzene sulphonyl chloride in pentane, hexane and heptanes. The decrease in adiabatic compressibility implies that there is an enhanced molecular association in the system with increase in solute concentration [13-14].

The opposite trend of ultrasonic velocity and adiabatic compressibility indicates association among interacting benzene sulphonyl chloride and hydrocarbon molecules. In the present system free length varies non linearly with increase in molar concentration suggest the significant interaction between solute and solvent due to which structural arrangement is also affected [15]. The variation of intermolecular free length of the binary mixture with rise in mole fraction of Benzene sulphonyl chloride in pentane, hexane and heptane is depicted in figure -4. Perusal of figure -4 illustrate that the intermolecular free length is decreasing non linearly with increase in concentration of Benzene sulphonyl chloride in pentane, hexane and heptane intermolecular free length is related to ultrasonic velocity. As the ultrasonic velocity increases due to the increase in concentration the intermolecular free length has to decrease and vice – versa. Increase in concentration leads to decrease in gap between two species of the binary mixture and which is referred to as intermolecular free length. This show that dipole - induced dipole attraction increases with concentration of Benzene sulphonyl chloride in pentane, hexane and heptanes. So this decrease in intermolecular free length with increase in concentration of solute support molecular interaction between the constituent of the mixture [16].

Table-3: Value of acoustic impedance (Z), wada constant (W) of binary mixture of benzene sulphonyl chloride with hydrocarbons at 303.15 K.

S. No.	Mole fraction X_1	Acoustic impedance (Z)	Wada constant (W)
Benzene sulphonyl chloride+ n-pentane			
1	0	5.98162	108.6591
2	0.2012	6.70752	109.7543
3	0.3618	7.47936	112.2415
4	0.4928	8.86061	115.7218
5	0.6018	9.75179	118.1214
6	0.6939	10.32384	121.3241
7	0.7728	11.35524	125.4623
8	0.8411	12.56780	127.1172
9	0.9006	14.02177	129.3211
10	0.9892	16.69316	135.1265
11	1	16.95922	140.9552
Benzene sulphonyl chloride+ n-hexane			
1	0	7.06308	124.5050
2	0.2012	7.38407	126.9199
3	0.3618	8.38607	128.8791
4	0.4928	9.77802	130.5172
5	0.6018	10.86910	132.0716
6	0.6939	12.21111	133.5187
7	0.7728	14.73075	135.7139
8	0.8411	15.38886	137.1179
9	0.9006	15.77716	138.5794
10	0.9892	16.30419	140.0515
11	1	16.95922	140.9552
Benzene sulphonyl chloride+ n-heptane			
1	0	7.31248	148.8556
2	0.2012	8.178258	147.1627
3	0.3618	8.67375	145.8335
4	0.4928	9.84456	144.7506
5	0.6018	10.27596	143.5137
6	0.6939	11.38615	143.1701
7	0.7728	12.65792	142.6048
8	0.8411	14.7537	142.1045
9	0.9006	15.59016	141.6832
10	0.9892	16.4412	140.0436
11	1	16.95922	140.9552

The evaluated thermo-acoustic parameters acoustic impedance and Wada's constant are illustrated in table 3 the variation in these parameters with rise in mole fraction of

Benzene sulphonyl chloride in pentane, hexane and heptane represented in figure 5 and 6 respectively.

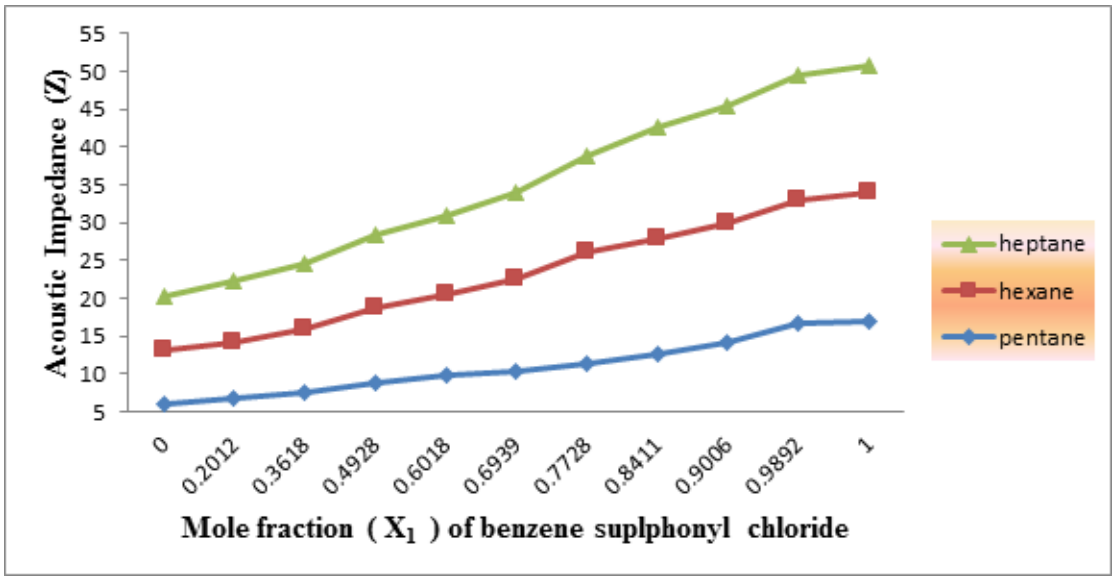

Figure 5: Plots of acoustic impedance (Z) with mole fraction (X_1) for the binary mixture of benzene sulphonyl chloride with pentane, hexane and heptanes at 303.15 K

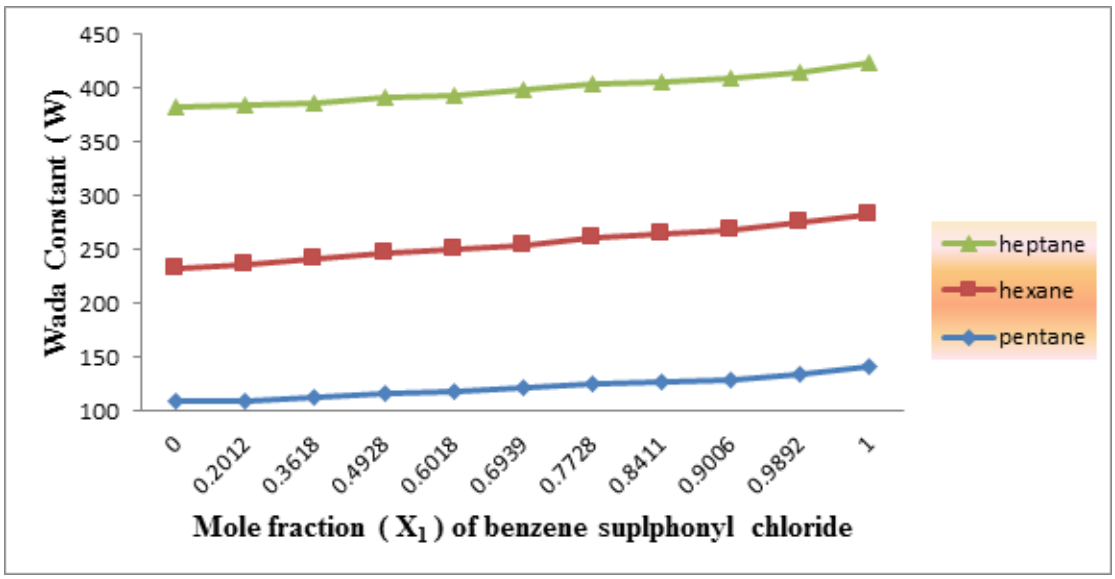

Figure 6: Plots of wada constant (W) with mole fraction (X_1) for the binary mixture of benzene sulphonyl chloride with pentane, hexane and heptanes at 303.15 K

The variation of acoustic impedance of binary mixture with rise in mole fraction of benzene sulphonyl chloride in pentane, hexane and heptane is shown in figure 5. Perusal

of figure 5 indicates the acoustic impedance is increasing non linearly with increase in concentration of benzene sulphonyl chloride in pentane, hexane and heptane impedance increases with increase in concentration of benzene sulphonyl chloride in pentane, hexane and heptane. It represent that there is strong interaction between the benzene sulphonyl chloride and hydrocarbon system this type of interaction is associated type producing concentration in the volume of the mixture [17].

The variation of wada constant of the binary mixture with rise in mole fraction of benzene sulphonyl chloride in pentane, hexane and heptane is shown in figure 6. Perusal of figure 6 indicates that the Wada constant is increasing non linearly with increase in concentration of Benzene sulphonyl chloride in pentane, hexane and heptane as the word account is increasing with increase in concentration of benzene sulphonyl chloride in pentane, hexane and heptane it indicates solute solvent interaction in the binary mixture therefore there is existence of strong inter molecular interaction between the constituents of the mixture it is increasing with increase of concentration of Benzene sulphonyl chloride in pentane, hexane and heptanes [18].

Table 4: Values of mole fraction (X_1), excess ultrasonic velocities (u^E), excess adiabatic compressibility (β_S^E), excess free length (L_f^E), excess Acoustic Impedance (Z^E) and excess Wada constant (W^E) of binary liquid mixture of benzene sulphonyl chloride with hydrocarbons at 303.15 K.

Mole Fraction (x_1)	**Density (ρ) gm.cm^{-3}**	**Excess Ultrasonic Velocity (u^E) ms^{-1}**	**Excess Adiabatic Compressibility (β_S^E)X10^6 (Pa)$^{-1}$**	**Excess Free length (L_f^E)X10^6 (m)**	**Excess Acoustic Impedance (Z^E)**	**Excess Wada constant (W^E)**
Benzene suplhonyl chloride + pentane						
0.0000	0.6135	0.0000	0	0	0	0
0.2012	0.6576	-4.2940	-0.0051	-0.00261	-1.482797114	-5.40278
0.3618	0.7056	-4.6410	-0.0752	-0.0126	-2.473958871	-8.10233
0.4928	0.8129	-5.7360	-0.0902	-0.1231	-2.530773816	-8.85282
0.6018	0.8746	-6.3400	-0.1020	-0.2416	-2.836151671	-9.97349
0.6939	0.9056	-5.0050	-0.1230	-0.3214	-3.275138171	-9.74526
0.7728	0.9789	-4.3360	-0.1435	-0.2011	-3.109870416	-8.15523
0.8411	1.0696	-5.0690	-0.1020	-0.1256	-2.647080155	-8.70615
0.9006	1.1783	-4.6470	-0.0926	-0.0943	-1.846277057	-8.42387
0.9892	1.3796	-3.6540	-0.0524	-0.0802	-1.022098244	-5.4799
1.0000	1.3901	0.0000	0	0	0	0
Benzene suplhonyl chloride + hexane						
0.0000	0.6632	0.0000	0.0000	0.0000000	0	0
0.2012	0.6901	-2.8430	-0.0020	-0.0030817	-1.670113368	-0.89488
0.3618	0.7801	-5.6000	-0.1295	-0.0320588	-2.257428452	-1.57758
0.4928	0.9012	-6.4120	-0.2420	-0.0657714	-2.161877792	-2.09446
0.6018	1.9881	-5.5410	-0.2880	-0.0806284	-2.149477052	-2.33313

0.6939	1.1001	-5.2200	-0.3175	-0.0919964	-1.718901546	-2.40109
0.7728	1.3094	-4.8520	-0.3719	-0.1166242	-1.163822467	-1.50381
0.8411	1.3499	-5.8950	-0.3384	-0.1078767	-0.565764172	-1.22336
0.9006	1.3601	-4.4170	-0.2512	-0.0796264	-0.198383684	-0.74065
0.9892	1.3701	-3.3550	-0.1267	-0.0399554	-0.050686821	-0.72604
1.0000	1.3901	0.0000	0.0000	0.000000	0	0
Benzene suplhonyl chloride + heptane						
0.0000	0.6529	0.0000	0.0000	0.000000	0	0
0.2012	0.7289	-3.050	-0.0945	-0.0254458	-1.075146088	-0.10334
0.3618	0.7710	-5.6900	-0.1173	-0.0307664	-2.128920532	-0.16374
0.4928	0.8712	-7.0300	-0.1964	-0.0548775	-2.221833472	-0.21168
0.6018	0.9014	-6.2000	-0.1888	-0.0616430	-2.841928132	-0.58744
0.6939	0.9901	-5.3090	-0.2180	-0.0879219	-2.620202886	-0.20341
0.7728	1.0912	-4.8000	-0.2360	-0.0683470	-2.109560672	-0.14537
0.8411	1.2610	-3.7700	-0.2520	-0.0654896	-0.672653014	-0.10607
0.9006	1.3212	-2.7200	-0.1990	-0.0621138	-0.410174044	-0.0573
0.9892	1.3701	-1.1700	-0.1150	-0.0381756	-0.413835208	-0.0409
1.0000	1.3901	0.0000	0.0000	0.0000000	0	0

The excess thermo-acoustic parameters excess sound velocity Excess adiabatic compressibility excess intermolecular free length Excess acoustic impedance and excess word a constant are depicted in table 4 the variation of the parameters with rise of mole fraction is shown in figure 7 to 11 respectively.

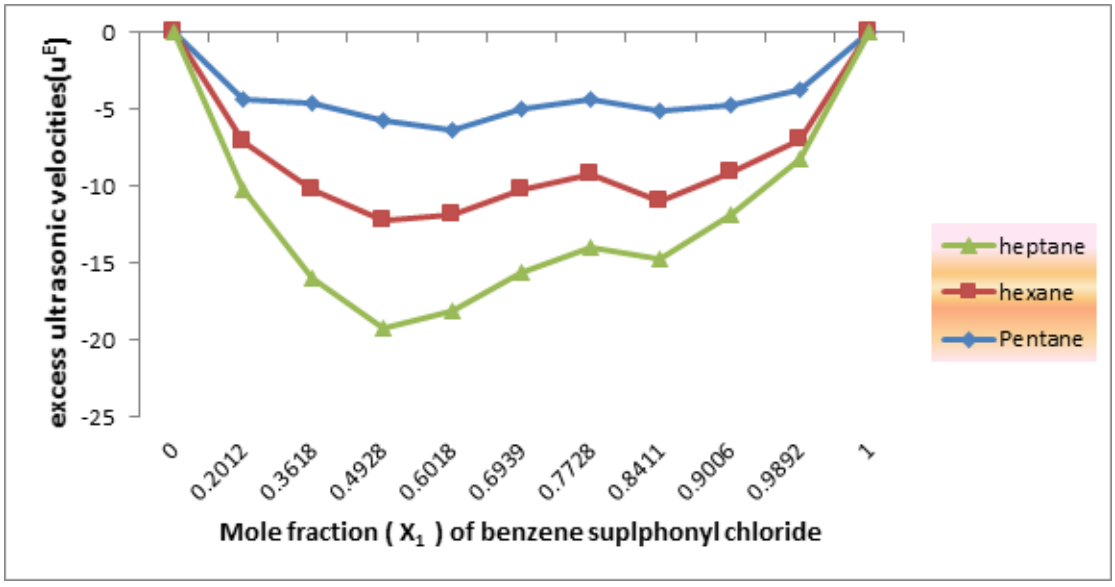

Figure 7: Plots of excess sound velocity (u^E) with mole fraction (X_1) for the binary mixture of benzene sulphonyl chloride with pentane, hexane and heptanes at 303.15 K

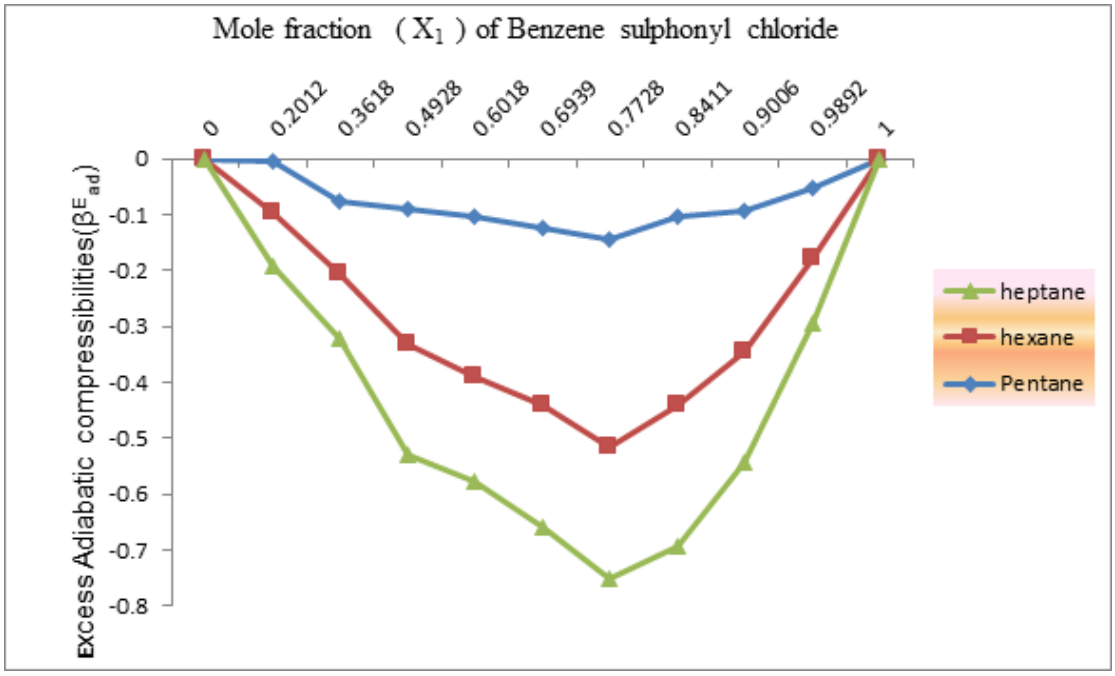

Figure 8: Plots of excess adiabatic compressibilities (β_S^E) with mole fraction (X_1) for the binary mixture of benzene sulphonyl chloride with pentane, hexane and heptanes at 303.15 K

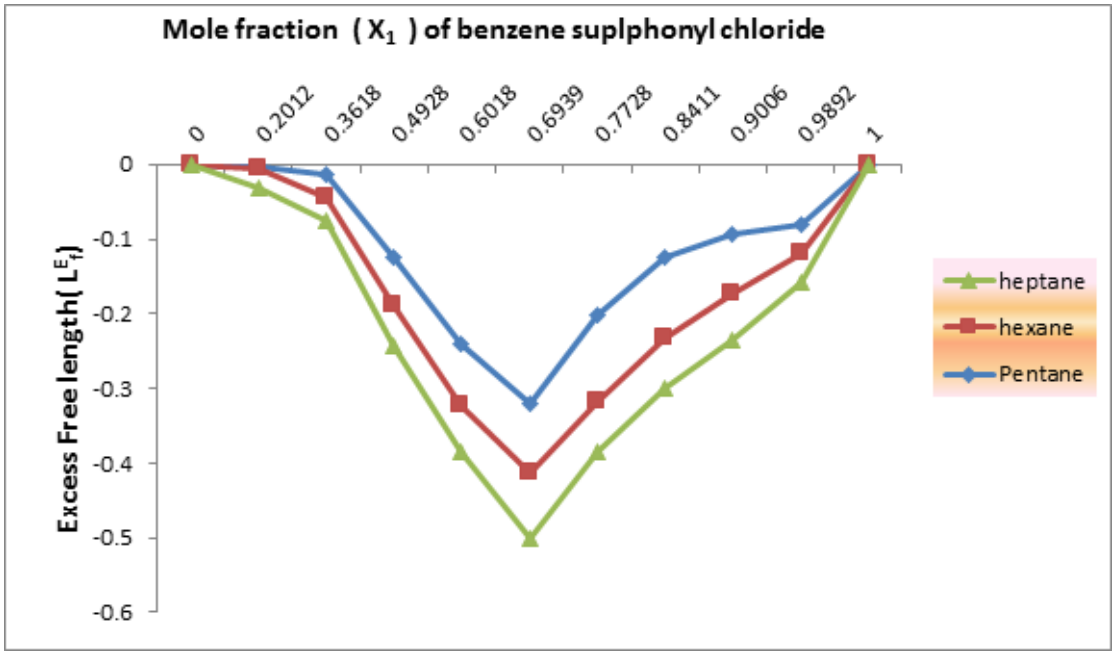

Figure 9: Plots of Excess free length (L_f^E) with mole fraction (X_1) for the binary mixture of benzene sulphonyl chloride with pentane, hexane and heptanes at 303.15 K

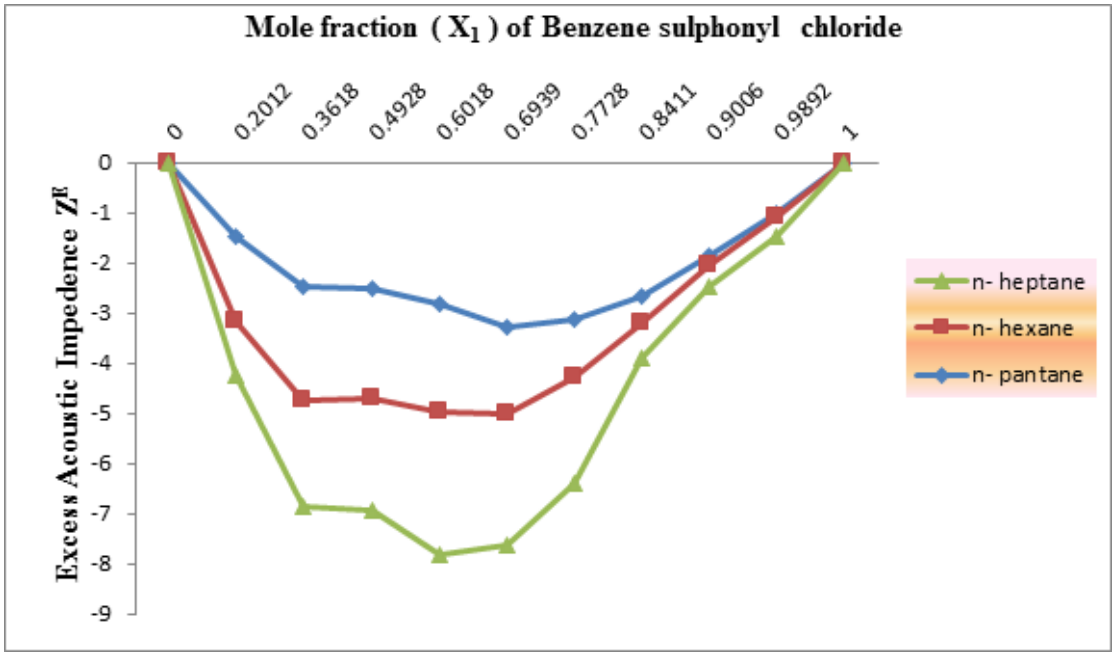

Figure 10: Plots of excess acoustic impedance (Z^E) with mole fraction (X_1) for the binary mixture of benzene sulphonyl chloride with pentane, hexane and heptanes at 303.15 K

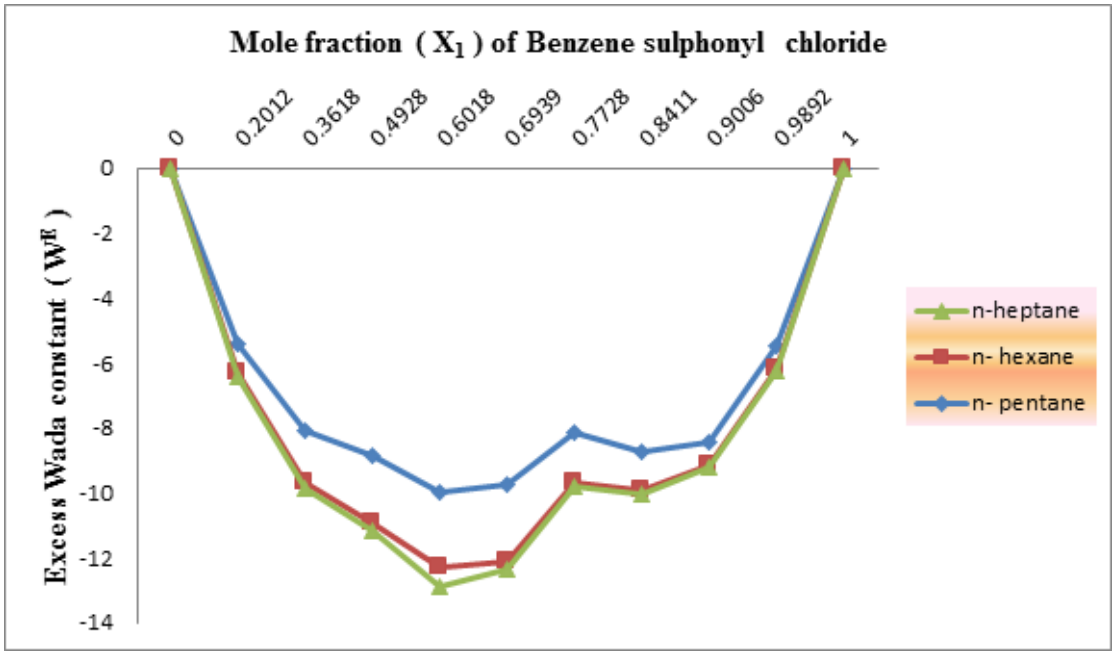

Figure 11: Plots of Excess Wada constant (W^E) with mole fraction (X_1) for the binary mixture of benzene sulphonyl chloride with pentane, hexane and heptanes at 303.15 K

The variation of excess sound velocity of the binary mixture with rise in mole fraction of Benzene sulphonyl chloride in pentane, hexane and heptane is shown in figure-7. Perusal of figure -7 indicates that the excess sound velocity is non linearly negative deviations with increase in concentration of Benzene sulphonyl chloride in pentane, hexane and heptane this shows strong interaction between the constituent of binary mixture [18].

The variation of excess adiabatic compressibility of the binary mixture with rise in mole fraction of benzene sulphonyl chloride in pentane, hexane and heptane illustrated in figure -8. Perusal of figure -8 indicates that the excess adiabatic compressibility is non linearly negative deviation with increase in concentration of benzene sulphonyl chloride in pentane, hexane and heptane it indicates that strong molecular interaction due to any of the cohesive forces [19].

The variation of excess intermolecular free- length of the binary mixture with rise in mole fraction of benzene sulphonyl chloride and hydrocarbon is shown in figure-9. Perusal of figure-9 indicates excess in the molecular free length is non linearly negative deviation with increase in concentration of benzene sulphonyl chloride in pentane, hexane and heptane this show significant interaction between the concentration of the binary mixture the non linear interaction between the constituents of this binary system [20].

The variation excess acoustic impedance of the binary mixture with rise in mole fraction of benzene sulphonyl chloride in pentane, hexane and heptane is illustrated in figure -10. Perusal of figure -10 indicates that the excess acoustic impedance is non linearly negative deviations with increase in concentration of benzene sulphonyl chloride in pentane, hexane and heptane it is indicate that the forces of cohesion between the unlike constituent of binary mixture this causes contraction of volume of the binary mixture [21-22].

The variation of excess wada constant of binary mixture with rise in mole fraction of benzene sulphonyl chloride in pentane, hexane and heptane is illustrated in figure -11. Perusal of figure-11 indicates that the excess word account is non linearly negative deviation with increase in concentration of benzene sulphonyl chloride in pentane, hexane and heptane. This shows strong in the molecular interaction between the constituents of the mixture.

CONCLUSION

In the present investigation, we have studied various thermo-acoustic properties of benzene sulphonyl chloride in pentane, hexane and heptane. Density and sound velocity shows linear increase with concentration of benzene sulphonyl chloride in pentane, hexane and heptane. Ultrasonic velocity shows non linear increase and intermolecular free length and adiabatic compressibilities the non linear decrease with increase in concentration of benzene sulphonyl chloride in pentane, hexane and heptane binary mixtures. The excess parameters excess sound velocity, excess adiabatic compressibility, excess intermolecular free length, excess acoustic impedance and excess wada constant show non linear negative deviations. The investigation shows support strong intermolecular interaction and so concentration in the volume of the

mixture with increase of benzene sulphonyl chloride in pentane, hexane and heptane. Thus, it can be concluded that there exist strong molecular interaction between the constituent of benzene sulphonyl chloride in pentane, hexane and heptane mixture.

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