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Ultrasonic studies of Some Transition Metal Acetates with Poly Ethylene Glycol at 303K

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ABSTRACT

Ultrasonic velocity, viscosity and density of solution containing transition metal acetates with poly (ethylene glycol) were determined at 303K. From the experimental values the acoustical parameters such as adiabatic compressibility (β), acoustic impedance (Z), free path length (L_f), Free Volume (V_f), Internal pressure (πi), Absorption Coefficient (α/f^2), Available Volume (V_a), Viscous Relaxation Time (τ)and Cohesive Energy (CE) have been computed. The trend in acoustical parameters with concentration identifies the strong interaction between the solute and solvent. The variations of these parameters with composition of the mixture suggest the strength of molecular interactions in these mixtures.

Keywords: Ultrasonic velocity, Intermolecular free length, and adiabatic compressibility

INTRODUCTION

Ultrasonic studies of liquid mixtures provide much information about their physicochemical properties. Measuring of ultrasonic velocity is used to characterizing thermodynamic and physicochemical behavior between the liquid mixtures. Using densities, viscosities and ultrasonic velocities, the acoustical parameter such as adiabatic compressibility (β), acoustic impedance (z) and free length (L_f) have been calculated. The variation of ultrasonic velocity and other acoustical properties used to elucidate the intermolecular interaction of liquid systems [1-4] and ionic interactions in electrolytic solutions [5-7].Ultrasonic technique is also useful to investigate the thermodynamic behaviour of binary mixture of Polyethylene Glycol + Ethanol[8]and Water and poly ethylene glycols (PEG 200 and PEG 400) [9]. The interaction of water with poly ethylene glycols has been studied by measuring the density of aqueous solutions of a series of poly ethylene glycols (PEGs) ranging in number average molecular weights from 106 to 5607[10].The ultrasonic studies were carried out in aqueous solution of polyethylene glycol at different temperatures [11]. Recently the nanotechnology is an interesting tool to prepare nanoparticles. Many researchers have synthesized Zinc oxide nanoparticle [12-14] from solution of certain zinc salts. Polyethylene glycol (PEG) is also used to prepare the zinc oxide nanoparticles. However researchers have not used the ultrasonic technique in this technology. At present study is done to analyse the interaction of transition metal acetate solutions of manganese, cobalt, nickel and zinc in polyethylene glycol. Nano particle such as ZnO is a white powder that is insoluble in water, and it is widely used in food industries, paints and pigments, ceramic, rubber industries, semiconductors etc. Polyethylene glycol is a condensation polymer and soluble in water and other organic solvent. Poly ethylene glycol is used to make emulsifying agents, detergents, soaps, plasticizers, ointments etc. Ultrasonic velocity (U), density (ρ) and viscosity (η) at room temperature and at different grams (2 to 16) have been experimentally carried out by the authors. Acoustical parameters such as adiabatic compressibility (β), Intermolecular free length (L_f) and acoustic impedance (Z) were calculated from the experimental data. The results were analyzed and it may be concluded that the molecular interactions between the solute and the solvent do exit.

EXPERIMENTAL SECTION

In the present study chemicals of metal acetates were used of analytical grade and supplied by Sigma Aldrich, Mumbai. Poly ethylene glycol 200 was purchased from E Merck Ltd. Mumbai. Manganese acetate, cobalt acetate, nickel acetate and zinc acetate were used to prepare the 0.6M salt solutions. Mixture of Poly ethylene glycol 200 and solutions of metal acetates were prepared as synthesis of zinc oxide nanoparticle [13 &24]. 10ml of metal salt solution with various grams of poly ethylene glycol (2g-16g). The densities of salt solution were measured using a specific gravity bottle. The ultrasonic velocity in the liquid mixtures has been measured using an Ultrasonic interferometer (F81, Research Model, Mittal Enterprises, New Delhi) working at 2 MHz frequency with accuracy ± 0.1 ms^{-1}. The density and viscosity are measured using a gravity bottle and an Ostwald's viscometer of accuracy of ± 0.1kgm-3 and ± 0.001mNsm^{-2} respectively.

THEORY AND CALCULATIONS

From the measured value of ultrasonic velocity, density and viscosity the acoustical parameters such as adiabatic compressibility (βa), acoustic impedance (z) and intermolecular free length (Lf) were calculated and evaluated by using the standard equation

The expression used to determine the Ultrasonic velocity is $U = f \lambda\ ms^{-1}$---------- (1)

The densities of the mixture were measured using the formula $\rho_2 = (w_2/w_1)\ \rho_1$---------- (2)

Where w_1 = weight of distilled water, w_2 = weight of experimental liquid, ρ_1 = Density of water, ρ_2 = Density of experimental liquid.

The viscosity was determined using the relation,

$\eta_2 = \eta_1\ (t_2/t_1)\ (\rho_2/\rho_1)$ ---------- (3)

Where η_1 = viscosity of water, η_2 = Viscosity of mixture, ρ_1 = Density of water, ρ_2 = Density of mixtures, t_1 = Time of flow of water, t_2 = Time of flow of mixture.

Using the measured data, acoustical parameters such as adiabatic compressibility (βa), acoustic impedance (z), intermolecular free length (L_f), Free Volume **(V_f) ,** Internal pressure (πi), Absorption Coefficient (α/f^2), Available Volume (Va) Viscous Relaxation Time (τ),and Cohesive Energy (CE)were calculated and evaluated by using the standard equation

Adiabatic Compressibility (β)

$(\beta a) = (1/U^2\rho)\ kg^{-1}ms^{-2}$ ---------- (4)

Acoustic Impedance (Z)

$Z == U\ \rho\ kg\ m^{-2}s^{-1}$---------- (5)

Free Length (L_f)

$L_f == (K/U\rho^{1/2})\ m$ ---------- (6)

Where, K is Jacobson's constant. This constant is a temperature dependent parameter whose value at any temperature (T) is given by (93.875 + 0.345T) X 108.

Free Volume (V_f)

$V_f == (M_{eff}\ U/k\eta)^{3/2}\ m^3$---------- (7)

Where, Meff is the effective molecular weight ($M_{eff} = \sum$ mi xi, in which mi and xi are the molecular weight and the mole fraction of the individual constituents respectively and k is a temperature independent constant equal to 4.28 x 10^9 for all liquids.

Internal pressure (πi)

On the basis of statistical thermodynamics, Suryanarayana derived an expression for the determination of internal pressure through use of concept of free volume

$\Pi i == bRT\ (k\Pi/U)^{1/2}\ (\rho^{2/3/}M_{eff})^{7/6}$---------- (8)

Where
T = is the absolute temperature
P = is the density and R is the gas constant.
M_{eff} = is the effective molecular weight.

Absorption Coefficient (a/f^2):
It can be calculated from the viscosity using the relation,

$a/f^2 = 8\pi^2\Pi/3\rho U^3$----------(9)

Viscous Relaxation Time (τ)
It is calculated using the relation,

$\tau = 4\Pi/\ 3\rho U^2$---------- (10)

Available Volume (Va):
It can be calculated from Schaff's relation

$V_a = V_m\ (1\text{-}U/U_a)\ m^3$---------- (11)

Where V_m is the molar volume and $U_a = 1600\ ms^{-1}$.
Cohesive Energy (CE):
It is usually given as a product of internal pressure (πi) and molar volume (V_m).

$CE = \pi_i\ V_m\ kJ\ mol^{-1}$---------- (12)

Viscous Relaxation Time (τ)
It is calculated using the relation,
$\tau = 4\Pi/\ 3\rho U^2$ ---------- (13)

RESULTS AND DISCUSSION

The experimentally measured values of ultrasonic velocity (u), density (ρ) and viscosity (η) of the electrolytic solutions and calculated values of acoustical parameters such as adiabatic compressibility (βa), acoustic impedance (z) and intermolecular free length (Lf), Free Volume **(V_f) ,** Internal pressure (πi), Absorption Coefficient (α/f^2), Available Volume (V_a) Viscous Relaxation Time (τ),and Cohesive Energy (CE) are reported in Table1-8 for the systems of Manganous acetate + PEG 200, Cobalt acetate+ PEG 200, Nickel acetate+ PEG 200 and zinc acetate + PEG 200 respectively. The graphs are plotted for ultrasonic velocity (u), adiabatic compressibility (βa), acoustic impedance (z) and intermolecular free length (L_f) in various mole fractions (corresponding to weight of PEG) are shown in fig.1 to fig 4.

Table-1 Ultrasonic velocities (U), densities (ρ), viscosities (η), adiabatic compressibility's (βa), acoustic impedance (Z) and intermolecular free length (L_f) in various mole fraction of manganous acetate + Poly ethylene glycol 200 at 303K

Mole Fraction of PEG	Velocity (U) ms^{-1}	Density (ρ) kgm^{-3}	Viscosity (η) $x10^{-3}$ $(Nm^{-2}s)$	Adiabatic compressibility $(\beta)/10^{-10}Kg^{-1}ms^{-2}$	Acoustic impedance (Z) $/10^6$ $Kgm^{-2}S^{-1}$	Int. mole. free length $(Lf)/10^{-11}m$
0.0135	1566	1036.16	12.7872	3.93541	1.62262	3.93603
0.0306	1614	1049.32	14.9856	3.65835	1.69360	3.79495
0.0532	1639	1071.12	20.3184	3.47539	1.75556	3.69884
0.0842	1675	1096.18	28.4328	3.25154	1.83610	3.57773
0.1297	1701	1111.85	36.187	3.10846	1.89125	3.49813
0.2023	1721	1119.06	48.2128	3.01707	1.92590	3.44632
0.337	1729	1126.67	64.0848	2.96902	1.94801	3.41877
0.673	1728	1153.42	107.52	2.90352	1.99311	3.38085

Table-2 Ultrasonic velocities (U), densities (ρ), viscosities (η), adiabatic compressibility's (βa), acoustic impedance (Z) and intermolecular free length (L_f) in various mole fractions of Cobalt acetate + Poly ethylene glycol 200 at 303K

Mole Fraction of PEG	Velocity(U) ms^{-1}	Density (ρ) kgm^{-3}	Viscosity (η) $x10^{-3}$ $(Nm^{-2}s)$	Adiabatic compressibility (β)/$10^{-10}Kg^{-1}ms^{-2}$	Acoustic impedance (Z) /10^6 $Kgm^{-2}S^{-1}$	Int. mole. free length (Lf)/10^{-11}m
0.0135	1569	1044.87	12.528	3.88769	1.639401	3.9121
0.0306	1606	1053.29	15.644	3.68096	1.691584	3.80666
0.0532	1639	1066.59	21.1976	3.49015	1.748141	3.70669
0.0842	1665	1078.21	28.459	3.34555	1.795220	3.62909
0.1297	1698	1090.33	42.852	3.18102	1.851380	3.53873
0.2023	1720	1104.78	62.7072	3.05962	1.900222	3.47054
0.337	1726	1119.17	94.2512	2.99932	1.931687	3.43617
0.673	1729	1139.46	134.3368	2.93569	1.970126	3.39953

Table-3 Ultrasonic velocities (U), densities (ρ), viscosities (η), adiabatic compressibility's (βa), acoustic impedance (Z) and intermolecular free length (L_f) in various mole fraction of Nickel acetate + Poly ethylene glycol 200 at 303K

Mole Fraction of PEG	Velocity(U) ms^{-1}	Density (ρ) kgm^{-3}	Viscosity (η) $x10^{-3}$ $(Nm^{-2}s)$	Adiabatic compressibility (β)/$10^{-10}Kg^{-1}ms^{-2}$	Acoustic impedance (Z) /10^6 $Kgm^{-2}S^{-1}$	Int. mole. free length (Lf)/10^{-11}m
0.0135	1566	1062.17	10.1224	3.83904	1.66335	3.88754
0.0306	1622	1078.22	15.5971	3.52526	1.74887	3.72528
0.0532	1640	1098.15	18.3704	3.38572	1.80096	3.65081
0.0842	1675	1111.72	25.7496	3.20608	1.86213	3.55264
0.1297	1698	1128.09	34.8068	3.07455	1.91549	3.479
0.2023	1715	1166.92	50.3712	2.9136	2.00126	3.38672
0.337	1725	1192.14	131.7602	2.819	2.05644	3.33128
0.673	1729	1231.73	170.2578	2.71578	2.12966	3.26972

Table-4 Ultrasonic velocities (U), densities (ρ), viscosities (η), adiabatic compressibility's (βa), acoustic impedance (Z) and intermolecular free length (L_f) in various mole fraction of Zinc acetate + Poly ethylene glycol 200 at 303K

Mole Fraction of PEG	Velocity(U) ms^{-1}	Density (ρ) kgm^{-3}	Viscosity (η) $x10^{-3}$ $(Nm^{-2}s)$	Adiabatic compressibility (β)/$10^{-10}Kg^{-1}ms^{-2}$	Acoustic impedance (Z) /10^6 $Kgm^{-2}S^{-1}$	Int. mole. free length (Lf)/10^{-11}m
0.0135	1550	1047.77	12.0968	3.97256	1.62404	3.95457
0.0306	1586	1055.38	15.7944	3.76691	1.67383	3.85084
0.0532	1638	1063.11	22.7176	3.50586	1.74137	3.71501
0.0842	1670	1072.51	30.1380	3.34323	1.79109	3.62783
0.1297	1684	1081.04	37.9276	3.26193	1.82047	3.58344
0.2023	1703	1089.26	50.902	3.16548	1.85501	3.53007
0.337	1704	1108.43	68.376	3.10708	1.88876	3.49736
0.673	1708	1119.69	93.228	3.06145	1.91243	3.47158

Table-5 Internal Pressure(Πi), Free Volume (V_f), Cohesive Energy(CE), available Volume (Va), Absorption Coefficient(a/f^2) and Relaxation Time(Ţ) of manganous acetate + Poly ethylene glycol 200 at 303K

Mole Fraction of PEG	Internal Pressure Πi $x10^7$ Pa	Free Volume $(V_f)x10^{10}m^3$ mol^{-1}	Cohesive Energy(CE) $kJmol^{-1}$	available Volume $Va/10^{-4}$ m^3	Absorption Coefficient(a/f^2) $X\ 10^{-10}Npm^{-1}s^{-2}$	Relaxation Time Ţ $x\ 10^{-8}s$
0.0135	8.1779	5.0878	1.7579	4.5678	0.8449	0.6709
0.0306	7.4635	5.1811	1.8233	-2.1376	0.8931	0.7309
0.0532	7.2588	4.2656	2.0375	-6.842	1.1133	0.9415
0.0842	6.9541	3.5116	2.2941	-15.464	1.4512	1.2327
0.1297	6.0735	3.4859	2.4636	-25.605	1.7387	1.4998
0.2023	5.0797	3.4833	2.6945	-40.114	2.2223	1.9395
0.337	3.8182	3.9778	2.9078	-61.4	2.8933	2.5369
0.673	2.582	4.304	3.3984	105.29	4.75	4.1625

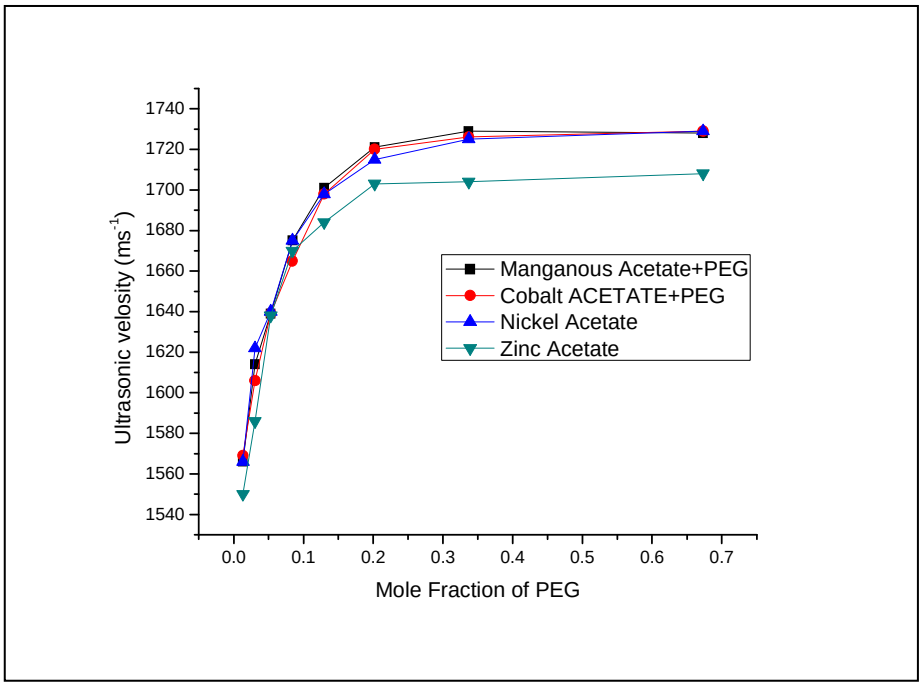

Fig.1- Ultrasonic velocity Versus Mole Fraction of polyethylene glycol

Table-6 Internal Pressure(Πi), Free Volume (V_f), Cohesive Energy(CE), available Volume (Va), Absorption Coefficient(a/f^2) and Relaxation Time(ζ) of Cobalt acetate + Poly ethylene glycol 200 at 303K

Mole Fraction of PEG	Internal Pressure $\Pi i x 10^7 Pa$	Free Volume (Vf)$x10^{10}m^3$ mol^{-1}	Cohesive Energy(CE) $kJmol^{-1}$	available Volume $Va/10^4m^3$	Absorption Coeffient(a/f^2) $X10^{-10}Npm^{-1}s^{-2}$	Relaxation Time ζ x 10^{-8}s
0.0135	8.1185	5.2729	1.7331	4.136	0.8161	0.6494
0.0306	7.6513	4.8317	1.8648	-0.9139	0.9427	0.7678
0.0532	7.3812	4.0114	2.0836	-6.8806	1.1868	0.9864
0.0842	6.8906	3.4826	2.3142	-13.644	1.5035	1.269
0.1297	6.519	2.7035	2.7001	-25.369	2.1107	1.8175
0.2023	5.7364	2.351	3.0863	-40.351	2.9328	2.5581
0.337	4.6067	2.2288	3.5365	-60.454	4.3062	3.7692
0.673	2.8575	3.0906	3.8121	-107.56	5.9971	5.2583

Table-7 Internal Pressure(Πi), Free Volume (V_f), Cohesive Energy(CE), available Volume (Va), Absorption Coefficient(a/f^2) and Relaxation Time(ζ) of Nickel acetate + Poly ethylene glycol 200 at 303K

Mole Fraction of PEG	Internal Pressure $\Pi i x10^7$ Pa	Free Volume (Vf) $x10^{10}m^3$ mol^{-1}	Cohesive Energy (CE) $kJmol^{-1}$	Available Volume $Va/10^{-4}$ m^3	Absorption Coefficient (a/f^2) $X10^{-10}Npm^{-1}s^{-2}$	Relaxation Time ζ x 10^{-8}s
0.0135	7.3881	5.9618	1.5847	4.4608	0.6544	0.5181
0.0306	7.7247	3.2719	1.9241	-3.273	0.8913	0.7331
0.0532	7.007	2.58 5	2.0656	-6.852	0.9971	0.8293
0.0842	6.6722	1.596	2.412	-15.263	1.2959	1.1007
0.1297	6.0125	1.0242	2.7754	-24.512	1.657	1.4269
0.2023	5.3422	0.5857	3.292	-36.598	2.2499	1.9568
0.337	5.685	0.1345	5.2634	-56.285	5.6613	4.9524
0.673	3.3897	0.0836	6.0079	-99.469	7.0313	6.1651

Table-8 Internal Pressure(Πi), Free Volume (V_f), Cohesive Energy(CE), available Volume (Va), Absorption Coefficient(a/f^2) and Relaxation Time(ζ) of Zinc acetate + Poly ethylene glycol 200 at 303K

Mole Fraction of PEG	Internal Pressure Πi x10^7 Pa	Free Volume (V_f) x$10^{10}m^3$ mol^{-1}	Cohesive Energy(CE) $kJmol^{-1}$	available Volume (Va) X$10^{-5}m^3$	Absorption Coefficient(a/f^2) X$10^{-10}Npm^{-1}s^{-2}$	Relaxation Time ζ x 10^{-8}s
0.0135	8.1427	5.3703	1.7200	6.5821	8.1537	0.6409
0.0306	7.8187	4.6011	1.8800	2.1061	9.8041	0.7885
0.0532	7.7505	3.5567	2.1700	-6.6571	1.2887	1.0704
0.0842	7.1356	3.1612	2.3800	14.6212	1.5843	1.3417
0.1297	6.1938	3.1585	2.5600	21.7116	1.9302	1.6483
0.2023	5.2054	3.12	2.8100	34.7795	2.4875	2.1483
0.337	3.9697	3.4865	3.0400	49.8894	3.2792	2.8336
0.673	2.3939	5.1728	3.2200	90.7521	4.3922	3.8043

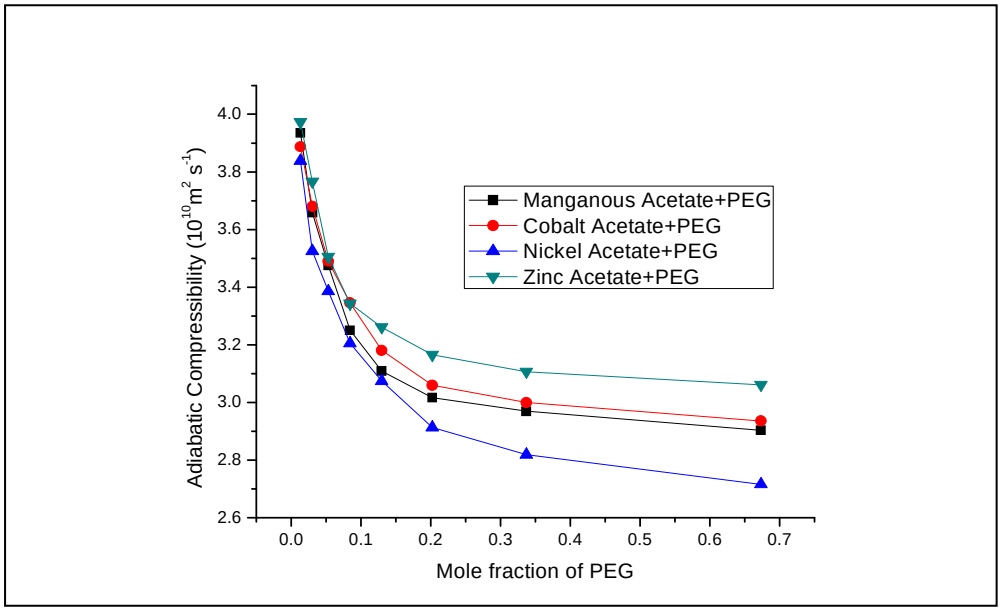

Fig.2-Adiabatic Compressibility Versus Mole Fraction of polyethylene glycol

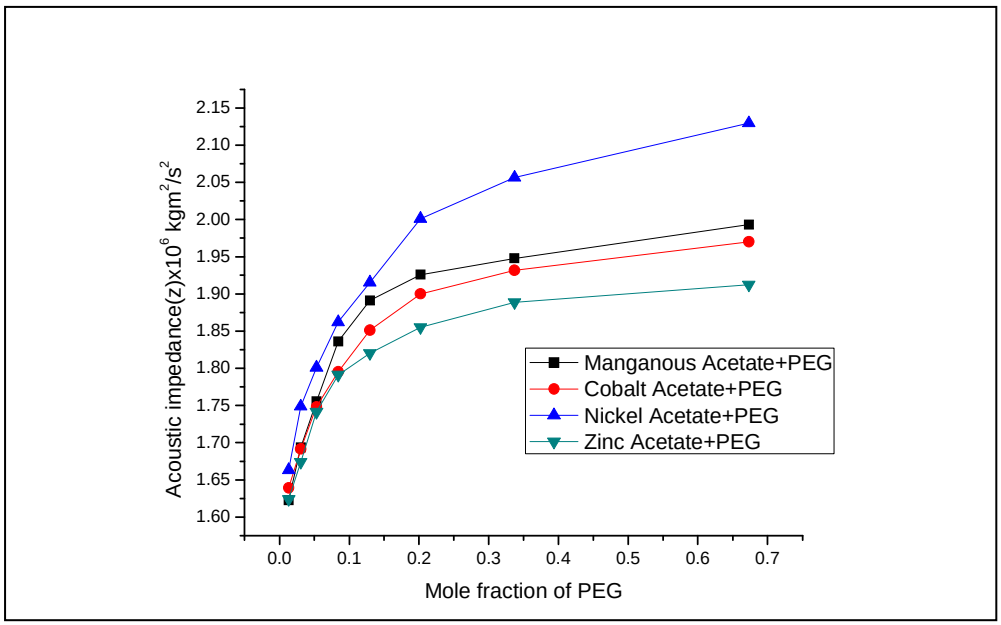

Fig.3- Acoustic impedance Versus Mole Fraction of polyethylene glycol

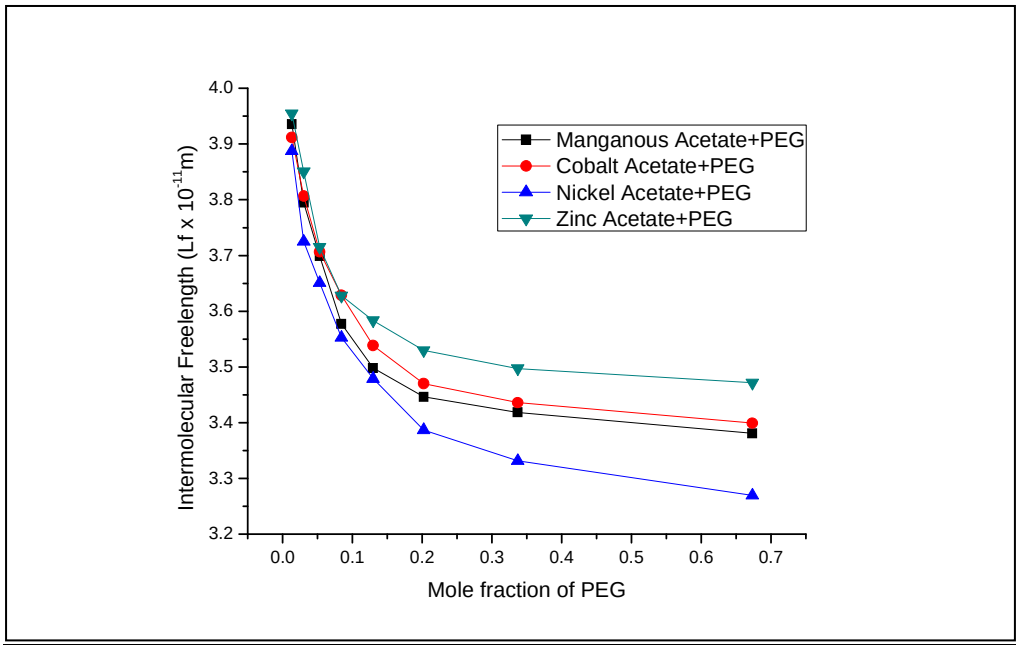

Fig.4- Intermolecular free length Versus Mole Fraction of polyethylene glycol

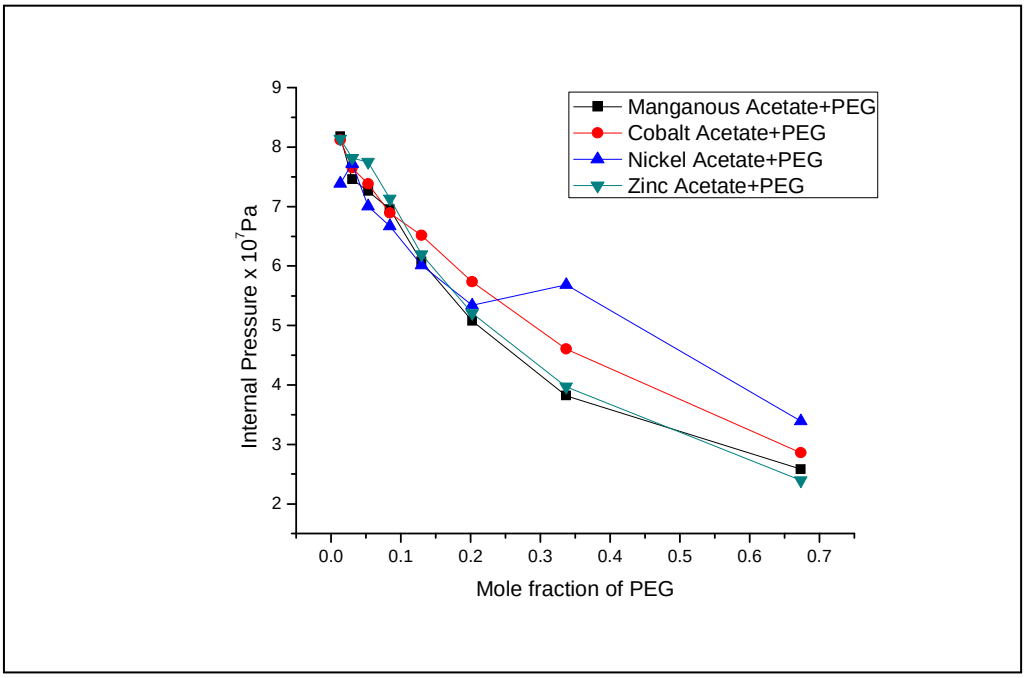

Fig.5- Internal pressure Versus Mole Fraction of polyethylene glycol

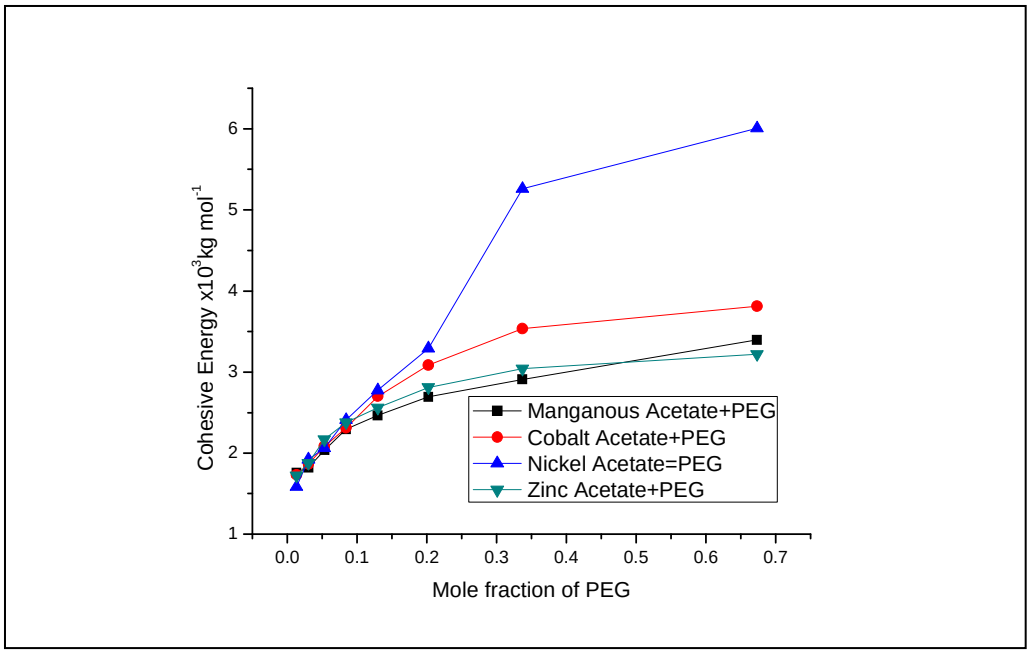

Fig.6- Cohesive Energy Versus Mole Fraction of polyethylene glycol

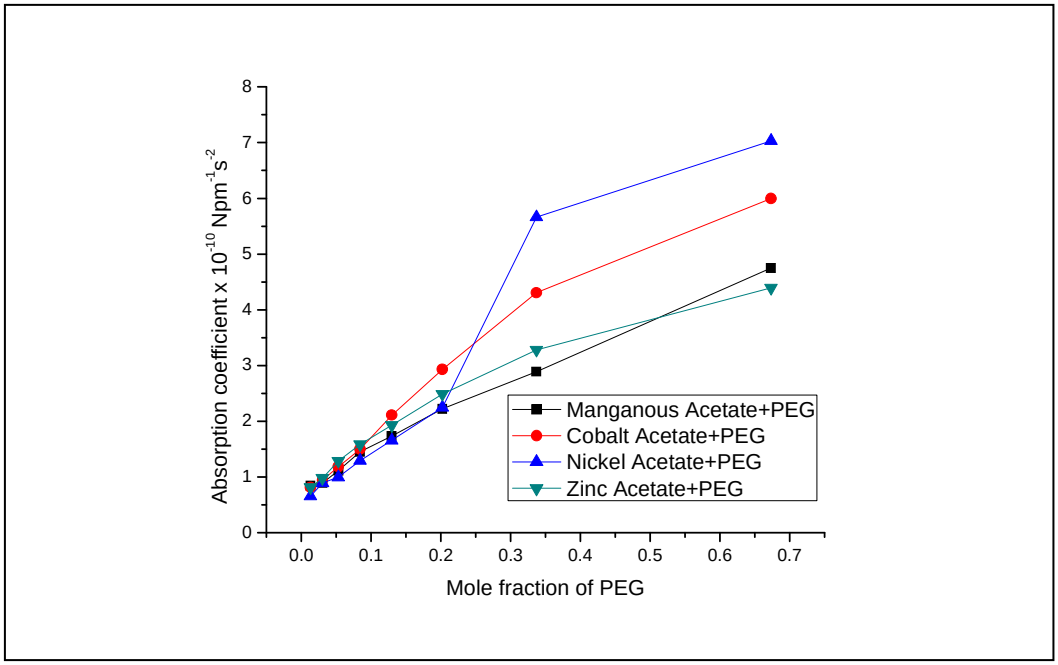

Fig. 7-Absorption Co-efficient Versus Mole Fraction of polyethylene glycol

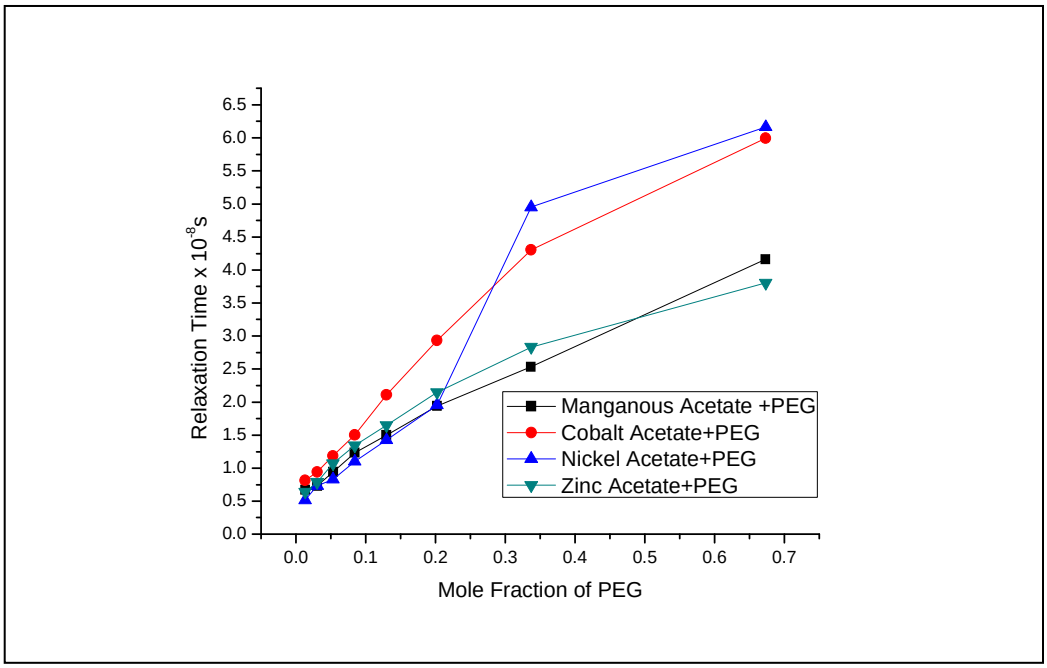

Fig.8- Relaxation Time Versus Mole fraction of Poly ethylene glycol

Table 1,2, 3 and 4 shows the measured values and the derived acoustical parameters such as adiabatic compressibility(β), acoustic impedance(z) and intermolecular free length(Lf) for the systems of Manganous acetate + PEG 200, Cobalt acetate+ PEG 200, Nickel acetate+ PEG 200 and zinc acetate + PEG 200 at 303K. When the co-sphere of both of molecules of metal acetates and poly ethylene glycol overlap/interact due to their proximity caused by van der waals, hydrogen bonding or electrostatic interactions, some of the co- spherical molecular structures are displaced/distorted or disrupted, causing changes in parameters[18].

Ultrasonic velocity increases with increase in concentration of PEG. Variation of ultrasonic velocity is in aqueous solution of metal acetates in polyethylene glycol depends upon the increase or decrease of intermolecular free length (L_f). The increase in velocity (fig.1) with concentrations suggests the increase in cohesive forces due to polymer-solvent interactions [20].Mole Fraction after 0.337M (Weight of poly ethylene glycol after 14gram) the ultrasonic values slightly increases in all the systems except zinc acetate –poly ethylene system. This indicates at 0.337 M may be strong interaction between the solute and solvent or may be form the nano particle of metal oxide at mole fraction 0.2023M(12gram) in zinc system may indicate formation of zinc oxide [12]. The density and viscosity values also occur in the same trend with velocity in the all systems due to the strong interaction of solutions.

From the Tables 1- 4 and fig .2, it is observed that adiabatic compressibility (βa) decreases with increase in mole fraction of poly ethylene glycol. This increase in structural order of metal acetates and poly ethylene glycol may result in more cohesion, and leads to a decrease in βa. The decrease in βa results in an increase in the value of U. the change in the adiabatic compressibility (βa) in the mixture of solution indicates there is contraction on mixing and the variation is may be due to formation of complex or nano material.[19].The reverse trend occurs in the acoustic impedance (Z) with increase weight of poly ethylene glycol in all the systems are shown in Table1-4 and fig.3.The increase in acoustic impedance with increase in concentration metal salt solution indicate solute-solvent interaction increase[21]. The calculated other parameter of intermolecular free length (L_f) is important parameter to access the molecular interactions between the molecules. Intermolecular free length decreases with increase in the concentration of polyethylene glycol with metal acetate solution. According to the Eyring and Kincaid model[17], ultrasonic velocity varies inversely with the intermolecular free length in the liquid mixtures. In the present investigation, the positive values of intermolecular free length of PEG with metal acetate solutions are found to decrease with respect to the various concentrations and increase and are given fig.4. Decrease in free length is due to compression of liquid which indicates that the molecules are coming closer to each other; hence the intermolecular cohesion is stronger leading to strong molecular association[22].

The values of Free Volume (V_f), Internal pressure (πi), Absorption Coefficient (a/f^2), Available Volume (Va) Viscous Relaxation Time (τ), and Cohesive Energy (CE) are given in Table 5-8 and fig. 5-9. The increase in cohesive energy with increase in mole fraction of poly ethylene glycol indicates the interaction between metal salt solutions and poly ethylene glycol. Fig.6-8 shows a strong interaction for cobalt and nickel solutions than other

metal solutions. The same trend occurs in the case of absorption coefficient and relaxation time values indicate solute-solvent interaction between the molecules. The internal pressure provides the information. The calculated internal pressure values are shown in Table 5-8. The decrease in internal pressure value indicates the higher repulsive force created between the molecule also in increase in mole fraction of poly ethylene glycol indicates the weak ionic –induced interaction between the solute –solvent molecule[23-31].

The structures of solvent and solute are changed in solution due to interactions, provides variation in their properties. The interaction is not responsible only for molecular structure and also due to dipole-dipole, solute-solvent, solvent-solvent, and charge transfer and or complex formation. The ultrasonic velocity values depend on the weight of polyethylene glycol for manganese, cobalt, nickel and zinc ions. At higher concentration in terms of mole fraction of poly ethylene glycol the ultrasonic velocity values are same for manganese, cobalt and nickel systems indicating strong molecular interaction indicates the nanomaterial formation. In zinc system the molecular interaction occurs at slightly lower concentration of polyethylene glycol due to nanoparticle formation.

CONCLUSION

Ultrasonic investigations of transition metal acetates in poly ethylene glycol solutions have been carried out at wide range of concentrations. The association of polyethylene glycol with transition metal acetates due to the strong interaction between solute –solvent depends on the increase in the ultrasonic velocity and other acoustical parameters such as adiabatic compressibility (βa), Intermolecular free length (L_f) and acoustic impedance (Z). In all systems the interactions occur at higher concentration of poly ethylene glycol. It may be because of polymer molecules come close to the solute molecules. However in zinc acetate-poly ethylene glycol system the interaction occurs at slightly low concentration than other systems.

REFERENCES

[1]R. K. Gupta, I. D. Gaba, C. P. Pande, Y. P. Singh and R. P. Singh, in *Polyimides*, Plenum Press, New York, **1987**, 1, 547–554.
[2]S. Krause, in *Polymer Blends*, D. R. Paul and N. Seymour, Eds., Academic Press, New York, 1978
[3]K. K. Chee, *Eur. Polym. J.*, ***1990***, 26**,** 423
[4]Z. Sun, W. Wang, and Z. Fung, *Eur. Polym. J.*, ***1992***, 28**,** 1259
[5]Y. P. Singh and R. P. Singh, *Eur. Polym. J.*, ***1984***, 20**,** 201
[6]Y. P. Singh and R. P. Singh, *Eur. Polym. J.*, ***1983,*** 19**,** 535
[7]R. Paladhi and R. P. Singh, *J. Appl. Polym. Sci.*, ***1994***, 51**,** 1559
[8]R. Paladhi and R. P. Singh, *Eur. Polym. J.*, ***1994***, 30**,** 251
A.Varada Rajulu, R. Lakshminarayana Reddy,and R. N. V. Ranga Reddy, *Acustica*,***1997***,83**,**
[9]Varada Rajulu and P. Mabu Sab, *Eur. Polym. J.*, ***1996,*** 32**,** 257
[10]Varada Rajulu and P. Mabu Sab, *Eur. Polym. J.*, **(1998)**34**,** 31
[11]Aneesh P. M., Vanaja K. A. and Jayaraj M. K., **2007**. Nanophotonic Martials IV, *Proc. of SPIE*, 6639 66390J 1-9
[12]Hsieh C-H, **2007**. *J. of the Chinese Chemical Society*, 54, 31-34
[13]Hai Y. X., Hao W., Yong C. Z, and et al, *Ceramics International*, **2004**, 30, 93-97
[14]Husnu E.U., Pritesh H., Nalin R., et.al, **2008** , 19, 255608, 1-5
[15]Swain, B., Mishra, R.N. and Dash, U.N. 2016. *J. Pure Appl. Ultrason*. 38(1): 14-22.
[16]Eyring H & Kincaid J F, *J Chem Phys***, 1938**, 6, 620.
A.P. Mishra, *Ind. J. Chem*. **2004**, 43A, 730
[17]K. Mohankrishnan, K. Rambabu, D. Ramachardran and G.K. Raman, *Phys. Chem. Liq* (UK), **1995**, 29:257
[18]A.Sadasivarao, Vijayakumar Naidu and Chawdoji Rao, *Journ. Acoust Ind*, **2000**, 28, 303
[19]Palani. R, Geetha. A, and Rabindra Kumara Swara, *Rasayan J. Chem*, **2009**, 2, 602
[20]V. Karthikeyan and Palaniappan, Ind. J. Phys. **2005**, 79, 153
[21]S.Ravichandran and K.Ramanathan, *Rasayan J. Chem*, **2010**, 2, 375-384
[22]Abdullah M, Okuyama K *(***2004***) PROC ITB Eng.* Sci 36*:*141–153*. 14.*
[23]Suryanarayana, C.V., *Indian J. Pure & Appl. Phys*., **1989**, 27, 751.
[24]Suryanarayana, C.V. and Kuppusamy, J., J. Acoust. Soc. India, IX (**1981**)
[25]S.K. Mehta, Rajni Jain, Shweta Sharma, K.K. Bhasin, *J. of Molecular Liquids*, **2005**,122, 15-20
[26]V. K. Syal, Anita Chauhan and Suvarcha Chauhan, *J. Pure and Applied Ultrasonics*, **2005**, 27, 61-69,
[27]G. J. Price, P.J. West, P.F. Smith, *Ultrason. Sonochem.* **1994**, 1(1)51
[28]U.D. Harkal, P.R. Gogate, A.B. Pandit and M.A. Shenoy, Ultrason. Sonochem. **2006**, 13, 423- 428
[29]S.C. Bhatt, H. K. Semwal, V. Lingwal, K. Singh and B.S. Semwal, *J. Acous. Soc. India*, **2000**, 2 (8), 293-296