

# Research on Ion-Solvent Interactions in the Inorganic Liquid Mixtures by Ultrasonic Technique

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**ABSTRACT**---Ultrasonic speed, density and viscosity of binary liquid mixtures of aqueous ammonium per sulphate with other sulphate solutions at 303.15 K have been measured. From these experimental data, the adiabatic compressibility, intermolecular free length, internal pressure, acoustic impedance, relaxation time, molar volume, classical absorption coefficient and surface tension have been computed. The excess viscosity, excess compressibility, excess intermolecular free length, excess acoustic impedance and excess molar volume values are evaluated to find the nature and the extent of the interactions between the constituent molecules of the liquid mixture systems.

**Keywords:** Molecular interaction, ammonium persulphate, Ultrasonic velocity, Relaxation time, excess acoustic impedance

## INTRODUCTION

The structural arrangements and the change in physico chemical behavior of liquid mixtures are mainly due the change in molecular orientations and change in physical quantities. Ultrasonic velocity measurements and other acoustical parameters of liquid mixtures are the powerful technique in the understanding of chemical nature and the molecular interactions. Some earlier researches have shown that the propagation of ultrasound in the solution is the significant probing technique for the study of intermolecular interactions and the structure of the constituent molecules of the liquid mixtures<sup>1-7</sup>. Acoustical and thermo dynamical study of liquid mixtures provide enough knowledge about the association of molecular packing, molecular motion and strength of intermolecular interactions<sup>8</sup>. Thermodynamic and acoustical properties such as adiabatic compressibility, intermolecular free length, internal pressure, acoustic impedance, relaxation time, molar volume, classical absorption and surface tension are calculated from measured ultrasonic velocity, density and viscosity for binary mixtures and they are very much helpful to interpret nature and type of intermolecular interactions between the component molecules<sup>9</sup>.

Ultrasonic study of molecular interactions in binary liquid mixtures is widely useful in industrial and biological process. Molecular interaction study found enormous application in pharmaceutical, garment and food industries.

The non linearity in the ultrasonic velocity and other acoustical quantities may arise from the structural modification of the molecules, and nature of interaction between the solute and solvent molecules<sup>10-13</sup>.

The excess parameters play a vital role in the understanding of the existence of complex formation in the liquid mixtures. The negative values of excess parameters exhibit the presence of strong interactions<sup>14</sup>. The shape of the molecule and the nature of the interactions intensely influence complex formation occurrence inside the liquid mixtures<sup>15</sup>.

It is observed from variety of literature survey, no ultrasonic investigation has been reported for the Ammonium persulphate with other sulphate anions. S.Ravichandran and K.Ramanathan analyzed the intermolecular interactions based on the acoustical properties and excess values in binary liquid mixtures of Zinc sulphate and Zinc nitrate<sup>16</sup>.

Ammonium persulphate is taken for our present study because of its industrial importance. It is a strong oxidizing agent and radical initiator. It is used to etch copper on printed circuit boards as an alternative to ferric chloride solution. It is also used along with tetra methyl ethylenediamine to catalyze the polymerization of acryl amide in making a polyacrylamide gel. It has also been utilized to study protein - protein interactions via photo initiated cross linking chemistry.

The present paper focused on ultrasonic investigation in the aqueous solutions of binary mixtures of following five systems. The whole study has been made at the temperature of 303.15K.

System I: Ammonium Persulphate+Copper Sulphate

System II. Ammonium Persulphate + Ferrous ammonium sulphate

System III. Ammonium Persulphate +Zinc Sulphate

System IV: Ammonium Persulphate + Manganese Sulphate

System V: Ammonium Persulphate + Ammonium Sulphate

From the measured ultrasonic speed (U), density ( $\rho$ ), and viscosity ( $\eta$ ), adiabatic compressibility ( $\beta$ ), intermolecular free length ( $L_f$ ), internal pressure ( $\pi_i$ ), acoustic impedance (Z), relaxation time ( $\tau$ ), molar volume ( $V_m$ ), classical absorption coefficient ( $\alpha/f^2$ ) and surface tension ( $\sigma$ ) have been evaluated. The surface tension for the liquid mixtures has been calculated by applying Altenberg relation between

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ultrasonic velocity and density of liquid mixtures<sup>17</sup>. The excess viscosity ( $\eta^E$ ), excess compressibility ( $\beta^E$ ), excess intermolecular free length ( $L_f^E$ ), excess acoustic impedance ( $Z^E$ ) and excess molar volume ( $V_m^E$ ) values have been computed to study the nature of interaction among the liquid mixtures.

## EXPERIMENTAL

The inorganic salts used for preparing liquid mixtures are AR grade from Merck. The solutions were prepared by using distilled water. Ultrasonic velocity for the liquid mixtures for all concentrations were measured with a single crystal ultrasonic interferometer with frequency of 2 MHz (model F-81), manufactured from Mittal enterprises having accuracy in ultrasonic velocity of  $\pm 0.02\%$ . The viscosity of mixtures were determined by using Ostwald's viscometer. The density of the solutions was measured by specific gravity bottle of 5 ml with accuracy of  $\pm 0.5\%$ . Ultrasonic speed, viscosity and density measurements had been made at 303.15 K. The various acoustical parameters like adiabatic compressibility, intermolecular free length, internal pressure, acoustic impedance, relaxation time, molar volume, classical absorption coefficient and surface tension were calculated for the liquid mixtures. From the computed acoustical parameters, excess parameters were calculated.

### Theory and Calculations

The acoustical parameters which are calculated from measured ultrasonic velocity density, and viscosity provide complete information about interaction between ions, dipoles, the intermolecular hydrogen bonding and cohesive and dispersive forces. The experimental values of ultrasonic velocity, density and viscosity of the binary liquid mixtures of all the five system are measured applying the standard procedure and formulae.

### Adiabatic compressibility

The change in the adiabatic compressibility is due to the variation in the structural arrangement of molecules. It depends only on the ultrasonic velocity and density of the solution not the temperature.

Adiabatic compressibility can be calculated using the relation<sup>18</sup>,

$$\beta = \frac{1}{U^2 \rho} \quad (1)$$

### Intermolecular free length

Free length is extremely important parameter to examine the nature and strength of interactions<sup>5</sup>. The free length is the distance between the surfaces of neighboring molecules. From Jacobson's Formula, free length is calculated as<sup>19</sup>

$$L_f = K_T \beta^{\frac{1}{2}} \quad (2)$$

where,  $K_T$  is temperature dependent constant known as Jacobson constant.

### Internal Pressure

Internal Pressure is the measure of the resultant force of attraction and force of repulsion between interacting components of liquid mixture<sup>20</sup>. It is derived from the relation.

$$\pi_i = bRT \left( \frac{K\eta}{U} \right)^{\frac{1}{2}} \left( \frac{\rho^{\frac{2}{3}}}{M_{eff}^{\frac{6}{5}}} \right) \quad (3)$$

where, R is gas constant, T is the absolute temperature, temperature of the system and K is temperature independent constant. b stands for the cubic packing factor<sup>5</sup>.

### Acoustic Impedance

When an ultrasonic wave encounters at interface of two media, the reflection of ultrasonic occur due to the impedance<sup>21, 22</sup>. It describes how much resistance and ultrasound beam experiences, as it passes through a medium. It is very important physical quantity for estimating the absorption of sound in the material medium. Acoustic impedance can be obtained from the expression

$$Z = U\rho \quad (4)$$

where U is ultrasonic velocity and  $\rho$  is density of liquid mixtures.

### Relaxation time

Relaxation time is the property of the liquid mixture which affects the ultrasonic velocity. There is some correlation between relaxation time and absorption coefficient. It can be computed using the<sup>23</sup>,

$$\tau = \frac{3}{4} \eta \beta \quad (5)$$

where,  $\eta$  is the viscosity of the liquid mixtures.

### Molar Volume

Molar Volume is the volume occupied by one mole of substance. The molar volume of the liquid mixtures has been calculated using the expression

$$V_m = (X_1 M_1 + X_2 M_2) / \rho \quad (6)$$

where,  $X_1$  and  $X_2$  are mole fraction of the solute and solvent and  $M_1$  and  $M_2$  are molecular weight of the solute and solvent respectively

### Classical absorption coefficient

The classical absorption is always several times less than the actual measured absorption, since it is only due to the viscosity of the medium. The classical absorption coefficient ( $\alpha/f^2$ ) class can be obtained by

$$(\alpha/f^2) \text{ class} = 8\pi^2 \eta s / 3\rho u \quad (7)$$

### Surface Tension

The surface tension is calculated from ultrasonic velocity and density<sup>24</sup> as

$$\sigma = 6.3 \times 10^{-4} \rho U^{\frac{3}{2}} \quad (8)$$

The modified relation of surface tension<sup>17</sup> is expressed as,

$$\sigma = 10^{-4} T^{\frac{1}{3}} \rho U^{\frac{3}{2}} \quad (9)$$

### Excess Parameters

The excess functions<sup>5</sup> for the acoustical parameters are calculated using the relation,



$$Y^E = Y_{\text{mix}}[X_1 Y_1 + X_2 Y_2] \quad (10)$$

The excess viscosity, excess compressibility, excess intermolecular free length, excess acoustic impedance and excess molar volume are derived from the following expressions,

$$\eta^E = \eta_{\text{mix}} - [X_1 \eta_1 + X_2 \eta_2] \quad (11)$$

$$\beta^E = \beta_{\text{mix}} - [X_1 \beta_1 + X_2 \beta_2] \quad (12)$$

$$L_f^E = L_{f\text{mix}} - [X_1 L_{f1} + X_2 L_{f2}] \quad (13)$$

$$Z^E = Z_{\text{mix}} - [X_1 Z_1 + X_2 Z_2] \quad (14)$$

$$V_m^E = V_{m\text{mix}} - [X_1 V_{m1} + X_2 V_{m2}] \quad (15)$$

where,  $\eta_1$  and  $\eta_2$ ,  $\beta_1$  and  $\beta_2$ ,  $V_{m1}$  and  $V_{m2}$ ,  $L_{f1}$  and  $L_{f2}$ ,  $Z_1$  and  $Z_2$  are the viscosity, adiabatic compressibility, free length acoustic impedance and molar volume of the solute and solvent respectively.

### RESULTS AND DISCUSSION

While mixing two liquids, the molecular interaction between the liquids is due to the presence of dispersive

force, charge transfer, hydrogen bonding and dipole induced dipole interactions. The acoustical parameters which are calculated from measured ultrasonic velocity density, and viscosity provide complete information about interaction between ions, dipoles, the intermolecular hydrogen bonding and cohesive and dispersive forces. From the measured and calculated acoustical parameters for the excess parameters like excess viscosity, excess compressibility, excess molar volume, excess acoustic impedance and excess intermolecular free length are calculated. The deviation in the experimental and theoretical ultrasonic velocity shows that molecular interactions takes place between unlike molecules. The deviation of experimental values from values calculated using Ideal mixing relation, may be because of compressibility of component liquids is present in the mixtures.

Surface tension, modified surface tension and molar sound velocity along with the measured ultrasonic speed, density, and viscosity for all the five systems at 303.15 K are presented in Table-1.

**Table 1 Ultrasonic Speed, Density, Viscosity, Surface tension, Modified surface tension, and Molar sound velocity, for the systems I,II,III,IV and V at 303.15K.**

Mole Fraction		U m/s	$\rho$ Kg $m^{-3}$	$\eta \times 10^3$ $Nsm^{-2}$	$\sigma_{\text{AUR}}$ $Nm^{-1}$	$\sigma_{\text{MOD}}$ $Nm^{-1}$	$R \times 10^3$ $m^3 mol^{-1} (m/s)^{1/3}$
$X_2$	$X_2$						
<b>System I: Ammonium Persulphate+Copper sulphate</b>							
0.0000	1.0000	1572	1142	1.793	44875	478422.542	
0.1084	0.8916	1574	1141	1.720	44909	478782.542	
0.2148	0.7852	1578	1140	1.697	45044	480232.503	
0.3192	0.6808	1579	1138	1.688	44998	479732.485	
0.4218	0.5782	1583	1135	1.663	45071	480512.470	
0.5225	0.4775	1593	1129	1.672	45195	481832.467	
0.6214	0.3786	1603	1133	1.565	45830	488602.441	
0.7185	0.2815	1606	1129	1.510	45787	488152.429	
0.8140	0.1860	1611	1123	1.415	45735	487592.425	
0.9078	0.0922	1616	1119	1.384	45808	488372.413	
1.0000	0.0000	1629	1118	1.369	46306	493682.401	
<b>System II: Ammonium Persulphate +Ferrous Ammonium Sulphate</b>							
0.0000	1	1695	1199	2.466	52710	561953.901	
0.1603	0.8397	1681	1187	2.288	51544	549523.665	
0.3005	0.6995	1677	1181	2.229	51110	544893.449	
0.4241	0.5759	1666	1173	2.138	50282	536073.260	
0.5339	0.4661	1651	1165	1.976	49242	524983.091	
0.6321	0.3679	1653	1159	1.838	49045	522882.944	
0.7205	0.2795	1639	1148	1.711	47976	511492.814	
0.8132	0.1868	1641	1141	1.687	47779	509392.676	
0.8730	0.1270	1640	1132	1.560	47361	504932.583	
0.9393	0.0607	1628	1124	1.438	46527	496042.493	
1.0000	0.0000	1644	1116	1.528	46841	499382.414	
<b>System III: Ammonium Persulphate+Zinc sulphate</b>							
0.0000	1	1610	1176	1.738	47876	510422.866	
0.1228	0.8772	1617	1168	1.449	47872	510382.815	

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0.2395	0.7605	1632	1165	1.423	48373	515712.762
0.3507	0.6493	1634	1158	1.377	48168	513532.714
0.4565	0.5435	1634	1153	1.276	47964	511362.657
0.5575	0.4425	1631	1146	1.270	47576	507222.613
0.6540	0.3460	1650	1142	1.185	48210	513982.573
0.7462	0.2538	1643	1140	1.177	47802	509622.519
0.8344	0.1656	1662	1133	1.165	48354	515512.488
0.9190	0.0810	1663	1125	1.073	48059	512362.455
1.0000	0.0000	1633	1119	1.101	46546	496242.401

**System IV:Ammonium Persulphate+Magnesium Sulphate**

0.0000	1.0000	1636	1114	1.747	46426	494952.608
0.1071	0.8929	1631	1109	1.626	46042	490862.595
0.2126	0.7874	1618	1110	1.547	45505	485142.566
0.3164	0.6836	1616	1111	1.499	45457	484622.544
0.4186	0.5814	1622	1113	1.466	45793	488212.522
0.5192	0.4808	1637	1113	1.390	46433	495032.510
0.6183	0.3817	1656	1112	1.344	47216	503382.503
0.7159	0.2841	1663	1115	1.207	47628	507772.479
0.8120	0.1880	1630	1112	1.219	46100	491482.452
0.9067	0.0933	1648	1112	1.264	46864	499632.442
1.0000	0.0000	1661	1111	1.055	47401	505352.432

**System V:Ammonium Persulphate +Ammonium sulphate**

0.0000	1.0000	16241070	1.213	44103	470191.450	
0.0604	0.9396	16181069	1.145	43813	467101.525	
0.1265	0.8735	16261075	1.149	44385	473201.579	
0.1988	0.8012	16401082	1.155	45257	482491.648	
0.2785	0.7215	16481086	1.112	45763	487891.729	
0.3677	0.6333	16641090	1.096	46591	496721.823	
0.4648	0.5352	16431089	1.115	45689	487101.916	
0.5747	0.4253	1652	1104	1.124	46709	497982.007
0.6985	0.3015	1637	1109	1.096	46284	493442.118
0.8390	0.1610	1658	1194	1.156	50749	541052.109
1.0000	0.0000	1633	1118	1.083	46505	495802.403

From the variation in values of surface tension for the five systems listed as in the Table 1. It is inferred that the presence of attractive interactions between the liquid mixtures. There is the migration of species having lowest surface tension at the interface of two media. This migration produces the variation in the surface tension of liquid mixtures. Addition of solute increases the surface tension accompanied with variation of mean free length<sup>25,26</sup>. In our present study, the non linearity in the surface tension of the solutions of all the inorganic salt mixtures confirm the migration of constituent molecules and strong interactions in liquid mixtures.

The adiabatic compressibility, intermolecular free length and acoustic impedance are listed in the Table 2. The decreasing trend in the Molar volume for the systems I-V is noted from the Table 2. The linear variation in the molar volume with the concentration show the adhesive forces between the constituent molecules of the liquid mixtures.

The variation in the adiabatic compressibility shows the variation depending upon the concentration of solute. It is due to the change in ultrasonic velocity. The similar results are obtained by Elangovan and Mullainathan<sup>4</sup>. The increasing trend in the compressibility of mixtures with

increase in concentration of solute molecule may be attributed to the presence of dipolar interactions between unlike molecules. The decrease in intermolecular systems indicates the variation in the structural arrangement in the molecules. The non-linear variation of intermolecular free length observed in all the five sulphate mixtures of with concentration of the solute may arise from the hydrogen bonding.

The non linearity in the internal pressure is used to measure the attractions repulsions of the molecules in the liquid systems. Decrease in the values of internal pressure with increasing mole fraction observed in system I, IV and V, and the increase in the internal pressure values in the systems II and III exhibit the increase in the attractive forces between the components<sup>27</sup>.

The increasing trend in the acoustic impedance for the system I is observed from the Table 2. Acoustic impedance values are decreased with increase in mole fractions in the Systems II, III, IV and V. These variations suggest that the presence of complex formation in the

solutions and it is attributed due to solute solvent interaction. The relaxation time with the order of  $10^{-13}$  seconds, may be because of structural relaxation process<sup>28</sup>. The decreasing values of relaxation time with the increase in concentration is observed in all the five systems confirms solute solvent interactions. The decreasing trend in the Molar volume for the systems I-V is noted from the Table 2. The linear variation in the molar

volume with the concentration show the adhesive forces between the constituent molecules of the liquid mixtures.

Table 2 provides the values of classical absorption coefficient for all the five systems at 303.15 K. The uniformity in the decreasing trend in the values of classical absorption coefficient with concentration is the clear evidence solute solvent interactions between the constituent molecules.

**Table 2 Adiabatic compressibility, Inter molecular free length, Acoustic impedance, Relaxation time, Classical absorption coefficient, Internal pressure and molar volume for the systems I, II, III, IV and V at 303.15 K**

Mole Fraction	$\beta \times 10^{10}$ Kg ms <sup>-2</sup>	$L_f \times 10^{11}$ m	$Z \times 10^{-6}$ Kgm s <sup>-1</sup>	$\tau \times 10^{13}$ sec	$\alpha / f^2 \times 10^{15}$ Neperm <sup>-1</sup>	$\pi_i \times 10^6$ atm	$V_m \times 10^6$ m <sup>3</sup>	
$x_1$		$x_2$						
<b>System I: Ammonium Persulphate+Copper sulphate</b>								
0.0000	1.0000	3.540	3.763	1.796	8.463	10.613	6.336	218.57
0.1084	0.8916	3.536	3.761	1.797	8.109	10.156	6.134	218.78
0.2148	0.7852	3.520	3.753	1.800	7.964	9.950	6.081	214.94
0.3192	0.6808	3.523	3.754	1.797	7.931	9.903	6.123	213.37
0.4218	0.5782	3.513	3.748	1.798	7.787	9.697	6.067	211.93
0.5225	0.4775	3.493	3.738	1.798	7.788	9.642	6.108	211.27
0.6214	0.3786	3.433	3.706	1.817	7.162	8.808	5.751	208.56
0.7185	0.2815	3.434	3.706	1.814	6.914	8.490	5.588	207.42
0.8140	0.1860	3.432	3.705	1.809	6.476	7.927	5.253	206.83
0.9078	0.0922	3.421	3.699	1.809	6.315	7.707	5.165	205.61
1.0000	0.0000	3.371	3.672	1.821	6.152	7.449	5.115	204.05
<b>System II: Ammonium Persulphate +Ferrous Ammonium Sulphate</b>								
0.0000	1.0000	2.903	3.408	2.032	9.543	11.100	4.929	327.17
0.1603	0.8397	2.981	3.453	1.995	9.096	10.670	4.970	308.20
0.3005	0.6995	3.009	3.469	1.981	8.946	10.517	5.022	290.32
0.4241	0.5759	3.069	3.504	1.955	8.751	10.357	5.385	274.94
0.5339	0.4661	3.148	3.549	1.923	8.294	9.905	5.342	261.52
0.6321	0.3679	3.160	3.555	1.915	7.745	9.241	5.272	248.99
0.7205	0.2795	3.083	3.511	1.881	7.401	8.907	5.225	238.65
0.8132	0.1868	3.072	3.506	1.872	7.321	8.797	5.474	226.39
0.8730	0.1270	3.045	3.490	1.856	6.833	8.218	5.273	219.93
0.9393	0.0607	2.980	3.453	1.830	6.435	7.793	5.132	211.88
1.0000	0.0000	3.014	3.472	1.834	6.758	8.108	5.648	204.54
<b>System III: Ammonium Persulphate+Zinc sulphate</b>								
0.0000	1.00001	3.279	3.622	1.894	7.600	9.306	5.187	244.52
0.1228	0.8772	3.273	3.618	1.890	6.322	7.708	4.417	239.85
0.2395	0.7605	3.224	3.591	1.901	6.116	7.391	4.418	234.61
0.3507	0.6493	3.236	3.598	1.891	5.939	7.168	4.374	230.43
0.4565	0.5435	3.249	3.605	1.883	5.529	6.673	4.157	225.60
0.5575	0.4425	3.279	3.621	1.870	5.554	6.714	4.243	221.99
0.6540	0.3460	3.218	3.588	1.884	5.084	6.077	4.462	217.77
0.7462	0.2538	3.252	3.607	1.872	5.102	6.124	4.097	213.47
0.8344	0.1656	3.196	3.575	1.883	4.965	5.891	4.096	210.01
0.9190	0.0810	3.214	3.586	1.871	4.597	5.463	3.845	207.19
1.0000	0.0000	3.350	3.661	1.828	4.491	5.934	4.104	203.86

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**System IV: Ammonium persulphate+Magnesium Sulphate**

0.0000	1.0000	3.545	3.766	1.737	5.732	6.969	8.349	123.36
0.1071	0.8929	3.575	3.781	1.729	5.455	6.655	7.513	129.91
0.2126	0.7874	3.520	3.752	1.747	5.393	6.547	7.149	134.28
0.3164	0.6836	3.438	3.708	1.774	5.295	6.375	6.778	139.78
0.4186	0.5814	3.391	3.683	1.789	5.028	6.022	6.142	146.34
0.5192	0.4808	3.315	3.641	1.813	4.842	5.744	5.645	153.82
0.6183	0.3817	3.402	3.689	1.789	5.055	6.073	5.462	162.38
0.7159	0.2841	3.318	3.643	1.824	4.972	5.939	5.165	169.73
0.8120	0.1880	3.364	3.668	1.816	4.917	5.929	4.748	179.66
0.9067	0.0933	3.049	3.492	1.979	4.699	5.596	4.810	178.22
1.0000	0.0000	3.352	3.662	1.827	4.840	5.850	4.035	204.04

**System V: Ammonium persulphate +ammonium sulphate**

0.0000	1.0000	3.355	3.663	1.822	7.813	9.416	5.921	221.35
0.0604	0.9396	3.388	3.681	1.810	7.343	8.877	5.565	220.42
0.1265	0.8735	3.442	3.711	1.796	7.098	8.651	5.390	218.57
0.1988	0.8012	3.447	3.713	1.795	6.888	8.405	5.278	216.74
0.2785	0.7215	3.416	3.697	1.805	6.677	8.118	5.199	214.63
0.3677	0.6333	3.354	3.663	1.822	6.216	7.488	4.930	212.96
0.4648	0.5352	3.278	3.621	1.841	5.873	6.991	4.747	211.55
0.5747	0.4253	3.244	3.602	1.854	5.222	6.193	4.297	209.27
0.6985	0.3015	3.385	3.680	1.812	5.502	6.656	4.456	208.31
0.8390	0.1610	3.312	3.640	1.832	5.582	6.679	4.611	206.77
1.0000	0.0000	3.261	3.612	1.846	4.585	5.443	3.847	205.36

Excess Viscosity, Excess Compressibility, Excess Free length, Excess impedance and Excess molar volume for the systems at 303.15 K are presented in the Table 3. The excess values are the appropriate tool for investigating the degree of molecular interactions in the liquid mixtures. The excess functions exhibit the deviations in ultrasonic velocity and viscosity which are due to the strong or weak interactions between the unlike molecules of the mixtures<sup>14</sup>. The positive values of  $V_f^E$  and  $L_f^E$  shows the occurrence of dissociation of hydrogen bonding between like molecules than the formation of new bonds between unlike molecules. The negative values of  $V_f^E$  and  $L_f^E$  are

may be the result of complex formation. The positive and negative values of excess functions are the influence of dissociation or association between unlike molecules. The dipole induced dipole and dipole-dipole interactions and the dispersive forces make the excess values to be negative and positive values respectively<sup>29-30</sup>. The excess viscosity values are negative for all concentrations for the systems II-V. The positive values of excess viscosity at mid concentrations observed in the system I reflect the increase in the strength of interaction in the solutions [14].

**Table 3 Excess Viscosity, Excess Compressibility, Excess Free length, Excess impedance and Excess molar volume for the systems I, II, III, IV and V at 303.15K.**

Mole Fraction	$\eta^{Ex} \times 10^3$ Nsm <sup>-2</sup>	$\beta^E \times 10^{10}$ Kg <sup>-1</sup> ms <sup>2</sup>	$L_f^E \times 10^{11}$ M	$Z^{Ex} \times 10^{-6}$ Kgm <sup>-2</sup> s <sup>-1</sup>	$V_m^E \times 10^6$ m <sup>3</sup>	
$x_2$	$x_2$					
<b>System I: Ammonium Per sulphate+ Copper sulphate</b>						
0.1084	0.8916	-0.027	0.013	0.007	-0.003	1.784
0.2148	0.7852	-0.005	0.016	0.009	-0.002	-0.511
0.3192	0.6808	0.031	0.037	0.020	-0.007	-0.565
0.4218	0.5782	0.049	0.044	0.024	-0.009	-0.516
0.5225	0.4775	0.101	0.041	0.022	-0.012	0.287
0.6214	0.3786	0.035	-0.002	-0.001	0.005	-0.987
0.7185	0.2815	0.022	0.015	-0.008	-0.001	-0.717
0.8140	0.1860	-0.032	0.029	0.016	-0.008	0.079
0.9078	0.0922	-0.024	0.035	0.019	-0.010	0.221

**System II:Ammonium Persulphate +Ferrous Ammonium sulphatemmonium Sulphate**

0.1603	0.8397	-0.027	0.060	0.035	-0.005	0.688
0.3005	0.6995	0.045	0.073	0.042	0.009	0.000
0.4241	0.5759	0.070	0.119	0.069	0.007	-0.223
0.5339	0.4661	0.011	0.186	0.107	-0.003	-0.178
0.6321	0.3679	-0.035	0.186	0.107	0.008	-0.666
0.7205	0.2795	-0.079	0.099	0.057	-0.008	-0.165
0.8132	0.1868	-0.016	0.079	0.045	0.001	-0.587
0.8730	0.1270	-0.087	0.045	0.026	-0.003	-0.184
0.9393	0.0607	-0.147	-0.027	-0.016	-0.016	-0.104

**System III:Ammonium Persulphate+Zinc sulphate**

0.1228	0.8772	-0.211	-0.015	-0.009	0.004	-0.086
0.2395	0.7605	-0.163	-0.072	-0.040	0.023	-0.970
0.3507	0.6493	-0.138	-0.068	-0.038	0.021	-0.998
0.4565	0.5435	-0.171	-0.062	-0.034	0.019	-1.879
0.5575	0.4425	-0.112	-0.040	-0.220	0.013	-1.719
0.6540	0.3460	-0.136	-0.108	-0.060	-0.007	-2.336
0.7462	0.2538	-0.086	-0.080	-0.044	0.027	-3.194
0.8344	0.1656	-0.041	-0.142	-0.079	0.044	-3.362
0.9190	0.0810	-0.080	-0.130	-0.072	0.037	-3.024

**System IV:Ammonium per sulphate+Magnesium sulphate**

0.1071	0.8929	-0.047	0.043	0.024	-0.015	0.781
0.2126	0.7874	-0.053	0.107	0.058	-0.031	0.623
0.3164	0.6836	-0.029	0.122	0.067	-0.035	0.451
0.4186	0.5814	0.009	0.100	0.055	-0.027	-0.026
0.5192	0.4808	0.003	0.049	0.027	-0.012	-0.087
0.6183	0.3817	0.025	-0.018	-0.010	0.005	0.086
0.7159	0.2841	-0.044	-0.044	-0.024	0.015	-0.632
0.8120	0.1880	0.034	0.106	0.058	-0.029	-0.053
0.9067	0.0933	0.145	0.042	0.023	-0.011	-0.087

**System V:Ammonium Persulphate + Ammonium Sulphate**

0.0604	0.9396	-0.060	0.041	0.022	-0.014	1.677
0.1265	0.8735	-0.047	-0.007	0.003	-0.002	0.714
0.1988	0.8012	-0.032	-0.007	-0.037	0.019	0.381
0.2785	0.7215	-0.065	-0.100	-0.054	0.027	0.511
0.3677	0.6333	-0.071	-0.163	-0.090	0.041	0.671
0.4648	0.5352	-0.038	-0.054	-0.029	0.010	1.520
0.5747	0.4253	-0.014	-0.116	-0.063	0.035	0.003
0.6985	0.3015	-0.026	-0.046	-0.249	0.016	-0.055
0.8390	0.1610	0.052	-0.334	-0.186	0.166	-12.831

The negative excess compressibility indicates the strong hetero molecular interactions of the constituent molecules. The negative values are due to the charge transfer, dipole-dipole and dipole – induced dipole interaction and by the hydrogen bonding between unlike components. Positive excess compressibility shows the weak interactions which will arise from the dispersive Forces<sup>14, 31</sup>. In our present work, the positive values of adiabatic compressibility in the system I, II and IV exhibit the weak interaction may be due to molecular dissociation. The compressibility is negative in the systems III and V. It is the evidence for the presence of strong molecular association.

It is observed that excess free length values are negative for the systems III and V. The negative values of excess intermolecular free length is mainly due to the hydrogen bonding between the unlike molecules<sup>32</sup>. The positive values of  $L_f$  indicate the weak molecular interaction between the components of mixtures, which may arise from dispersion forces<sup>33</sup>. The excess acoustic impedance values show the negative values for all the systems except systems III and V. The negative acoustic impedance values may arise from the molecular interaction between the unlike molecules. Acoustic impedance is positive for the higher concentrations of the

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systems III and V. It may be attributed due to weak interactions. The excess molar volume values are negative in all the five systems for entire composition. This is due to the reason that the constituent molecules are brought in to closer and is the evidence of strong interactions. Free dipoles of ammonium per sulphate induce the moments in the dipoles of other sulphate anions of the liquid mixtures.

## CONCLUSION

The measured values of ultrasonic velocity, density, viscosity, and computed acoustical parameters at 303.15 K for ammonium per sulphate with five different sulphate anions provide the knowledge about the existence of hydrogen bonding between unlike molecules. Evaluated excess viscosity, excess compressibility and excess free volume confirmed the presence of hydrogen bonding, and dipolar interactions.

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