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Department of Chemistry, Easwari Engineering College (SRM Group of Institutions), Chennai-600089, India.

Speed of Sound in Binary Mixtures Containing Stearates and Nitrobenzene

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ABSTRACT: We report the measurements of ultrasonic velocity in the binary mixtures of zinc stearate - nitrobenzene and calcium stearate - nitrobenzene at 303 K. The knowledge of the thermodynamic properties is essential in the chemical industry involving chemical seperations, heat transfer, mass transfer and fluid flow. It is used to evaluate the different thermo acoustical parameters along with the excess properties, the experimental data obtained is fitted with the models and percentage deviation is calculated. The sign, magnitude and variation in excess functions derived from physico-chemical properties reveal important information about the type of molecular interactions that are not usually seen from the variations in their excess volumes.

KEYWORDS: Stearates, stabilizer, solvent, positive and negative deviation, excess properties.

I. INTRODUCTION

Ultrasonic studies find extensive applications in characterizing aspects of the physic - chemical behavior of binary mixtures, such as molecular interactions, association, dissociation and complex formation. Knowledge of several properties, including densities is required for engineering design and for subsequent operations. Moreover, there is interest in using volumetric data to test molecular theories or models of solution to extend our understanding about molecular interactions between components. The study on the fundamental differences between pure solvents is essential for describing the numerous phenomena in solution chemistry. The self association of liquids and solids becomes one of the most interesting effects characterizing the solvent. It is especially important when the structure of the solvent plays crucial role in the studied field. Zinc stearate $(C_{18}H_{35}O_2)_2Zn$ and calcium stearate $(C_{17}H_{34}COO)_2Ca$ are the stabilizers used, a soap of zinc and calcium that repels water. It is the most powerful mold release agent among all metal soaps. It contains no electrolyte and has a hydrophobic effect. Its main application areas are the plastics and rubber industry where it is used as a releasing agent and lubricant which can be easily incorporated. Nitrobenzene is the aromatic hydrocarbon coupled with stearates and its molecular interaction is studied. The results have been discussed in terms of molecular interactions. The values of ultrasonic velocity (U), density (ρ) and viscosity (η) for the pure components is given in Table 1.

From the experimental values, a few acoustical parameters such as adiabatic compressibility (ß), acoustical impedance (Z), molar sound velocity (R), Wada's constant (W), molar volume (V_m), free volume (V_f), intermolecular free length (L_f), internal pressure (π), absorption coefficient (α/f^2) viscous relaxation time (ι), degree of intermolecular attraction (α), excess ultrasonic velocity (U^E), excess adiabatic compressibility ($ß^E$) , excess acoustical impedance (Z^E), excess free length (L_f^E) and excess molar volume (V_m^E) were derived over the entire mole fraction range. Ultrasonic velocities have also been evaluated theoretically with the help of Impedance relation, Nomoto relation, Van Dael & Vangeel relation and Junjie relation. The suitability of these theories and equations were checked by comparing theoretical values of ultrasonic speeds with the values obtained experimentally. Literature survey showed that no measurements have been previously reported for the mixtures reported in this paper.

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II. MATERIALS AND METHODS

The chemicals used were of analytical grade and obtained from E.Merck company. Thermostatically controlled well-stirred water bath whose temperature was maintained to ±0.01 K accuracy was used for all the measurements. Binary mixtures were prepared by weighing in airtight bottles, the possible uncertainty in the concentration is estimated to be less than ±0.0001. Densities of pure components and their mixtures were determined by using a 1 X 10^{-5} m^3 double arm pycnometer. The density values from triplicate replication at the temperature of 303 K were reproducible within ± 2 X 10^{-2} kg m^{-3}. The uncertainty in density and excess molar volume values were found to be ± 4 X 10^{-2} kg m^{-3} and ± 0.001 X 10^{-6} m^3 mol^{-1} respectively. Ostwald's viscometer having capacity of about 15 ml and the capillary having a length of about 90 mm and 0.5 mm internal diameter has been used to measure the flow times of pure liquids and liquid mixtures and it was calibrated with benzene (density ≈ 0.8738 g cm^{-3}) and doubly distilled water (density ≈ 0.9970 g cm^{-3}) at 303 K. The flow time of pure liquids and liquid mixtures were repeated for five times. The uncertainty of viscosity was ± 0.005 X 10^{-3} m Pas. Speed of sound was measured by using a variable path, single crystal interferometer. (United scientific company, India), working at 2 MHz frequency. The interferometer was calibrated using toluene. Measurement of speed of sound through medium was based on the accurate determination of the wavelength of ultrasonic waves of known frequency produced by quartz crystal in the measuring cell. The interferometer cell was filled with the test liquid, and water was circulated around the measuring cell from a thermostat. The uncertainty was estimated to be 0.1ms^{-1}.

The adiabatic compressibility (ßs) was calculated by the equation

$$ß = 1/ \rho U^2 \quad (1)$$

Where ρ is the density of mixture and U is the ultrasonic velocity of the mixture.

The acoustical impedance (Z) was calculated by the equation,

$$Z = \rho U \quad (2)$$

The molar sound velocity (R) was calculated by the equation

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

The molar compressibility or Wada's constant (W), was calculated by the equation

$$W = (M / \rho) ß^{-1/7} \quad (4)$$

The intermolecular free length (L_f) was calculated by the equation

$$L_f = k ß^{½} \quad (5)$$

Where K = 1.98 X 10^{-6}, the Jacobson constant (Jacobson 1952).

The Free volume was calculated by the equation

$$V_f = (M_{eff} U/K\eta)^{3/2} \quad (6)$$

Where K = 4.28 X 10^9 for all liquids which is a temperature independent constant.

The internal pressure was calculated by the equation

$$\pi = \{bRT / (V^2 V_f)^{1/3}\} \quad (7)$$

b is a packing factor, R is a gas constant, V_f is free volume and T is temperature.

The absorption coefficient was calculated by the equation

$$(\alpha/f^2) = (8\pi^2\eta/3\rho U^3) \quad (8)$$

The viscous relaxation time was calculated by the equation

$$\iota = (4\eta/3\rho U^2) \quad (9)$$

The degree of intermolecular attraction (α) was calculated by the equation

$$\alpha = (u^2 / u^2_{im}) - 1 \quad (10)$$

Where $u^2_{im} = 1/ \{(x_1M_1 + x_2M_2)(x_1/M_1u_1^2 + x_2/M_2u_2^2)\}$

The U^E, $ß^E$, Z^E, L_f^E, and V_m^E were derived over the entire mole fraction range by using the general equation

$$A^E = A - (X_i A_1 + (1-X_i) A_2) \quad (11)$$

Where A is the corresponding parameters (U, ß, Z, L_f, and V_m) of binary mixture and A_1 and A_2 are the corresponding pure component values.

The sound velocity can be correlated with the relation called Impedance relation which is represented as

$$U_{IM} = (X_1Z_1 + X_2Z_2) / (X_1\rho_1 + X_2\rho_2) \quad (12)$$

where X, Z, ρ denote the mole fraction, acoustic impedance and density of the component respectively.

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Nomoto derived an empirical formula for the sound velocity in binary mixture. It is given by the equation

$$U_{NR} = [R/V]^3 = \left\{ \frac{(X_1R_1 + X_2R_2)}{(X_1V_1 + X_2V_2)} \right\}^3 \quad (13)$$

Where X, R, V denote the mole fraction, molar sound velocity and molar volume at temperature T of the component. The acoustical behaviour of binary mixture was studied in detail by Van deal etal. The expression for sound velocity (U_{IMR}) of binary mixtures can be obtained from equation

$$U_{IMR} = \left\{ \frac{[1/(X_1M_1 + X_2M_2)]}{[X_1/M_1U_1^2 + X_2/M_2U_2^2]} \right\} 1/2 \quad (14)$$

Where X, M and U are the mole fraction, molecular weight and sound velocity of component.
Junjie derived an empirical formula for the sound velocity in binary mixture. It is given by the equation

$$U_{jun} = \left\{ \frac{(X_1V_1 + X_2V_2)}{(X_1M_1 + X_2M_2)^{1/2}} \left[\frac{X_1V_1}{\rho_{1U1}^2} + \frac{X_2V_2}{\rho_{2U2}^2} \right] \right\}^{-1/2} \quad (15)$$

Where X, V, M, ρ denote the mole fraction, molar volume, molecular weight and density of the components.
The percentage deviation of the experimental velocity from the theoretical value is given by the equation

$$\text{Percentage deviation in velocity} = \frac{U_{Theo} - U_{Expt}}{U_{Theo}} \times 100 \quad (16)$$

III. RESULTS

The ultrasonic velocity, density and viscosity data for the pure components at 303 K are given below:

Table 1

Comparison of density, ultrasonic velocity and viscosity data at 303 K

Component	U m/s	ρ Kg/m^3	η X 10^{-1} Nsm^{-2}
Zinc stearate	1404	1133	-
Calcium stearate	1310	1145	-
Nitrobenzene	1404	1200	18.9

Table 2 gives the measured and acoustic parameters such as ultrasonic velocities (U), density (ρ), viscosity (η), adiabatic compressibility (ß), acoustical impedence (Z), molar sound velocity (R), molar compressibility (W), molar volume (V_m), free volume (V_f), Table 3 gives the thermodynamic properties like intermolecular free length (L_f), internal pressure (π), absorption coefficient (α/f^2), viscous relaxation time (ι), degree of intermolecular attraction (α), Table 4 gives the excess parameters like excess ultrasonic velocity (U^E), excess adiabatic compressibility ($ß^E$) , excess acoustical impedance (Z^E) , excess free length (L_f^E), excess molar volume (V_m^E), Table 5 gives the theoretical values of ultrasonic velocity calculated from Impedance, Nomoto, Van Dael & Vangeel and Junjie's relation along with the experimental ultrasonic velocity and percentage deviation for the binary mixtures zinc stearate - nitrobenzene and calcium stearate - nitrobenzene over the entire composition range at 303 K..

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Table 2 : Measured and acoustic parameters of binary mixtures at 303 K

Conc of stearate	U ms^{-1}	ρ Kgm^{-3}	η / 10^{-1} Nsm^{-2}	β / 10^{-10} $Kg^{-1}ms^{-2}$	Z / 10^{6} $Kg\ m^{-2}s^{-1}$	R	W	V_m / 10^{-1} m^3mole^{-1}	V_f / 10^{-7} m^3mole^{-1}
				zinc stearate – nitrobenzene					
0.01	1420	1206.3	15.7	4.11	1.71	1.15	2.25	1.02	1.33
0.02	1472	1212.6	16.2	3.81	1.79	1.16	2.27	1.02	1.35
0.03	1608	1218.9	16.9	3.17	1.96	1.20	2.33	1.02	1.46
0.04	1664	1225.2	17.4	2.95	2.04	1.21	2.35	1.02	1.48
0.05	1708	1231.6	18.4	2.78	2.10	1.22	2.37	1.02	1.42
0.06	1844	1237.2	18.9	2.38	2.28	1.25	2.42	1.02	1.54
0.07	1932	1244.2	19.7	2.15	2.40	1.27	2.45	1.02	1.57
0.08	2012	1250.5	20.8	1.98	2.52	1.28	2.48	1.02	1.55
0.09	2060	1256.8	21.5	1.87	2.59	1.29	2.49	1.02	1.53
0.1	2216	1263.2	22.2	1.61	2.80	1.32	2.54	1.02	1.63
				calcium stearate – nitrobenzene					
0.01	1464	1206.0	23.0	3.87	1.77	1.16	2.27	1.02	0.789
0.02	1468	1212.1	23.9	3.83	1.78	1.16	2.27	1.02	0.752
0.03	1480	1218.2	25.0	3.75	1.80	1.17	2.27	1.02	0.716
0.04	1484	1224.2	26.7	3.71	1.82	1.17	2.27	1.02	0.654
0.05	1552	1230.3	28.8	3.37	1.91	1.18	2.30	1.02	0.627
0.06	1576	1236.4	31.4	3.26	1.95	1.19	2.31	1.02	0.568
0.07	1612	1242.4	32.0	3.10	2.00	1.19	2.32	1.02	0.576
0.08	1656	1248.5	32.9	2.92	2.07	1.20	2.34	1.02	0.577
0.09	1680	1254.6	33.5	2.82	2.11	1.21	2.35	1.02	0.578
0.1	1984	1260.6	34.7	2.02	2.50	1.28	2.46	1.02	0.708

Table 3 : Thermodynamic parameters of binary mixtures at 303 K

Conc of stearate	L_f / 10^{-11} m	π / 10^{6} Atm	α/f^2 / 10^{-12} $m^{-1}s^2$	ι / 10^{-10} s	α / 10^{-1} M
			zinc stearate – nitrobenzene		
0.01	4.02	4.50	12.0	8.61	0.264
0.02	3.87	4.48	11.0	8.22	1.07
0.03	3.53	4.37	8.75	7.14	3.25
0.04	3.41	4.35	8.08	6.82	4.24
0.05	3.31	4.42	7.90	6.85	5.05
0.06	3.06	4.31	6.42	6.00	7.60
0.07	2.91	4.28	5.76	5.64	9.38
0.08	2.79	4.31	5.36	5.47	11.1
0.09	2.72	4.32	5.14	5.37	12.2
0.1	2.52	4.23	4.25	4.77	15.7
			calcium stearate – nitrobenzene		
0.01	3.90	5.36	16.0	1.19	0.908
0.02	3.88	5.45	16.4	1.22	1.00
0.03	3.84	5.55	16.6	1.25	1.22
0.04	3.82	5.72	17.6	1.32	1.32
0.05	3.64	5.81	16.5	1.30	2.42
0.06	3.58	6.00	17.1	1.36	2.84
0.07	3.49	5.98	16.1	1.32	3.48
0.08	3.39	5.98	15.3	1.28	4.27
0.09	3.33	5.98	14.8	1.26	4.73
0.1	2.82	5.60	9.26	0.932	10.6

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Table 4 : Excess parameters of binary mixtures like U^E, $ß^E$, Z^E, L_f^E and v_m^E at 303 K

Conc of stearate	U^E ms^{-1}	$\beta^E / 10^{-10}$ $Kg^{-1}ms^{-2}$	$Z^E / 10^5$ $Kg\ m^{-2}s^{-1}$	$L_f^E / 10^{-12}$ m	$V_m^E / 10^{-3}$ m^3mole^{-1}
		zinc stearate – nitrobenzene			
0.01	16	-0.117	0.283	-0.567	-0.572
0.02	68	-0.422	1.00	-2.09	-1.14
0.03	204	-1.06	2.76	-5.46	-1.71
0.04	260	-1.28	3.54	-6.74	-2.28
0.05	304	-1.45	4.19	-7.70	-2.85
0.06	440	-1.85	5.98	-10.2	-3.41
0.07	528	-2.08	7.20	-11.7	-3.98
0.08	608	-2.25	8.32	-12.9	-4.54
0.09	656	-2.35	9.05	-13.6	-5.10
0.1	812	-2.62	11.2	-15.6	-5.66
		calcium stearate – nitrobenzene			
0.01	60	-0.360	0.810	-1.77	-0.541
0.02	64	-0.401	0.950	-1.98	-1.08
0.03	76	-0.483	1.19	-2.40	-1.63
0.04	80	-0.522	1.33	-2.60	-2.17
0.05	148	-0.857	2.26	-4.37	-2.70
0.06	173	-0.976	2.65	-5.02	-3.24
0.07	209	-1.14	3.19	-5.90	-3.78
0.08	253	-1.31	3.84	-6.92	-4.32
0.09	277	-1.41	4.25	-7.49	-4.85
0.1	581	-2.22	8.18	-12.7	-5.38

Table 5

Experimental velocities and theoretical velocities along with the percentage deviation of binary mixtures at 303 K

Conc of stearate	Ultrasonic velocity U / ms^{-1}					% Deviation			
	EXPT	Imp	Nom	VDV	Junjie's	Imp	Nom	VDV	Junjie's
				zinc stearate – nitrobenzene					
0.01	1420	1404	1404	1402	1404	-1.140	-1.140	-1.312	-1.141
0.02	1472	1404	1404	1399	1404	-4.843	-4.843	-5.199	-4.845
0.03	1608	1404	1404	1397	1404	-14.530	-14.530	-15.112	-14.533
0.04	1664	1404	1404	1395	1404	-18.519	-18.519	-19.319	-18.523
0.05	1708	1404	1404	1392	1404	-21.652	-21.652	-22.676	-21.658
0.06	1844	1404	1404	1390	1404	-31.339	-31.339	-32.662	-31.346
0.07	1932	1404	1404	1388	1404	-37.607	-37.607	-39.219	-37.615
0.08	2012	1404	1404	1386	1404	-43.305	-43.305	-45.218	-43.315
0.09	2060	1404	1404	1383	1404	-46.724	-46.724	-48.921	-46.735
0.1	2216	1404	1404	1381	1404	-57.835	-57.835	-60.454	-57.848
				calcium stearate – nitrobenzene					
0.01	1464	1404	1403	1402	1403	-4.280	-4.311	-4.441	-4.317
0.02	1468	1404	1403	1399	1403	-4.572	-4.633	-4.895	-4.645
0.03	1480	1404	1402	1397	1402	-5.434	-5.526	-5.922	-5.543
0.04	1484	1404	1402	1395	1402	-5.726	-5.849	-6.376	-5.871
0.05	1552	1404	1402	1393	1401	-10.577	-10.737	-11.425	-10.766
0.06	1576	1403	1401	1391	1401	-12.295	-12.488	-13.325	-12.523
0.07	1612	1403	1401	1389	1400	-14.867	-15.097	-16.094	-15.138
0.08	1656	1403	1400	1386	1400	-18.010	-18.278	-19.446	-18.326
0.09	1680	1403	1400	1384	1399	-19.728	-20.032	-21.362	-20.086
0.1	1984	1403	1399	1382	1398	-41.402	-41.799	-43.540	-41.870

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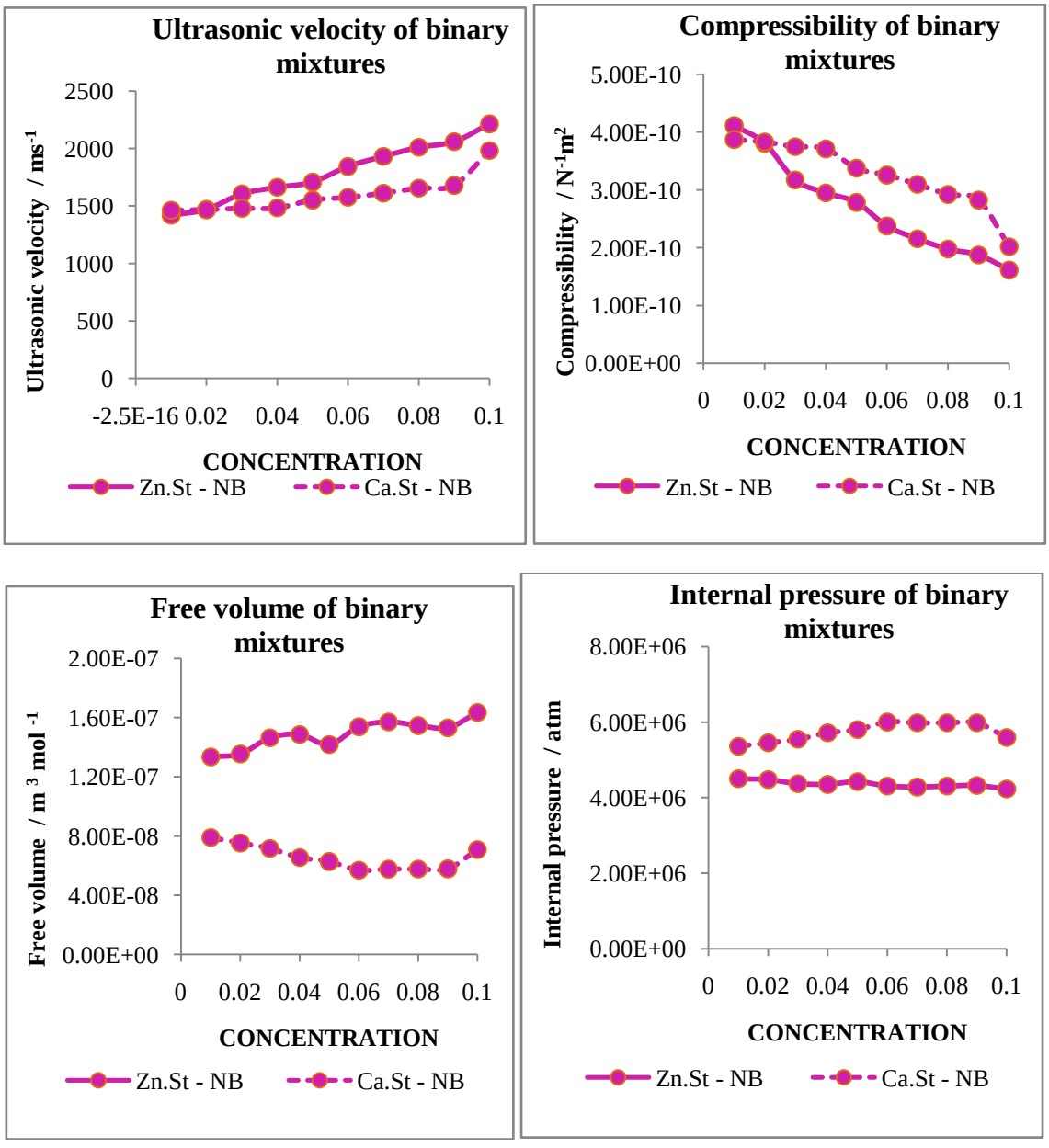

Fig. 1 Computed parameters of zinc stearate – NB and calcium stearate – NB at 303 K

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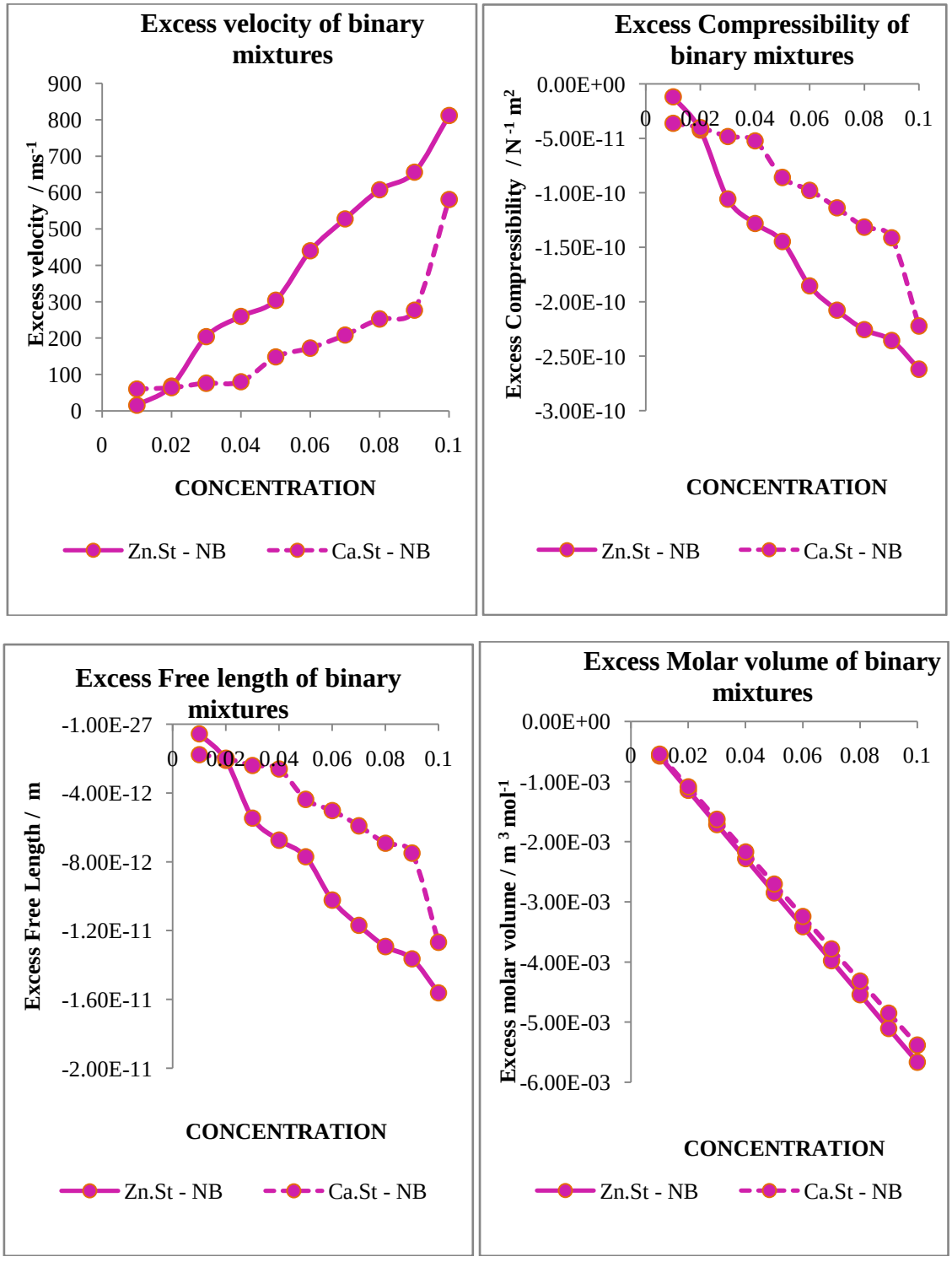

Fig. 2 Excess parameters of zinc stearate – NB and calcium stearate – NB at 303 K

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IV. RESULTS AND DISCUSSION

The ultrasonic velocity values (U) increases linearly with increase in stearate concentration in addition of stearates with nitrobenzene. Increase in ultrasonic velocity values may be due to decrease in space between chains inside the structure of components, thus it may be attributed to increase in cross linking between chains which consequently cause increase in rigidity of the molecules. In system Zn. St – NB and Ca. St – NB system, interaction appears to be stronger as evident from the higher values, it may be due to the depletion of πe^- density on benzene ring [1]. Oxygen of nitro group becomes electron rich and interacts strongly with the positive dipoles of ester in stearates. It leads to strong dipole – induced dipole interaction. The maximum interaction is due to the presence of lone pair on nitrogen atom of the nitro group on aromatic ring. The density values (η) increases with increase in stearate concentration and viscosity values (η) increases with increase in stearate concentration. As concentration increases, association increases or steric crowding is more so that the intermolecular interaction between the molecules is weakened [2].

The adiabatic compressibility (β) exhibits an exact reverse trend as that of ultrasonic velocity for both the binary mixtures studied. The compressibility of solvent is greater than that of solution and it decreases with increase in concentration of solution [3]. Solvents examined were chosen to cover a wide range of adiabatic compressibility. In both Zn. St – NB and Ca. St – NB systems, non linear decrease trend is observed. The trend in non linear variation indicates the presence of complex formation which may be due to strong solute – solvent interaction. The disruption of stearates by solvents and weak interaction between unlike molecules leave the binary mixtures more compressible [4]. Acoustic impedance (Z) increases with increase in stearate concentration for both the system. This favours increase in intermolecular distance between stearate and solvent molecules making relatively wider gaps between the molecules and becoming the main cause of impediment in the propagation of ultrasonic waves. It confirms the presence of molecular association between solute – solvent molecules through intermolecular hydrogen bonding [5]. Rao constant (R) and Wada's constant (W) show linear variation and almost it is constant with increase in stearate concentration, indicating the presence of solute – solvent interaction. Molar volume (V_m) shows constant value over the entire concentration range for both the system investigated. For Zn. St – NB system, free volume increase and decrease with increase in stearate concentration. Comparatively, Ca. St – NB system, free volume decrease and increase with increase in stearate concentration. The decrease in the free volume also confirms the increasing order of symmetry [6] except for the system, both being aliphatic or aromatic components. The increase in free volume suggests the packing of molecules become looser predicting the presence of weaker interaction among the molecules [7].

The intermolecular free length (L_f) also follows the same trend as that of adiabatic compressibility. Free length is greater at low stearate concentration which may be due to solvent self association. As solvent density is not affected by association, one can deduce that the distance between the aggregate is greater than between the monomeric solvent molecules [8]. The decrease in free length with increase in ultrasonic velocity along with increase in stearate concentration increases intermolecular force between stearates and solvents. It strengthens the idea of molecular association in each system [9]. The values indicates significant interaction between the components of the mixture through dipole – dipole interaction, dipole – induced dipole, hydrogen bonding etc., The internal pressure (π_i) values suggest the presence of inter – molecular interactions in addition of stearates to solvents. For Ca. St – NB system, internal pressure increase at low concentration and decrease at high concentration. Comparatively, for Zn. St – NB system, internal pressure decrease at low concentration and increase at high concentration. Non linear variation with both increased and decreased value suggests the presence of molecular association between unlike molecules. It predicts the existence of greater molecular interaction among the molecules in binary mixture. The absorption coefficient values (α/f^2) shows non linear increase and decrease trend in Ca. St – NB system. However, absorption coefficient value decreases in Zn. St – NB system with increase in stearate concentration. It shows the existence of different type of molecular interactions in these binary systems. The values of relaxation time (τ) shows both increase and decrease data with increase in stearate concentration for Ca. St – NB systems, viscous relaxation time increases at low concentration which may be due to increase in frictional resistance force and change in molecular area. As concentration increases, τ value decreases with decrease in available space between the molecules. The reverse trend is observed for Zn. St – NB systems. Interaction parameter values (α) value increases with increase in stearate

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concentration for both Zn. St – NB and Ca. St – NB systems, confirms the existence of molecular interaction between them [10]. Maximum value confirms the presence of intermolecular interaction in system.

Excess parameters is the combination of interaction and non interaction part [11]

$X^E_{observed} = X^E_{interaction} + X^E_{size\ effect}$

$X^E_{observed}$ = excess property

In order to understand the nature of molecular interaction between the components, it is of interest to discuss the same in terms of excess parameters than actual values. Non ideal liquid mixture shows considerable deviation from linearity in their physical behaviour with respect to concentration and these have been interpreted as arising from the presence of strong or weak interactions. The excess velocity shows positive deviations [12] which predict the weak interaction due to dispersion force. It shows non linear variation for Zn. St – NB and Ca. St – NB systems. Non linear variation shows specific intermolecular interaction between binary mixtures and the positive values predicts the strong association due to rupture of cohesion and growing adhesion leading to the formation of dipole – induced dipole interaction. In Zn. St – NB system, positive larger value is observed that confirms the existence of molecular association between the components. The excess compressibility value depends upon two factors ie, first factor is increase in free length which may be due to loss of dipolar association, breaking up of hydrogen bonding, differences in size and shapes of the component. The second factor is the decrease in free length which is due to dipole – dipole interactions, hydrogen bonding association, complex formation, interstitial accommodation of unlike molecules [13]. The first effect contributes to increase in the spacing between the molecules, such that ultrasound waves cover smaller distances in mixtures than in pure components. This would result in negative deviation of both excess compressibility and free length. The second effect contributes to decrease in the interspace between molecules and ultrasound waves which cover larger distances in the mixtures. This would result in positive deviation in ultrasonic velocity and negative deviation in compressibility and free length. For Zn. St – NB, and Ca. St – NB systems, non linear trend is observed with respect to stearate concentration. In all binary mixtures, it shows large deviation at higher concentration implies that the specific interaction dominate over the dispersive interaction between unlike molecules. However, decrease in excess compressibility with increase in ultrasonic velocity suggests that there may be strong intermolecular hydrogen bond between them making the binary mixture less compressible [14]. It was reported that the positive deviation in excess impedance indicates the presence of strong interactions between component molecules in the mixture. Excess impedance increases with increase in stearate concentration with addition of stearates to solvents which confirms the strong molecular interaction. Excess molar volume shows negative deviation in both the system and linear decrease is observed with increase in stearate concentration. Increase in chain length and polarizability decreases excess molar volume that can be attributed to strong unlike interactions between molecules [15].

It is assumed that all the liquid molecules are spherical in shape which is not true every time, it is supposed that volume does not change on mixing. The deviation factor from the calculated and experimental values of ultrasonic velocity is reasonable and provides very good agreement with experimental value. The observed deviation of theoretical velocity from the experimental values should be rather treated as evidence of molecular interaction which takes place between stearates and solvents. Deviation is larger in Van Dael and Vangeel relation which is due to the strengthening among unlike molecules. At all concentrations experimental ultrasonic velocity is found to be in good agreement with theoretical Nomoto velocity. It may be due to weak dipolar dispersive interaction between like molecules [16]. For Ca. St – NB systems, deviation follows as $U_{Vdv} > U_{Jun} > U_{Nom} > U_{Imp}$. However, for Zn. St – NB system shows deviation in the order $U_{Vdv} > U_{Jun} > U_{Imp} = U_{Nom}$.

V. CONCLUSION

The present investigation measures ultrasonic velocity, density and viscosity of stabilizers with solvent at 303 K. It may be suggested that the strength of interactions between aliphatic molecule and aromatic component will be greater than that of aliphatic – aliphatic and aromatic – aromatic components. Based on the above consideration, both Zn. St – NB and Ca. St – NB systems shows strong dipole – induced dipole interaction. It may be due to the presence of non linear variation in U, β, MCE, LJP, π_i, α, ΔG, ΔH values. In comparison among stearates, molecular interaction is greater with zinc stearate than with calcium stearate.

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Zn. St – NB > Ca. St – NB

From the computed data, standard relations like Impedance relation, Nomoto relation, Van Dael and Vangeel and Junjie relation are calculated. The large deviation of ultrasonic velocity is found in Van Dael & Vangeel and Junjie relation and it is found to be least in Nomoto and Impedance relation.

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