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Original Article

Ultrasonic studies of NaCl, NaBr and NaI in Glycol + Water & Glycerol + Water at 303.15 K.

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ABSTRACT

Density and ultrasonic velocity have been measured for NaCl, NaBr and NaI in Glycol + Water & Glycerol + Water at 303.15 K.A quantitative relationship has been established among the thermodynamic properties like sound velocity (U), adiabatic compressibility (β_s), intermolecular free length (L_f), Acoustic impedance (Z), apparent molar compressibility ($K_{\varnothing}$), apparent molar volume ($V_{\varnothing}$) limiting apparent molar compressibility ($K_{\varnothing}^0$) limiting apparent molar volume ($V_{\varnothing}^0$) and their constants (S_K, S_v). From the obtained values, molecular interaction study has been made successfully in the light of these acoustical properties through hydrogen bonding between solute and solvent mixture.

Keywords: Ultrasonic velocity, apparent molar volume, acoustical impedance, molecular interaction, hydrogen bonding.

1. INTRODUCTION

In the recent years ultrasonic velocity measurements are helpful to interpret solute-solvent, ion- solvent, solvent-solvent interaction in aqueous and non aqueous medium [1-4]. Recently acoustic parameters studies of metal complexes have been carried out from our laboratory [5] and Mishra et al have also reported the similar work [6]. The interaction helps in better understanding the types of solute and solvent i.e.

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whether the added solute modifies or distorts the structure of solvent. Apparent molar volume gives valuable information about ion-ion and ion-solvent interaction in solution [7-11] .The addition of organic solvent to an aqueous solvent of electrolyte brings about the change in ion salvation that result a large change in reactivity of dissolved electrolyte. [12-13] Intermolecular interactions in various binary liquid mixtures at different temperatures have been studied by several authors[14-17] Physico chemical properties like density, viscosity and speed of sound have got considerable importance in forming theoretical models as well as their applications in a number of branches of science. A considerable progress has been made towards theoretical understanding of liquid – liquid mixture[18-21]. The binary mixture are indispensable for many chemical processing industries e.g. petroleum, petrochemicals, where physico-chemical processes are involved to handle the mixtures of hydrocarbons, alcohols, ketones etc[22]. For accurate designing equipment it is necessary to know the interaction between the components of mixture. The thermodynamic studies of binary solutions have attracted much attention of scientists and experimental data on a number of systems are available from review and publications. Viscosity, density measurements and the properties derived from these are excellent tools to detect solute – solute and solvent interactions. It is used in different fields of scientific researches in physics, chemistry, biology, medicines and industries. The present work deals with the measurement of density (ρ), relative viscosity (η_r), apparent molar volume (ϕ_v), ultrasonic velocity (U) and the derived acoustical parameters with Glycol + Water & Glycerol + Water mixture at 303.15 K using NaCl, NaBr and NaI as electrolytes.

It is also observed that the values of A (Falkenhagen Coefficient) are positive in both the systems since A is a measure of ionic interaction. *B*-coefficient is also known as a measure of order or disorder introduced by the solute into the solvent. It is also a measure of solute-solvent interaction and relative size of the solute & solvent molecules. The values of *B*-coefficient are also positive in both the systems. In aquo-organic solution of NaCl positive a values suggest the predominance of ion-ion interaction.

2. MATERIALS AND METHOD

The entire chemical used in this present research work are spectroscopic reagents (SR) and analytical reagent (AR) grades of minimum assay of 99.9% obtained from E-Merck, Germany and SD fine chemicals, India, which are used without further purification. Water used in these experiments was deionized and distilled. The required quantity of NaCl, NaBr and NaI for a given molality was dissolved in binary mixture of aqueous Glycol and Glycerol and similar procedure has been adopted for different molalities of NaCl, NaBr and NaI. The density was determined using a specific gravity bottle by relative measurement method .The ultrasonic velocity was measured by ultrasonic interferometer having frequency $2MH_Z$ (Mittal Enterprises, model no F-81). The constant temperature is mentioned by circulatory water through the double wall measuring cell made up of steel.

3. RESULTS AND DISCUSSION

Using the measured data various acoustic parameters[23-27] have been calculated. These parameters include adiabatic compressibility, intermolecular free length, acoustic impedance, apparent molar compressibility, apparent molar volume, limiting apparent molar compressibility, limiting apparent molar volume and the associated constants S_K and S_V. The apparent molar volume (V_{ϕ}) was determined from the following:

$$V_{\phi} = 1000(cd_0)^{-1}(d_0 - d) + M_2 d_0^{-1}$$

and the results are noted in " Table 1 " where c is the molar concentration of the solution, M_2 is the molecular mass of the solute, d_0 and d are the densities of pure solvent and solution respectively.The apparent molar volume thus obtained is found to vary linearly with $c^{1/2}$. The V_ϕ data were fitted by a method of least squares to Masson's eqution[28],

$$V_\phi = V_\phi^0 + S_v c^{1/2}$$

The values of limiting apparent molar volume (V_ϕ) and slope S_v calculated from the graph are recorded in "Table 2". The positive value of S_v indicates ion–ion interaction. The increase of V_ϕ^0 with increasing concentration of glycol may be attributed due to low charge density.

The viscosity data of electrolyte solutions both in aqueous and non-aqueous solutions follow the Jone-Dole[29] equation and recorded in " Table 1"

$$\eta_r = \frac{\eta}{\eta_0} = 1 + Ac^{1/2} + Bc$$

Where η_r in the relative viscosity of the solution. η and η_0 are the viscosities of solution and solvent respectively. c is the molar concentration. A and B are constants. Falkenhagen[30] coefficient A is due to the contributions from interionic forces. The B-coefficient of Jones-Dole equation indicates the ion-solvent interaction in solutions.[31]

The plot of $\left(\frac{\eta_r - 1}{\sqrt{C}}\right)$ vs. $\sqrt{C}$ is linear (Fig.1)

The values of A and B obtained from the graph are recorded in "Table 2".

It is also observed that the values of A (Falkenhagen Coefficient) are positive in both the systems. Since A is a measure of ionic interaction, *B*-coefficient is also known as a measure of order or disorder introduced by the solute into the solvent. It is also a measure of solute-solvent interaction and relative size of the solute & solvent molecules. The values of *B*-coefficient are also positive in both the systems. In aquo-organic solution of NaCl positive values of A suggest the predominance of ion-ion interaction.

The following observations have been made on $K_\varnothing^0$ and $K_\varnothing$ of sodium Chloride, Bromide and Iodide in aqueous Glycol, and Glycerol mixtures. The limiting apparent molar compressibility K_φ^0 provides information regarding ion-solvent interaction. The values of $K_\varnothing^0$ are negative for all the systems over the entire range of concentration. . In other words the large negative value of K_φ may indicate the presence of packing or caging effect[32]. The decrease in the negative value indicates that with increase in the mole fraction of aqua-organic solvents, ion-solvent interaction increases as a result caging effect diminishes.

- The values of K_φ increases linearly with increasing ion concentration.
- The values of $K_\varnothing$ are positive for both Glycol and Glycerol.

This $K_\varnothing$ value increases with the increase in organic solvent. This Shows that in presence of Glycol and Glycerol, there is increase in electrostriction of solvation and the order is Glycol + water > Glycerol + water and the reverse is the structure making order.

This can be explained considering following aspects:

- Glycerol has got three -OH groups, Glycol two -OH groups whereas, water is both a proton donor and acceptor.
- It accepts a proton and the three dimensional water structures are easily broken down. Glycol and glycerol containing greater number of -OH groups are not able to break the hydrogen bond so easily as their molecules are linked with each other by hydrogen.

At all temperatures of the present study, the limiting apparent slope S_v) of Masson's equation is positive suggesting ion-ion interaction. It may be attributed due to the change in the mobility of the ions due to the change in the dielectric constant. The ion-ion interaction in different solvents is of the order :Glycol + water > Glycerol +water. The volume behavior of solute at infinite dilution is satisfactorily represented by V_φ^0 which is independent of ion-ion interaction and provides information concerning ion-solvent interaction. The values of V_φ^0 are positive for aqueous Glycol, and Glycerol mixtures. Positive values of V_φ^0 suggest that ion-ion interactions predominate. The variation of relative viscosity, molar sound velocity (R), sound velocity (U), adiabatic compressibility (β_s), intermolecular free length (L_f), Acoustic impedance (Z) are shown in Table 3-10.The variation of the isentropic compressibility (β) values of the substrates solution goes on decreasing with increase in concentration of the solution. As such the internal pressure increases with the increase in concentration of solute. At lesser values of (β_s), ultrasonic velocity increases. From this we can conclude that the formation of more clusters of the solute solvent molecules with increasing hydrodynamic volume increases the isothermal compressibility while the density increases nominally over the solvent, the value thereby causing increased sound velocity. The intermolecular free length (L_f) decreases with increasing concentration of the solute in the solution. The values are comparatively less in Glycol + water than in the Glycerol + water (Fig.9& 10). This variation is probably due to higher internal pressure in Glycol + water mixture than Glycerol+ water mixture. The slope (S_v) is positive in all the solution. This agrees with our earlier findings that all the solutions contain electrolytes. The molar sound velocity (R) decreases linearly with increase in the concentration as shown in Figure 7 & 8.This decreasing order of molar sound velocity with concentration shows that the relative association in the solution decreases with the increase in concentration. The molar compressibility (W) decreases with the increase in solute concentration and acoustic impedance (Z) increases with increase in solute concentration in almost linear manner. The increasing order of Z with concentration can be explained on the basis of the decreasing number of free solvent molecules. As most of the solvent molecules are engaged in interaction with the solute. Addition of more solute to the solvent leads to the acceleration of the process of breaking of aggregates of solvent molecules. This process leads to the inhibition of propagation of sound waves due to large sized solute molecules acting as structure promoters. The variation in molar sound velocity is identical to that of ultrasonic velocity in the bulk. As the values of (Z) decrease over all the solvent, the value thereby causing increased sound velocity.

4. CONCLUSION

The data measured shows that the ultrasonic velocity increases with increase in concentration (Fig. 5 & 6) in all cases along with acoustic impedance (Z) (Fig. 11 & 12) while intermolecular free length (L_f) (Fig. (9 & 10) and molar sound velocity (R) (Fig.7 & 8) decreases with increase in concentration. The increase in isentropic compressibility (β_s) (Table 3-10) with decreasing concentration suggest minimum interaction between the unlike molecules (i.e. solute & solvent molecules). Acoustic impedance (Z) decreases with decrease in concentration, which supports the possibility of weak interactions between unlike molecules and is also used for accessing the absorption of sound in a media. The increasing ultrasonic velocity (U) and molar compressibility (W) with increasing concentration represents the decrease in cohesive force which is responsible for the structure breaking nature of the solute. The hydrogen bond existing glycol and water and Glycerol+ Water is disrupted by the solute molecules and thereby formation of new bonding between solute and solvent molecules has occurred. As most of the solvent molecules are engaged in interaction with the solute, addition of more solute molecules to the solvent leads to the acceleration of the process of breaking of aggregates of solvent molecules. This process leads to the inhibition of propagation of sound waves due to large sized solute molecules acting as structure promoters. To conclude the formation of more cluster of the solute – solvent molecules with increase in hydro-dynamic volume increases the isothermal compressibility. Recently similar study was reported[33] from our laboratory about the ion – solvent interaction of Drug and metal complex in mixed solvents.

Table 1: Variations of η_r, d and V_ϕ at different concentrations of NaCl

Concentration In mol dm^{-3}	η_r	d in g ml^{-1}	V_ϕ in cm^{3}mol^{-1}	η_r	d in g ml^{-1}	V_ϕ in cm^{3}mol^{-1}	η_r	d in g ml^{-1}	V_ϕ in cm^{3}mol^{-1}
10% Glycol + Water				20% Glycol + Water			30% Glycol + Water		
0.1000	1.07239	1.019060	96.8286	1.08014	1.033281	103.0697	1.09860	1.046397	106.9823
0.0750	1.05546	1.017633	96.6104	1.06131	1.031852	102.8460	1.07612	1.044942	106.7569
0.0500	1.03828	1.016200	96.3516	1.04221	1.030421	102.5806	1.05212	1.043475	106.4896
0.0250	1.02062	1.014776	96.0143	1.02262	1.028989	102.2348	1.02761	1.042028	106.1412
0.0100	1.00942	1.013912	95.7150	1.01025	1.028126	101.9280	1.01227	1.041150	105.8320
0.0075	1.00744	1.013771	95.6460	1.00807	1.027934	101.8573	1.00959	1.041004	105.7607
0.0050	1.00537	1.013618	95.5642	1.00580	1.027840	101.7734	1.00683	1.040859	105.6762
0.0025	1.00315	1.013481	95.4575	1.00338	1.027695	101.6640	1.00390	1.040711	105.5660
0.0010	1.00163	1.013391	95.3629	1.00173	1.027609	101.5670	1.00195	1.040623	105.4682

Table 2: Constants Ax10^2 (mol$^{-½}$ L^{½}) and B (mol^{-1} L) of NaCl in Glycol+ Water and Glycerol +Water at 303 ^{0}K

Solvent	10%		20%		30%	
	A	B	A	B	A	B
Glycol + water	6.60	9.80	6.40	9.70	5.80	9.70
Glycerol + water	5.95	8.70	6.10	8.60	5.40	9.65

Table-3: Density, Viscosity, and acoustic parameters for NaCl at 303.15K in 10% Glycol

Conc. Mole.dm^{-3}	Isentropic Compressibility $_s$ x 10^{-11} cm^2 dyne^{-1}	Apparent molar volume (Kø)in ml.mol^{-1}	Molar compressi-bility 'W'	Molar sound velocity 'R'	Acoustic impedance Z x 10^{-4} CGS unit	Inter molecular free length L_f in x10^{-6}m.	Apparent molar compres-sibility Kø^0 x 10^{-14} in cm^2.dyn^{-1}
0.1000	4.1628	112.9338	4.0737	100.2492	15.3841	4.0732	-6.1994
0.0750	4.1802	112.6211	4.0854	100.5844	15.3255	4.0817	-6.5513
0.0500	4.1977	112.2502	4.0975	100.9339	15.2662	4.0903	-7.0853
0.0250	4.2154	111.7669	4.1098	101.2859	15.2069	4.0989	-8.5672
0.0100	4.2288	111.3380	4.1168	101.4872	15.1663	4.1054	-11.9834
0.0075	4.2312	111.2391	4.1177	101.5142	15.1597	4.1066	-11.4583
0.0050	4.2384	111.1218	4.1184	101.5342	15.1438	4.1100	-10.3554
0.0025	4.2451	110.9690	4.1187	101.5439	15.1294	4.1133	-11.6333
0.0010	4.2515	110.8334	4.1187	101.5430	15.1165	4.1164	-8.1032
0.0000	4.2578	110.6247	4.1187	101.5422	15.1037	4.1195	….

Table 4: Density, Viscosity, and acoustic parameters for NaCl at 303.15K in 20% Glycol

Conc. Mole.dm^{-3}	Isentropic Compressibility $_s$ x 10^{-11} cm^2 dyne^{-1}	Apparent molar volume Kø in ml.mol^{-1}	Molar compressi-bility 'W'	Molar sound velocity 'R'	Acoustic impedance Z x 10^{-4} in CGS unit	Inter molecular free length L_f x10^{-6}m.	Apparent molar compres-sibility Kø^0 x 10^{-14} in cm^2.dyn^{-1}
0.1	4.1472	105.7515	4.0268	98.9048	15.5065	4.0656	-6.2239
0.075	4.1668	105.4499	4.0379	99.2219	15.4437	4.0752	-6.5724
0.05	4.1869	105.0921	4.0494	99.5512	15.3794	4.085	-7.1149
0.025	4.2099	104.6258	4.0605	99.8722	15.3102	4.0962	-11.9581
0.01	4.2243	104.212	4.0672	100.0636	15.2678	4.1032	-12.101
0.0075	4.2287	104.1166	4.0683	100.0935	15.2567	4.1054	-11.5677
0.005	4.2327	104.0035	4.0689	100.1133	15.2471	4.1073	-10.4476
0.0025	4.2399	103.856	4.0696	100.1325	15.231	4.1108	-11.7502
0.001	4.2435	103.7252	4.0699	100.142	15.223	4.1126	-9.0908
0	4.2495	103.5113	4.0696	100.1307	15.2117	4.1154	-

Table 5: Density, Viscosity, and acoustic parameters for NaCl at 303.15K in 30% Glycol

Conc. Mole.dm^{-3}	Isentropic Compressibility $_s$ x 10^{-11} cm^2 dyne^{-1}	Apparent molar volume 'Kø ' in ml.mol^{-1}	Molar compres si-bility 'W'	Molar sound velocity 'R'	Acoustic impedance Z x 10^{-4} in CGS unit	Inter molecular free length L_f x10^{-6}m.	Apparent molar compres-sibility Kø^0 x 10^{-14} in cm^2.dyn^{-1}
0.1	4.172	121.8646	4.1315	101.912	15.2568	4.0777	-6.1334
0.075	4.1897	121.521	4.1435	102.2574	15.1977	4.0864	-6.4785
0.05	4.2082	121.1135	4.1555	102.6027	15.1376	4.0954	-7.0003
0.025	4.2274	120.5823	4.1675	102.9483	15.0765	4.1047	-8.4471

0.01	4.2421	120.111	4.1746	103.1518	15.034	4.1119	-11.8738
0.0075	4.2448	120.0023	4.1755	103.1786	15.0269	4.1132	-11.3261
0.005	4.2475	119.8735	4.1764	103.2055	15.0198	4.1145	-10.3542
0.0025	4.2506	119.7055	4.1777	103.2431	15.0111	4.116	-10.187
0.001	4.2528	119.5565	4.1783	103.2591	15.0056	4.1171	-10.7397
0	4.2587	119.3001	4.1779	103.248	14.9945	4.1199	….

Table 6: Density,Viscosity, and acoustic parameters for NaCl at 303.15K in 10% Glycerol

Conc. Mole.dm^{-3}	Isentropic Compressibility $_s$ x 10^{-11} cm^2 dyne^{-1}	Apparent molar volume 'Kø' in ml.mol^{-1}	Molar compressi-bility 'W'	Molar sound velocity 'R'	Acoustic impedance Z x 10^{-4} in CGS unit	Inter molecular free length L_f x10^{-6}m.	Apparent molar compres-sibility $K\text{ø}^0$ x 10^{-14} in cm^2.dyn^{-1}
0.1	3.9783	101.8618	5.0948	124.6337	16.0717	3.982	-3.3295
0.075	3.9971	101.5856	5.1087	125.033	16.0067	3.9913	-3.3295
0.05	4.0163	101.2579	5.1232	125.4473	15.9402	4.0009	-4.7772
0.025	4.0357	100.8309	5.1378	125.8646	15.8738	4.0106	-8.1392
0.01	4.0492	100.452	5.146	126.0981	15.8309	4.0173	-14.8909
0.0075	4.0534	100.3646	5.1473	126.1343	15.8196	4.0194	-14.962
0.005	4.0628	100.261	5.1476	126.1436	15.7981	4.024	-16.698
0.0025	4.0745	100.126	5.147	126.1269	15.7732	4.0298	-19.8192
0.001	4.0805	100.0062	5.147	126.1248	15.7599	4.0328	-20.6249
0	4.0866	99.8307	5.1469	126.1226	15.7467	4.0358	….

Table 7: Density, Viscosity, and acoustic parameters for NaBr at 303.15K in 10% Glycol

Mole.dm^{-3}	Isentropic Compressibility $_s$ x 10^{-11} cm^2 dyne^{-1}	Apparent molar volume 'Kø$_v$' in ml.mol^{-1}	Molar compressi-bility 'W'	Molar sound velocity 'R'	Acoustic impedance Z x 10^{-4} in CGS unit	Inter molecular free length L_f x10^{-6}m.	Apparent molar compres-sibility $K\text{ø}^0$ x 10^{-14} in cm^2.dyn^{-1}
0.1	4.0747	103.7345	5.2291	128.4574	15.6556	4.0299	-1.5549
0.075	4.0953	103.4486	5.2437	128.8763	15.5888	4.0401	-1.7935
0.05	4.1171	103.1093	5.2583	129.2926	15.5201	4.0508	-2.248
0.025	4.138	102.6673	5.2731	129.7174	15.4535	4.0611	-3.5995
0.01	4.1564	102.275	5.2809	129.9437	15.4029	4.0701	-5.0776
0.0075	4.1634	102.1846	5.2818	129.9687	15.3868	4.0735	-5.8144
0.005	4.1704	102.0773	5.2827	129.9937	15.3707	4.077	-7.4567
0.0025	4.1829	101.9375	5.2826	129.9909	15.3447	4.083	-12.0318
0.001	4.1918	101.8135	5.2821	129.9755	15.3269	4.0874	-11.6959
0	4.2003	101.6022	5.2811	129.947	15.3105	4.0915	….

Table 8: Density, Viscosity, and acoustic parameters for NaBr at 303.15K in 10% Glycerol

Conc. Mole.dm^{-3}	Isentropic Compressibility $_s$ x 10^{-11} cm^2 dyne^{-1}	Apparent molar volume 'Kø' in ml.mol^{-1}	Molar compressi-bility 'W'	Molar sound velocity 'R'	Acoustic impedance Z x 10^{-4} in CGS unit	Inter molecular free length L_f x10^{-6}m.	Apparent molar compres-sibility $K\text{ø}^0$ x 10^{-14} in cm^2.dyn^{-1}
0.1	3.8925	100.6954	3.8824	94.7791	16.3746	3.9388	-5.8887
0.075	3.9105	100.4281	3.8933	95.0889	16.3088	3.9479	-6.0776
0.05	3.9291	100.111	3.9041	95.3989	16.242	3.9573	-6.4016
0.025	3.9498	99.6977	3.9148	95.7029	16.1711	3.9677	-7.2607
0.01	3.9613	99.331	3.9215	95.8949	16.1305	3.9734	-9.5839
0.0075	3.965	99.2465	3.9222	95.9126	16.1206	3.9753	-10.2992
0.005	3.9742	99.1462	3.9224	95.9192	16.0989	3.9799	-8.4829
0.0025	3.9779	99.0155	3.923	95.9369	16.0891	3.9817	-9.4584
0.001	3.9918	98.8995	3.9222	95.9136	16.0586	3.9887	-12.0206
0	4.0024	98.7135	3.9211	95.8819	16.0365	3.994	….

Table 9: Density,Viscosity, and acoustic parameters for NaI at 303.15K in 10% Glycol

Conc. Mole.dm^{-3}	Isentropic Compressibility $_s$ x 10^{-11} cm^2 dyne^{-1}	Apparent molar volume 'Kø' in ml.mol^{-1}	Molar compressi-bility 'W'	Molar sound velocity 'R'	Acoustic impedance Z x 10^{-4} in CGS unit	Inter molecular free length L_f x10^{-6}m.	Apparent molar compres-sibility $K\text{ø}^0{}_k$ x 10^{-14} in cm^2.dyn^{-1}
0.1	3.942	101.2053	4.5053	123.6583	16.2106	3.9638	-1.4412
0.075	3.9659	100.8964	4.5259	124.3177	16.118	3.9757	-1.5418
0.05	3.99	100.5301	4.5472	124.9987	16.0247	3.9878	-1.7157
0.025	4.0145	100.0527	4.5682	125.6722	15.9321	4	-2.254
0.01	4.0305	99.629	4.5808	126.0795	15.8738	4.008	-3.9615
0.0075	4.0355	99.5313	4.5828	126.1406	15.8594	4.0105	-4.4065
0.005	4.0404	99.4155	4.5847	126.2017	15.8449	4.0129	-4.416
0.0025	4.0506	99.2645	4.5857	126.236	15.8203	4.018	-5.6747
0.001	4.0594	99.1305	4.5854	126.2256	15.8014	4.0223	-7.3815
0	4.0707	98.9754	4.5846	126.2	15.7775	4.0279	….

Table 10: Density, Viscosity, and acoustic parameters for NaI at 303.15K in 10% Glycerol

Conc. Mole.dm^{-3}	Isentropic Compressibility $_s$ x 10^{-11} cm^2 dyne^{-1}	Apparent molar volume 'Kø' in ml.mol^{-1}	Molar compressi-bility 'W'	Molar sound velocity 'R'	Acoustic impedance Z x 10^{-4} in CGS unit	Inter molecular free length L_f x10^{-6}m.	Apparent molar compres-sibility $K\text{ø}^0$ x 10^{-14} in cm^2.dyn^{-1}
0.1	3.8569	100.5642	4.4508	121.9143	16.5142	3.9207	-1.4412
0.075	3.8877	100.2608	4.4698	122.5222	16.4044	3.9364	-1.5418
0.05	3.9186	99.901	4.4888	123.1292	16.2958	3.952	-1.7157
0.025	3.9499	99.4321	4.508	123.7426	16.1874	3.9677	-2.254
0.01	3.9731	99.016	4.5191	124.0975	16.1136	3.9793	-3.9615

0.0075	3.9856	98.9201	4.5197	124.1167	16.0836	3.9856	-4.4065
0.005	3.9982	98.8063	4.5203	124.1359	16.0536	3.9919	-4.416
0.0025	4.0052	98.658	4.5213	124.1696	16.0355	3.9954	-5.6747
0.001	4.0119	98.5264	4.522	124.1912	16.019	3.9988	-7.3815
0	4.0179	98.3347	4.5219	124.1888	16.0056	4.0017	….

Fig 1: Viscosity of NaCl at 303 K (Glycol+Water)

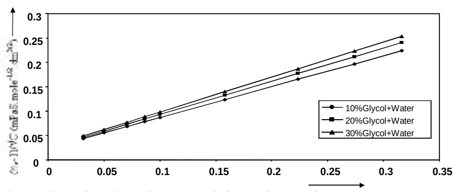


Fig 2: Viscosity of NaCl at 303 K (Glycerol+Water)

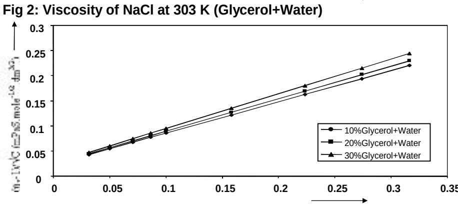


Fig 3: Apparent Molar Volume of NaCl at 303 K (Glycol+Water)

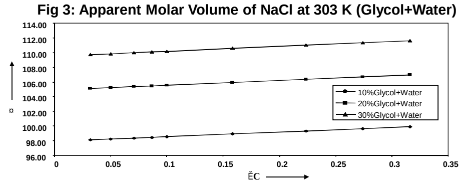


Fig 4: Apparent Molar Volume of NaCl at 303 K (Glycerol+Water)

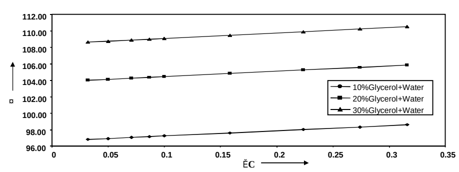


Fig 5: Ultrasonis Velocity of NaCl at 303 K (Glycol+Water)

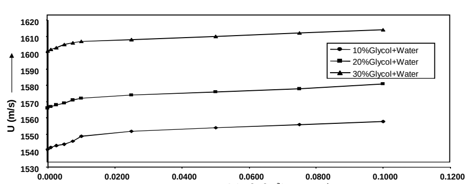


Fig 6: Ultrasonis Velocity of NaCl at 303 K (Glycerol+Water)

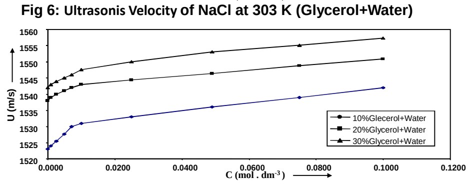


Fig 7: MOLAR SOUND VELOCITY (R), NaCl at 303 K (Glycol+Water)

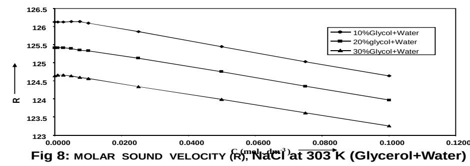


Fig 8: MOLAR SOUND VELOCITY (R), NaCl at 303 K (Glycerol+Water)

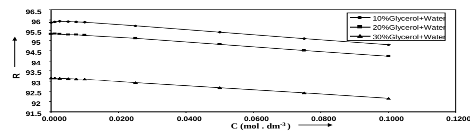


Fig 9: INTER MOLECULAR FREE LENGTH (L_f), NaCl at 303 K (Glycol+Water)

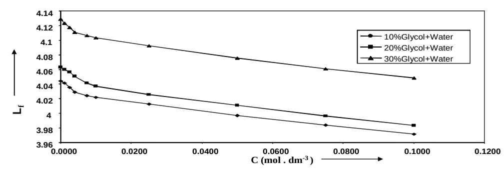


Fig 10: INTER MOLECULAR FREE LENGTH (L_f), NaCl at 303 K (Glycerol+Water)

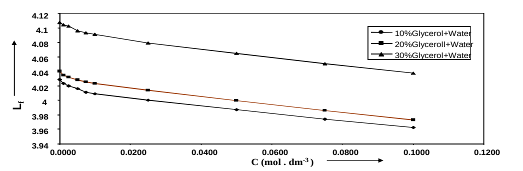


Fig 11: ACOUSTIC IMPEDANCE (Z), NaCl at 303 K (Glycol+Water)

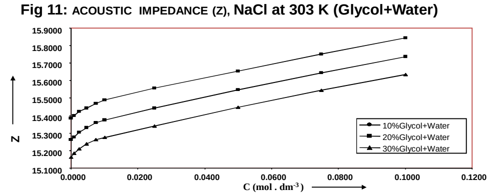
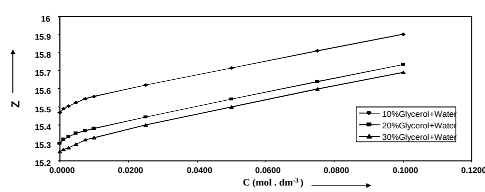


Fig 12: ACOUSTIC IMPEDANCE (Z), NaCl at 303 K (Glycerol+Water)



5. ACKNOWLEDGEMENT

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