International Journal of Basic and Applied Chemical Sciences ISSN: 2277-2073 (Online)
An Online International Journal Available at http://www.cibtech.org/jcs.htm
2012 Vol. 2 (1) April-June, pp.63-73/Baluja and Kachhadia
Research Article

DENSITY, VISCOSITY AND SPEED OF SOUND IN SOLUTIONS OF SOME IMIDAZOLINONE DERIVATIVES IN DMSO AT 308.15 K

***Shipra Baluja and Nikunj Kachhadia**
Physical Chemistry Laboratory, Department of Chemistry, Saurashtra University, Rajkot-360005, (Gujarat), India
**Author for Correspondence*

ABSTRACT
Density, ultrasonic velocity and viscosity of imidazolinone derivatives have been measured in dimethyl sulfoxide (DMSO) at 308.15 K over the wide range of concentration. From these experimental data, various acoustical parameters such as acoustic impedance (Z) isentropic compressibility (κ_s), intermolecular length (L_f) relaxation strength (r), Rao's molar sound function (R_m), Vander Waal's constant (b), molar compressibility (W), internal pressure (π), free volume (V_f), relative association (R_A), solvation number (S_n), apparent molar volume (Φ_v), apparent molar compressibility (Φ_k) etc. have been evaluated to study the molecular interactions occurring in these solutions. It is observed that both solute-solute and solute-solvent interactions exist in the studied systems.

Key Words: *Imidazolinone Derivatives, Density, Viscosity, Speed of Sound, DMSO,*

INTRODUCTION
Ultrasonic investigations find extensive applications in characterizing aspects of thermodynamics and physico chemical behavior of solutions of organic compounds (Varma *et al.*, 1991; Hakin *et al.*, 1994; Rajkotia and Parsania, 1998; Naidu and Prasad, 2005; Guler *et al.*, 2007; Kushare *et al.*, 2007). The measurement of ultrasonic speed enables to accurate determination of some useful parameters, which are highly sensitive to molecular interactions (Ogawa *et al.*, 1984; Mishra *et al.*, 1997; Meshram *et al.*, 2001**;** Kirnapure *et al.*, 2007) In the last few years, our investigation groups have carried out some studies on acoustical properties of organic compounds in various solvents (Baluja and Parsania, 1995; Baluja, 2002; Baluja and Oza, 2003; Baluja and Shah, 2004; Baluja *et al.*, 2005; Baluja and Shah, 2006). In continuation of these investigations, in the present study, we have selected some imidazolinone derivatives.

Literature survey shows that imidazolinone derivatives have broad biological spectrum. Many imidazolinone compounds are known to be potent herbicides (Forlani *et al.*, 1995; Ladner 2006). Some of imidazolinone derivatives are known to have anti-convulsant (Josh *et al.*, 2003), antimicrobial (Szymaoska *et al.*, 2002), CNS depressant activity (Heindel *et al.*, 2006) and antihypertensive activity (Ismail *et al.*, 2000). So, it was of our interest to study the interactions of these compounds in different solvents in different concentrations, which may be useful for their applications.

Thus, the present paper reports acoustical properties of imidazolinone derivatives in DMSO over a wide concentration range at 308.15K. The results are interpreted in terms of molecular interactions occurring in the solution.

MATERIALS AND METHODS
Theory
Various acoustical parameters were calculated using following standard equations using experimental data of density, viscosity and ultrasound velocity of pure solvent and solutions.

Acoustic impedance (Z): $Z = \rho U$ …..(1)
Where ρ is the density and U is the ultrasonic velocity of solution.

Isentropic compressibility (κ_S): $\kappa_S = 1/ (U^2\rho)$ …..(2)

Intermolecular length (L_f): $L_f = K_J \kappa_S^{1/2}$ .....(3)
Where K_J is Jacobson constant (= 2.0965×10^{-6}).

Relaxation Strength (r): $r = 1- (U/U_\infty)^2$ .....(4)

Where U_∞ = 1600 m/s.

Rao's molar sound function (R_m): $R_m = (M/\rho)U^{1/3}$ .....(5)
Where M is the molecular weight of solution.

Van der Waal's Constant (b): $b = (M/\rho)\ (1-RT/MU^2\ (\sqrt{(1+MU^2/3RT)-1))}$.....(6)
Where R is gas constant and T is absolute temperature.

Molar Compressibility (W): $W = (M/\rho)\ \kappa_S^{-1/7}$ .....(7)
Internal pressure (π): $\pi = P_f RT\ [K\eta/U]^{1/2}\rho^{2/3}/M^{7/6}$ .....(8)
Where P_f is the packing factor (= 2) and K is a constant (= 4.28×10^9) and η is viscosity of solutions
Free volume (V_f): $V_f = [MU/K\eta]^{3/2}$ .....(9)
Relative Association (R_A): $R_A = \rho/\rho_0\ (U_0/U)^{1/3}$ .....(10)
Where ρ and ρ_o are the densities of solutions and solvent respectively.
Solvation number (S_n): $S_n = M_2/M_1\ [1- \kappa_S / \kappa_{S1}]\ [(100- X) /X]$ .....(11)
Where X is the number of grams of solute in 100 gm of the solution. M_1 and M_2 are the molecular weights and κ_{S1} and κ_S are isentropic compressibility of solvent and solute respectively.
Apparent Molar Volume (ϕ_V): $\phi_V = [M/\rho]-[(1000\{\rho-\rho_o\})/(\rho C)]$.....(12)
C is the concentration of the solution in molarity.
Apparent Molar Compressibility (ϕ_k): $\phi_k=[(\rho_o\kappa_S-\rho\kappa_{S1})\ (1000/C\rho_o)] + [\kappa_{S1}\ M_2/\rho_o]$
..... (13)
Where M_2 is the molecular weight of the solute.

Experimental

The DMSO used in the present work were of AR grade and were purified according to the standard procedure (Riddick *et al.,* 1986). The purity of DMSO was checked by GC-MS and was found to be more than 99.97%. The compounds were recrystallized before use. The purity of compounds was checked by CHN analysis, IR, NMR and mass spectral data. The structures of all the compounds are given in Figure 1 along with their codes.

The solutions of all the synthesized compounds in DMSO were prepared in the concentration range 0.01 to 0.1M. The Mettler Toledo balance (Model No. AB 204-S) was used for the preparation of solutions.

The computation of ultrasonic and thermodynamic properties requires the measurements of ultrasonic velocity, viscosity and density.

The densities (ρ) of pure solvents and their solutions were measured by using a single capillary pycnometer, made of borosil glass having a bulb capacity of 10 ml. The ultrasonic velocity (U) of pure solvents and their solutions were measured by using single crystal variable path ultrasonic interferometer operating at 2 MHz. The accuracy of density and velocity are ± 0.0001 g/cm^3 and ± 0.1% cm/sec respectively. The viscosity (η) of pure solvents and solutions were measured by an Ubbelohde viscometer with an accuracy of 0.05%. All the measurements were carried out at 308.15 K. The temperature was maintained by digital controller NOVA thermostatic bath (Model: NV-8550-E). The uncertainty of temperature is ± 0.1 K and that of concentration is 0.0001 moles /dm^3.

RESULTS AND DISCUSSION

Table 1 shows density, viscosity and some other acoustical parameters of pure solvent and solutions of imidazolinone derivatives at 308.15K. Figure 2 shows the variation of ultrasonic velocity U with concentration. It is observed that density, viscosity and ultrasonic velocity (U) increases with concentration for all the compounds. The ultrasonic velocity depends on intermolecular free length (L_f). The velocity increases with decreases in L_f or vice versa (Koul *et al.,* 1985). Table 1 show that L_f

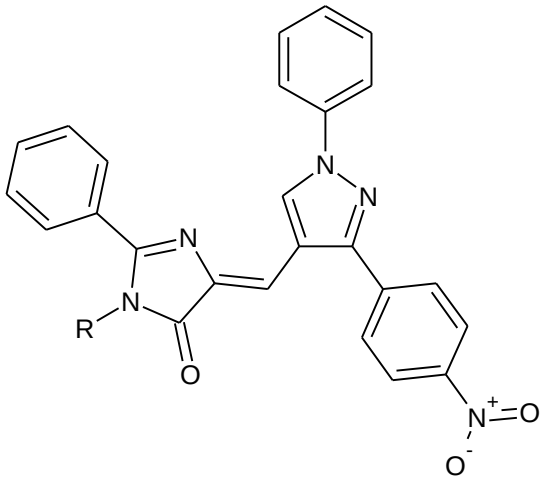


Figure 1: General structure of Imidazolinone derivative

Where R is:
PAIM-1: 4-CH_3-C_6H_4-
PAIM-2: 4-OCH_3-C_6H_4-
PAIM-3: 2-OCH_3-C_6H_4-
PAIM-4: $C_{10}H_7$-
PAIM-5: 4-F-C_6H_4-
PAIM-6: 4-Cl-C_6H_4-
PAIM-7: C_6H_5-
PAIM-8: 3-Cl-4-F-C_6H_3-
PAIM-9: 2,5-di-Cl-C_6H_3-

decreases continuously which suggests that there is strong interaction between DMSO and compound molecules (Abraham *et al.*, 2000).
This is further supported by isentropic compressibility (κ_s), which are also observed to decrease with concentration for all the compounds (as shown in Figure 3).

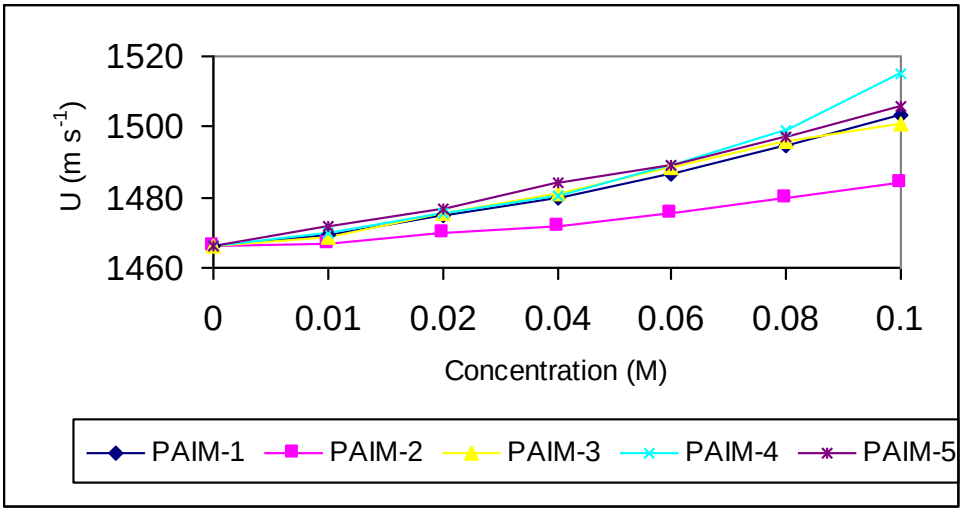


Figure 2: Variation of ultrasonic velocity (U) with concentration of imidazolinone derivatives in DMSO at 308.15K.

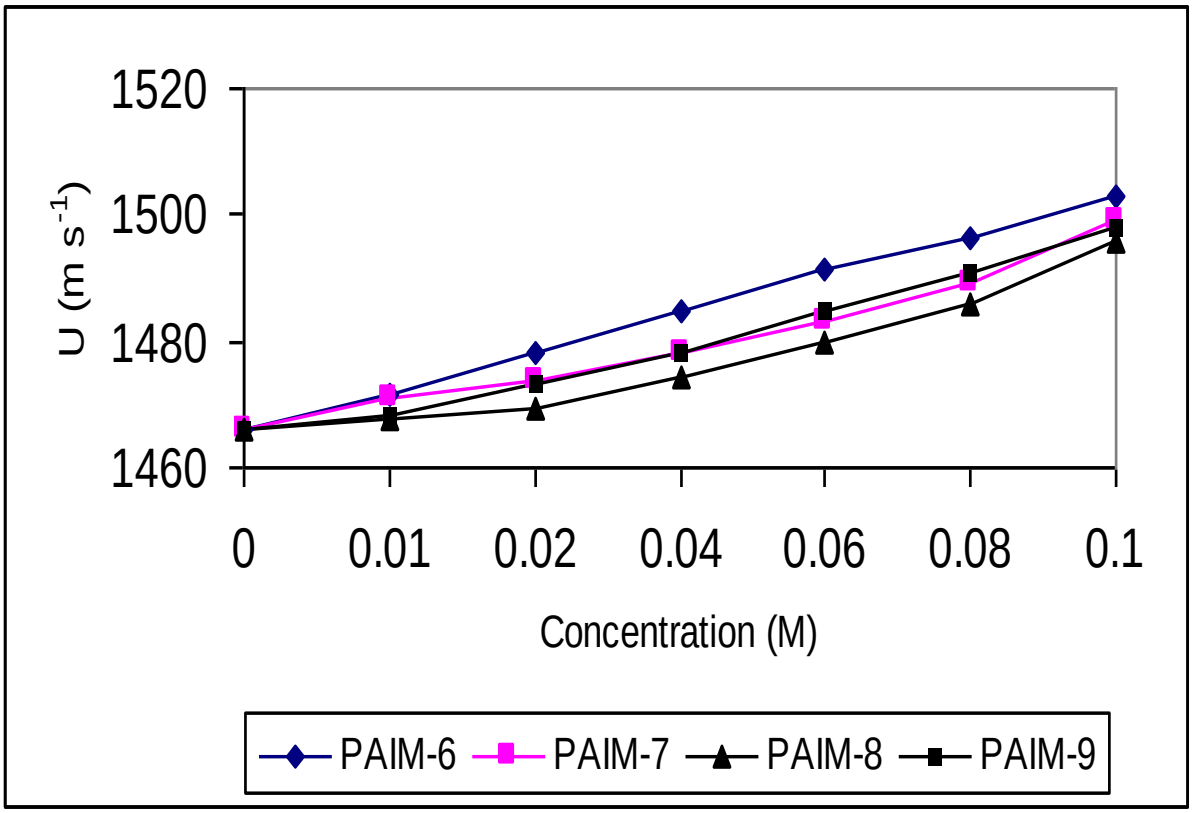
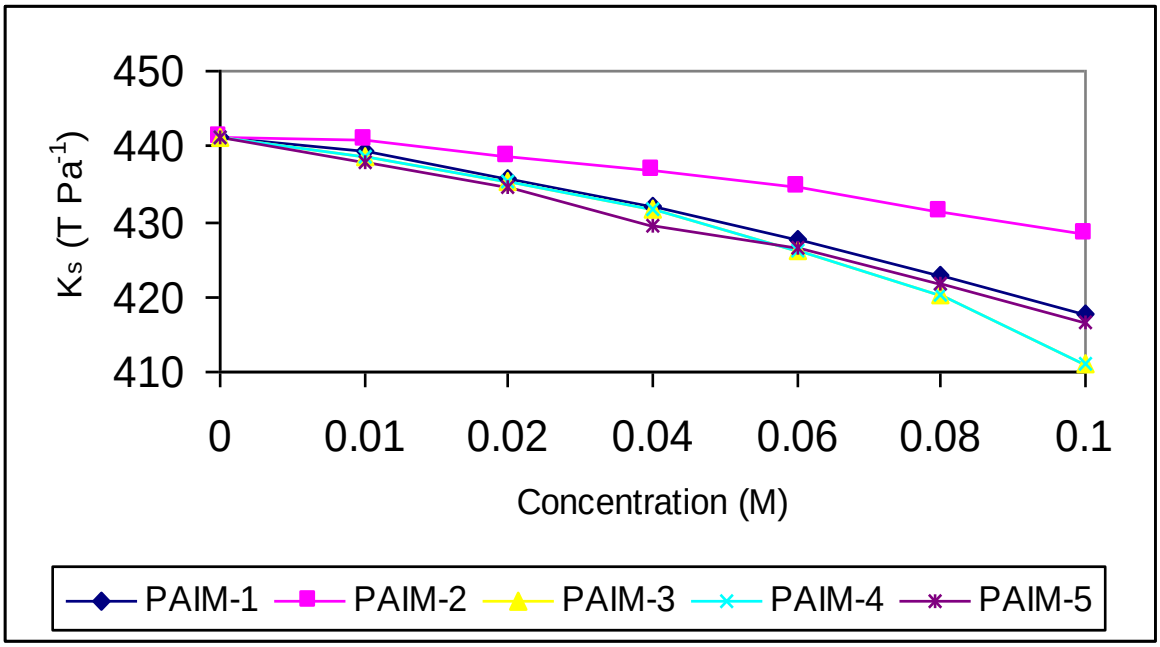


Figure 3: Variation of isentropic compressibility (κ_s) with concentration of imidazolinone derivatives in DMSO at 308.15K.



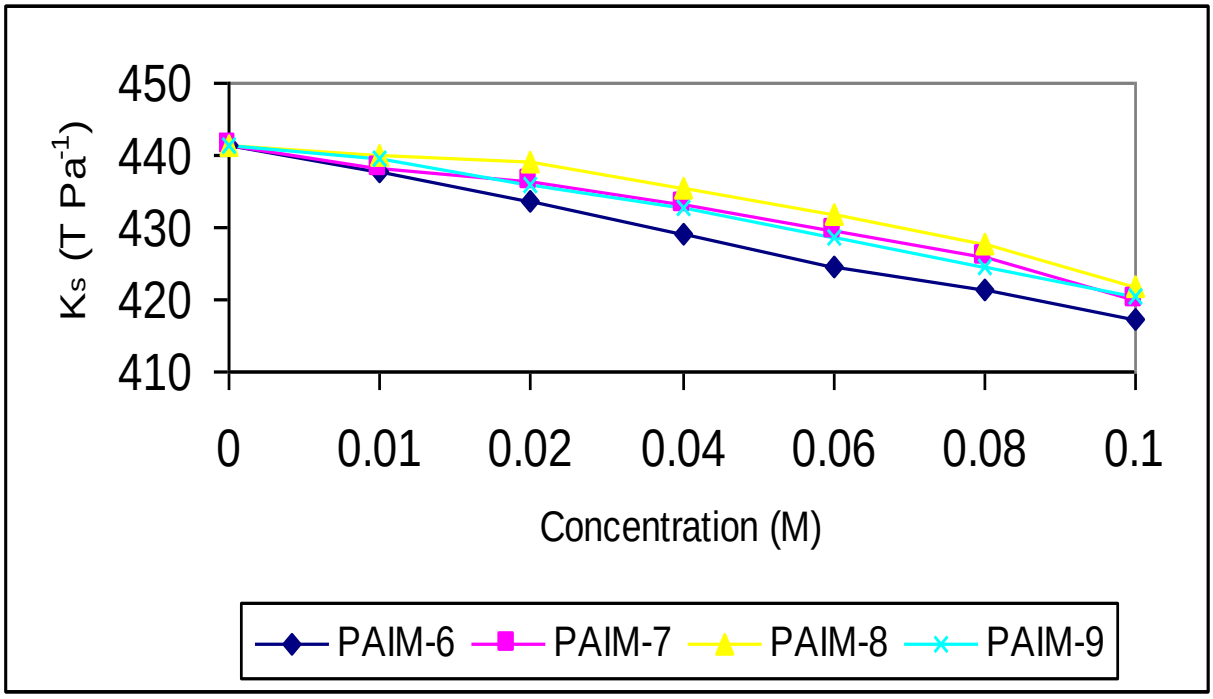
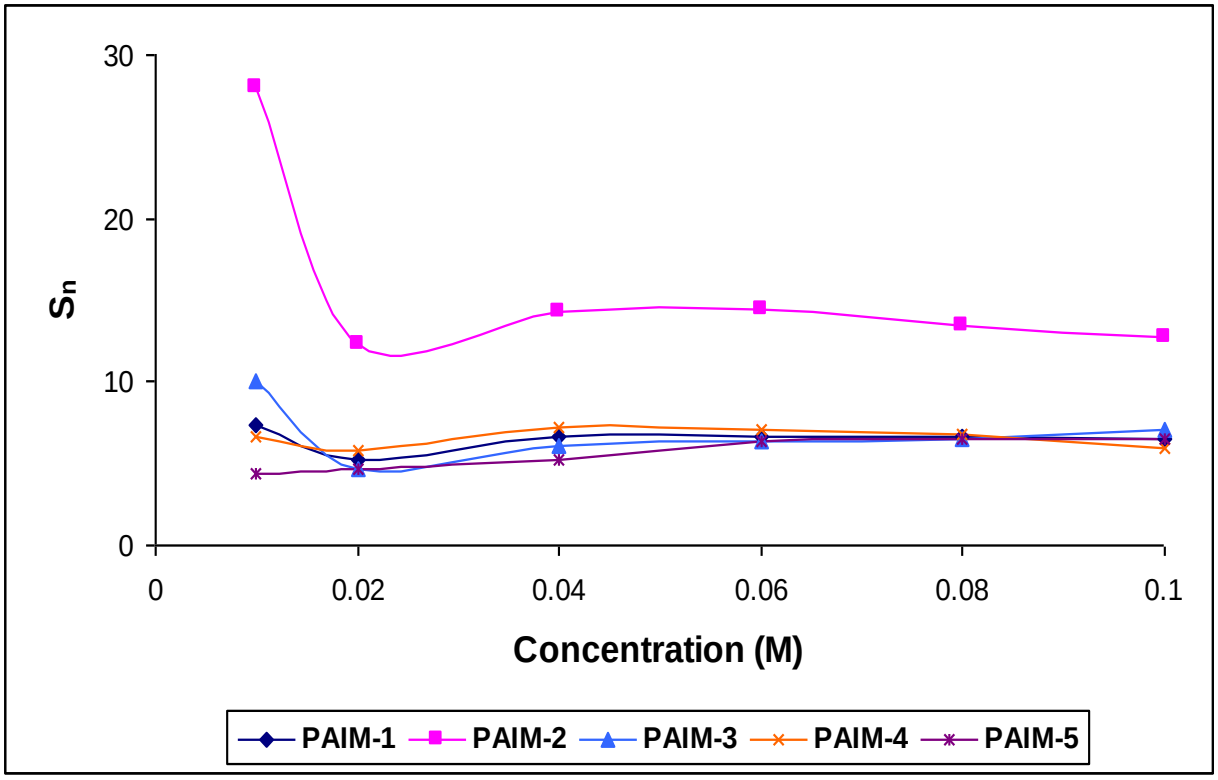
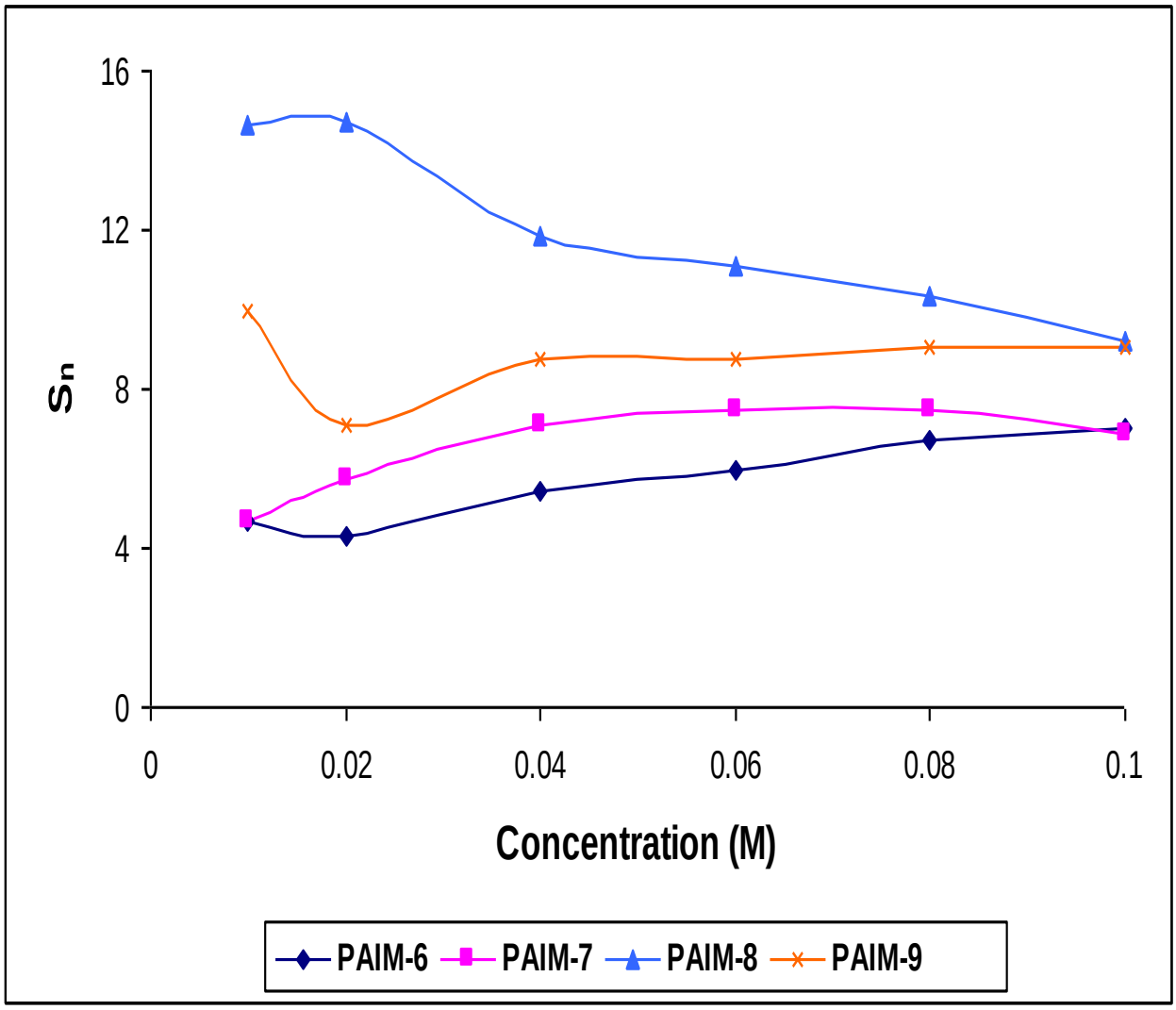


Figure 3 4: Variation of solvation number (S_n) with concentration of imidazolinone derivatives in DMSO at 308.15K.



The decrease of κ_s with increasing concentration might be due to aggregation of solvent molecules around solute molecules thereby indicating the presence of solute-solvent interactions (Jayakumar *et al.*, 1998; Eyring and Kincaid, 1932; Suryanaraana and Kuppuswamy, 1981; Nath and Rashmi, 1990; Ali and Nain, 1997; Roy *et al.*, 2007). The decrease of relaxation strength (r) and increase of acoustical impedance (Z) in Table 1 further confirms the solute-solvent interactions in these systems (Syal *et al.*, 1995).
Properties like Rao's molar sound function (R_m), molar compressibility (W) and Van der Waal's constant (b) are observed to increase linearly (correlation coefficient, γ = 0.9999 – 1.0000) with concentration for all the compounds. The linear variation of these acoustical properties indicates absence of complex formation (Wanchoo, 1987).



The internal pressure (π) is the results of forces of attraction and repulsion between the molecules in a solution. Table 1 show that internal pressure decreases with concentration, which indicates the decrease in cohesive forces (Naidu and Prasad, 2005). Although decrease in compressibility (κ_s), intermolecular free length (L_f), relaxation strength (r) and increase of velocity (U), viscosity (η) suggest predominance of

Table 1: Some acoustical parameters of imidazolinone derivatives in DMSO at 308.15K.

Conc. M	Density 10^{-3} kg.m^{-3}	Viscosity x 10^3 Pas	Z.10^{-6} kg.m^{-2} s^{-1}	L_f. 10^2 m	r	π.10^6 Pas	V_f.10^2 m	R_A	R_m10^4 $^{10/3}$s$^{-1/3}$ mol^{-1}	W 10^3 m^3 Pas$^{-8/7}$ mol^{-1}	b 10^5 m^{3}mol^{-1}
PAIM-1											
0.00	1.0546	10.6786	1.5460	0.4040	0.1605	580.2555	0.1255	1.0000	3.9064	2.2339	7.4083
0.01	1.0548	10.8684	1.5497	0.4030	0.1568	565.9824	0.1279	0.9995	4.0197	2.2986	7.6177
0.02	1.0556	11.0201	1.5568	0.4014	0.1504	551.3063	0.1312	0.9990	4.1330	2.3631	7.8224
0.04	1.0569	11.2149	1.5638	0.3998	0.1448	522.8142	0.1389	0.9991	4.3542	2.4897	8.2323
0.06	1.0578	11.3297	1.5727	0.3977	0.1365	494.9934	0.1484	0.9983	4.5793	2.6181	8.6439
0.08	1.0585	11.5119	1.5822	0.3954	0.1272	471.1396	0.1568	0.9972	4.8063	2.7475	9.0562
0.10	1.0593	11.6860	1.5928	0.3930	0.1169	449.2968	0.1655	0.9960	5.0338	2.8770	9.4662
PAIM-2											
0.01	1.0548	11.4230	1.5472	0.4037	0.1596	579.3780	0.1187	1.0000	4.0255	2.3021	7.6329
0.02	1.0556	11.4607	1.5513	0.4028	0.1564	560.6900	0.1238	1.0001	4.1440	2.3698	7.8526
0.04	1.0568	11.7311	1.5556	0.4019	0.1536	531.5112	0.1303	1.0007	4.3790	2.5045	8.2934
0.06	1.0576	11.8204	1.5602	0.4009	0.1499	501.3955	0.1398	1.0008	4.6160	2.6400	8.7359
0.08	1.0587	11.9286	1.5665	0.3995	0.1448	474.7798	0.1493	1.0008	4.8524	2.7752	9.1741
0.10	1.0596	12.0699	1.5729	0.3980	0.1393	451.3386	0.1583	1.0006	5.0898	2.9109	9.6127
PAIM-3											
0.01	1.0547	10.9877	1.5487	0.4033	0.1577	569.1968	0.1257	0.9995	4.0194	2.2984	7.6185
0.02	1.0560	11.1123	1.5582	0.4011	0.1495	553.6098	0.1297	0.9992	4.1320	2.3627	7.8193
0.04	1.0571	11.3051	1.5654	0.3995	0.1434	524.7778	0.1374	0.9990	4.3545	2.4898	8.2306
0.06	1.0577	11.5032	1.5743	0.3973	0.1346	498.4611	0.1453	0.9979	4.5815	2.6192	8.6448
0.08	1.0585	11.7619	1.5831	0.3952	0.1262	476.1012	0.1520	0.9970	4.8072	2.7479	9.0562
0.10	1.0592	12.1373	1.5896	0.3937	0.1202	458.2775	0.1559	0.9965	5.0312	2.8758	9.4673
PAIM-4											
0.01	1.0550	10.8602	1.5509	0.4028	0.1559	562.7173	0.1290	0.9995	4.0379	2.3089	7.6508
0.02	1.0557	11.0263	1.5574	0.4012	0.1499	545.8134	0.1329	0.9990	4.1693	2.3839	7.8905
0.04	1.0572	11.2326	1.5651	0.3995	0.1439	513.1970	0.1422	0.9992	4.4263	2.5310	8.3671
0.06	1.0584	11.4098	1.5757	0.3971	0.1342	483.2012	0.1524	0.9985	4.6874	2.6799	8.8439
0.08	1.0593	11.5934	1.5877	0.3942	0.1225	456.3501	0.1629	0.9971	4.9516	2.8305	9.3216
0.10	1.0603	11.7999	1.6061	0.3899	0.1037	431.9558	0.1739	0.9945	5.2224	2.9841	9.7966
PAIM-5											

0.01	1.0547	10.9877	1.5521	0.4024	0.1541	568.1955	0.1262	0.9988	4.0246	2.3012	7.6229
0.02	1.0554	11.0351	1.5582	0.4010	0.1485	550.5858	0.1314	0.9984	4.1399	2.3669	7.8327
0.04	1.0564	11.2105	1.5681	0.3986	0.1393	520.3800	0.1401	0.9976	4.3705	2.4984	8.2541
0.06	1.0572	11.3814	1.5744	0.3972	0.1337	493.7404	0.1485	0.9972	4.5987	2.6288	8.6758
0.08	1.0576	11.6108	1.5834	0.3950	0.1244	470.3091	0.1561	0.9958	4.8323	2.7618	9.1002
0.10	1.0585	11.8030	1.5937	0.3926	0.1145	448.5179	0.1646	0.9948	5.0639	2.8937	9.5185
PAIM-6											
0.01	1.0548	11.0262	1.5522	0.4024	0.1541	567.9824	0.1259	0.9989	4.0318	2.3053	7.6365
0.02	1.0556	11.1080	1.5602	0.4005	0.1467	549.8325	0.1310	0.9982	4.1557	2.3759	7.8598
0.04	1.0569	11.3038	1.5693	0.3984	0.1388	518.4728	0.1399	0.9979	4.3989	2.5148	8.3069
0.06	1.0582	11.5746	1.5784	0.3964	0.1309	492.2323	0.1473	0.9976	4.6415	2.6534	8.7519
0.08	1.0594	11.7557	1.5853	0.3949	0.1253	467.2369	0.1560	0.9977	4.8821	2.7910	9.1957
0.10	1.0601	11.9872	1.5935	0.3929	0.1173	445.2233	0.1639	0.9969	5.1273	2.9308	9.6430
PAIM-7											
0.01	1.0549	10.8387	1.5515	0.4026	0.1550	565.9095	0.1283	0.9992	4.0149	2.2957	7.6058
0.02	1.0556	10.9424	1.5555	0.4017	0.1518	551.4223	0.1319	0.9992	4.1200	2.3558	7.8000
0.04	1.0568	11.0514	1.5620	0.4003	0.1467	522.5358	0.1406	0.9994	4.3295	2.4757	8.1885
0.06	1.0581	11.2413	1.5694	0.3986	0.1407	498.2653	0.1479	0.9994	4.5388	2.5954	8.5743
0.08	1.0592	11.3327	1.5774	0.3968	0.1337	474.0378	0.1573	0.9991	4.7494	2.7157	8.9602
0.10	1.0596	11.4330	1.5886	0.3941	0.1220	451.3469	0.1673	0.9973	4.9682	2.8400	9.3519
PAIM-8											
0.01	1.0551	10.9261	1.5485	0.4034	0.1587	564.8399	0.1275	1.0001	4.0358	2.3080	7.6510
0.02	1.0556	11.2020	1.5509	0.4029	0.1568	551.0757	0.1290	1.0002	4.1651	2.3819	7.8932
0.04	1.0567	11.4350	1.5580	0.4013	0.1508	518.3843	0.1377	1.0001	4.4246	2.5303	8.3752
0.06	1.0581	11.5872	1.5656	0.3996	0.1448	487.9734	0.1477	1.0002	4.6822	2.6777	8.8524
0.08	1.0593	11.7623	1.5741	0.3976	0.1374	461.2044	0.1576	0.9999	4.9415	2.8258	9.3291
0.10	1.0599	11.9473	1.5852	0.3950	0.1262	436.7815	0.1677	0.9984	5.2076	2.9774	9.8106
PAIM-9											
0.01	1.0555	10.9900	1.5499	0.4031	0.1577	565.1664	0.1269	1.0003	4.0430	2.3122	7.6633
0.02	1.0566	11.2092	1.5566	0.4016	0.1522	548.4095	0.1302	1.0003	4.1808	2.3909	7.9158
0.04	1.0576	11.4516	1.5631	0.4001	0.1467	514.1080	0.1394	1.0001	4.4563	2.5484	8.4283
0.06	1.0587	11.6665	1.5720	0.3981	0.1388	483.1997	0.1493	0.9996	4.7329	2.7064	8.9378
0.08	1.0596	11.9465	1.5797	0.3963	0.1318	457.2147	0.1577	0.9991	5.0095	2.8644	9.4474
0.10	1.0603	12.0950	1.5883	0.3943	0.1234	431.4833	0.1689	0.9982	5.2885	3.0235	9.9577

Table 3: Bachem's constants A, B and ϕ^o_k and S_k of imidazolinone derivatives in DMSO at 308.15K.

COMPOUND CODES	$A.10^{-2}$ $TPa^{-1}m^{-3}mol^{-1}$	$B.\ 10^{-2}$ $TPa^{-1}m^{-9/2}mol^{-3/2}$	$\phi^o_k.\ 10^{-5}$ $TPa^{-1}mol^{-1}$	$S_k.\ 10^{-5}$ $TPa^{-1}m^{-3/2}mol^{-3/2}$
PAIM-1	-1.90	1.18	0.01	1.12
PAIM-2	-0.20	3.50	1.18	1.28
PAIM-3	-2.80	1.94	-1.10	2.84
PAIM-4	-2.60	2.18	-0.33	0.30
PAIM-5	-4.00	5.58	-2.10	6.00
PAIM-6	-3.80	4.59	-2.10	5.41
PAIM-7	-3.50	6.57	-1.90	9.09
PAIM-8	-0.80	3.50	1.30	3.23
PAIM-9	-1.85	0.94	0.30	0.75

Solute-solvent interaction, the decrease in internal pressure indicates the existence of solute-solute interactions also in these systems.

The free volume (V_f) of solute molecule at particular temperature and pressure depends on the internal pressure of liquid in which it was dissolved. The decrease in molecular association causes an increase in free volume (V_f). Thus, free volume is an inverse function of internal pressure. It is evident from Table 2 that V_f increases with concentration for all the compounds in DMSO solutions, indicating the presence of solute-solute interactions. This suggests that both solute-solute and solute-solvent interactions exist in these systems.

Further, the existence of solute-solute and solute –solvent interactions in these solutions were confirmed by some parameters calculated from Bachem's (Bachem, 1936) and Gucker's relation (Gucker, 1993) in which isentropic compressibility and apparent molar compressibility (ϕ_k) respectively, of the solutions are fitted. These equations are:

$$\kappa_s = \kappa^0_s + AC + BC^{3/2} \quad .....(14)$$

$$\phi_k = \phi^o_k + S_k \sqrt{C} \quad .....(15)$$

where C is the concentration. Using these equations, values of A and ϕ^o_k were evaluated from the intercept and B and S_k values are evaluated from the slope of the plots. All these values of intercept and slopes are given in Table 2.

It is evident from Table 2 that for all the compounds, **A** values are negative and B values are positive but low. The negative A and low B values indicate solute-solvent interactions in these systems (Nikam *et al.*, 1998). Further, ϕ^o_k values are negative except for PAIM-1, PAIM-2, PAIM-8 and PAIM-9, which have low positive values. However, for all the compounds, S_k values are positive. These negative or low positive ϕ^o_k values and positive S_k confirms the existence of solute-solvent interactions (Pandey *et al*., 1987; Naidu and Prasad, 2005; Nikam and Hiray, 1996).

The interactions occurring in different solutions can also be confirmed by the solvation number (S_n), which is measure of structure forming or structure breaking tendency of solute in a solution. Figure 3 shows that except for PAIM-8, S_n values decrease suddenly at the beginning and then increase with concentration for all other compounds. For PAIM-8, it decreases with concentration. However, for all compounds, S_n values are positive. The positive values of solvation number indicate structure forming tendency of solute in a solvent. (Pandey *et al.,* 2000). Thus, all compounds show structure forming tendency in DMSO. This further confirms the existence of solute-solvent interactions in these systems. Although, in PAIM-8 solutions S_n values decrease, values are positive. So, PAIM-8 also exhibit structure forming tendency, which decreases with concentration. Further, for some compounds, after increasing S_n values become almost constant, which may due to dominant effect of intermolecular attractions between solute molecules (i.e., solute-solute interactions) over solute-solvent interactions (Bhullar *et al.,* 1991). This suggests that structure forming tendency decreases with concentration in most of the compounds,

which may be due to dipole-dipole interactions, steric hindrance etc. Such interactions may cause weakening between solute and solvent molecules due to which structure forming tendency also decreases. This weak association is further confirmed by low relative association value (R_A), which is almost same for some compounds (Table 1). Results of other authors (Sanaria and Parsania, 2000) also indicated predominance of solute-solvent interactions over solute-solute interactions in some systems. However, it is observed in some cases (Desai and Parsania, 1997; Rajkotia and Parsania, 1998) that solute exhibits structure forming tendency and also solute-solute interactions.

Thus, it is concluded that in DMSO solution of studied compounds, both solute-solute and solute-solvent interactions exist. Some of the acoustical parameters suggest predominance of solute-solvent interactions in the studied systems.

ACKNOWLEDGEMENT

Authors are thankful to Head of Chemistry Department, Saurashtra University, Rajkot, for providing facilities.

REFERENCES

Abraham R, Abdulkhadar M and Asokan CV (2000). Ultrasonic investigation of molecular interaction in binary mixtures of nitriles with methanol/toluene. *Journal Chemistry Thermodynamics* **32** 1-16.

Bachem CH (1936). The compressibility of electrolytic solution. *Z Physik* **101** 541-577.

Baluja S and Parsania PH (1995). Acoustical properties of 3-α Furyl acrylic acid in protic and aprotic solvents. *Asian Journal of Chemistry* **7** 417-423.

Baluja S (2002). Ultrasonic studies of resorcinol in protic and aprotic solvents at 40° C. Journal Indian Chemical Society **79** 142-144.

Baluja S and Oza S (2003). Ultrasonic studies of some derivatives of 6-ethylbenzene-1,3-diol in 1,4-dioxane. *Fluid Phase Equilibria* **208** 83-89.

Baluja S and Shah A (2004). Acoustical studies of some derivatives of 4-amino antipyrine in 1,4-dioxane and dimethylformamide at 318.15 K. *Fluid Phase Equilibria* **215** 55-59.

Baluja S, Pandaya N, Kachhadia N, Solanki A and Inamdar P (2005). Thermodynamic and acoustical studies of binary mixtures of diethyl malonate at 308.15 K. *Physics and Chemistry of Liquids* **43** 309-316.

Baluja S and Shah A (2006). Acoustical studies of some Schiff bases in 1,4-dioxane and DMF at 318.15 K.Russ. *Journal of Physics Chemistry* **80**(7) 1-5.

Desai JA and Parsania PH (1997). Ultrasonic studies of poly(1,1'-cyclohexlidonyl-4,4' diphenylene-2,4-toulene) disulfonate at 30^0 C. *Journal of Pure Applied Ultrasonic* **19** 65-69.

Eyring H and Kincaid JF (1938). Free volumes and free length ratios of molecules in liquids. *Journal of Chemistry Physics* **6** 620-629.

Forlani G, Mantelli M, Branzoni M, Nielsen E and Favilli, F (1995). Differential sensitivity of plant-associated bacteria to sulfonylurea and imidazolinone herbicides. *Plant and Soil* **176**(2) 243-253.

Gucker (Jr.) FT (1933). *Chemical Reviews* **13** 111.

Guler A, Melike S and Ayranci E (2007). Volumetric properties of ascorbic acid (vitamin C) and thiamine hydrochloride (vitamin B1) in dilute HCl and in aqueous NaCl solutions at (283.15, 293.15, 298.15, 303.15, 308.15 and 313.15) K. *Journal of Chemical Thermodynamics* **39**(12) 1620-1631.

Hakin AW, Duke MM, Klassen SA, McKay RM and Preuss KE (1994). Apparent molar heat capacities and volumes of some aqueous solutions of aliphatic amino acids at 288.a5, 298.15, 313.15 and 328.15K. *Canadian Journal of Chemistry* **72**(2) 362-368.

Heindel ND and Chun MC (2006). Synthesis and CNS depressant activity of imidazolinone glyoxylates. *Journal of Pharmaceutical Science* **62** 496 – 498.

Ismail MAH, Abouzid K, Farag AE and Khalifa AE (2000). Synthesis and Evaluation for Potential Antihypertensive Activity of a Series of Imidazolinone Oximes and Cyclohexanespiro-8-imidazo[5,1-c]-1,2,4-oxadiazines, Alex. *Journal of Pharmaceutical Science* **14**(2) 151-161.

Jayakumar S, Karunanidhi N and Kannappan V (1998). Acoustical studies of molecular interaction in polyvinyl alcohol solution, *Journal of Pure Applied Ultrason* **20**(3-4) 79-81.

Joshi H, Upadhyay P, Karia D and Baxi AJ (2003). Synthesis of some novel imidazolinones as potent anticonvulsant agents. Eur. *Journal of Medical Chemistry* **38** 837-840.

Kirnapure KT and Khobragade BG (2007). Studies in acoustical properties of glycyl-glycyl-glycine peptide in 20% dioxane-water mixture at different temperatures. *Asian Journal of Chemistry* **19**(1) 366-374.

Koul BL, Wanchoo RK, Razdan TK, Murti R and Khosa (1985). Ultrasonic study of a binary liquid mixture:Benzene-ethylacetate. *Acustica* **58** 101-104.

Kushare SK, Dagade DH and Patil KJ (2007). Volumetric and compressibility properties of liquid water as a solute in glycolic, propylene carbonate and tetramethylurea solutions at T = 298.15K. *Journal of Chemical Thermodynamics* **40**(1) 78-83.

Ladner DW (2006). Structure activity relationships among the imidazolinone herbicides. *Pesticide Science* **29**(3) 317 - 333.

Meshram YK and Narwade ML (2001). Studies in acoustical properties of some substituted pyrazolines in 70% acetone-water mixture at 30ºC. *Acta Ciencia Indica Chemistry* **27**(2) 67-70.

Mishra K, Puri AK, Haroon S and Pandey JD (1997). Interaction studies of simple carbohydrates in IBA-water and dioxane-water co-solvent mixtures. *Indian Journal of Chemistry* **36**(A) 393-396.

Naidu PS and Prasad KR (2005). Molecular interactions in the binary mixtures of fenvalerate. *Journal of Pure Applied Ultrason* **27**(1) 15-24.

Nikam PS, Ansari HR and Hasan M (1998). Ultrasonic velocity studies of dextrose and sucrose in water and in aqueous ammonium chloride at different temperatures. *Journal of Pure Applied Ultrason* **20** 75-78.

Pandey JD, Misra K, Shukla A and Rai RD (1987). Ultrasonic and Thermodynamic studies of Tetracyclines in solutions. Can. *Journal of Chemistry* **65** 303-306.

Rajkotia KM, Baluja S and Parsania PH (1997) Studies on acoustical properties of poly (4,4-cyclopentylidene diphenylene toluene-2,4 disulphonate) in different solvents at 30^0C. *Eur Polym Journal* **33** 1005-1007.

Rajkotia KM and Parsania PH (1998). Ultrasonic studies on 1, 1'-bis-p(o/m/p-chlorobenzoyloxyphenyl) cyclohexane in dioxane at 30^0C. J. Pure Appl. Ultrason, 20(3 and 4): 86-89.

Syal, V. K., Lal, G., Bisht, P. and Chauhan, S., 1995. Ultrasonic measurements of some 1:1 electrolytes in chlorobenzene+methanol mixtures. *Journal of Molecular Liquids* **63** 317-328.

Szymaoska E, Kononowicz KK, Biaoecka A and Kasprowicz A (2002). Antimicrobial activity of 5-arylidene aromatic derivatives of hydantoin. *Farmaco* 2 **57**(1) 39-44.

Roy M, Dakua V and Sinha B (2007). Partial molar volumes, viscosity B-boefficients and adiabatic compressibilities of sodium molybdate in aqueous 1,3-dioxolane mixtures from 303.15 to 323.15 K. Int. *Journal Thermophysics* **28**(4) 1275-1284.

Pandey JD, Haroon S, Dubey KK, Upadhyaya M, Dey R and Misra K (2000). Interactions of 6-aminopurine (adenine) in water and aqueous urea solutions. *Canadian Journal of Chemistry* **78**(12) 1561-1569.

Rajkotia KM, Baluja S and Parsania PH (1999). Ultrasonic velocity and allied parameters of 1,1-bis (4-hydroxyloxy-R_1, R_2-phenyl) cyclohexane in 1,4-dioxane at 30^0C. *Journal Pure Applied Ultrasonics* **21** 132-135.

Riddick JA, Bunger WB and Sakano T (1986) Organic Solvents-Physical Properties and methods of purification, Fourth Edition., Techniques of Chemistry, II, A Wiley-Interscience Publication, John Wiley, New York.

Varma RP, Bhatnagar BB and Singh A (1991). Ultrasonic velocity and allied parameters of some organochloropesticides in methanol. *Acustica* **73** 45-47.

Wanchoo RK (1987). Ultrasonic behavior of phenyl-ethylacetate mixtures. *Acustica* **63** 70-74.