International Journal of Theoretical and Applied Sciences **4**(2): 12-18(2012)
ISSN No. (Print) : 0975-1718
ISSN No. (Online) : 2249-3247

Acoustical Behaviour of Nickel Sulphate in Aqueous Mannitol Systems at Different Temperatures

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(Received 11 June, 2012, Accepted 12 Augest, 2012)

ABSTRACT : The ultrasonic velocity, density and viscosity of nickel sulphate in water, 2, 4 and 6 wt. % of aqueous mannitol solutions at temperatures 303.15, 308.15, 313.15 and 318.15K have been measured. The data obtained are used to evaluate various acoustic parameters namely, adiabatic compressibility (β), intermolecular free length (L_f), relative association (R_A), specific acoustic impedance (Z), Rao's molar sound function (R), solvation number (S_N), molar compressibility (W), relaxation time (τ) and Gibb's free energy of activation for relaxation process (ΔG*) in view to investigate exact nature of the molecular interactions. These parameters have been further used to interpret the solute-solute and solute-solvent interactions and structure forming tendency of the solutes in the solvents.

Keywords : Solute-solvent interactions, solute-solute interactions, nickel sulphate, mannitol.

I. INTRODUCTION

Ion-solvation is the back bone of solution chemistry [1-3]. Ultrasonic study and transports properties of electrolytes in aqueous solution of carbohydrates are very useful to study various types of interactions in solutions. Ultrasonic velocity studies are extensively used to analyse the behaviour of the electrolyte and non-electrolyte solutions in aqueous [4-5] and non-aqueous solvent mixtures [6-7]. A number of researchers have studied the acoustical behavior of electrolyte solution containing metal ion [8-10]. Ultrasonic studies of maltose have been carried out by Rao [11]. Multi-component solutions similar to bio-fluids are the work systems of current interest, as they can be utilized for better understanding of biological processes [12-18]. Hence the molecular association, physico-chemical behaviour and acoustical properties of multi-component liquid mixture of nickel sulphate in water, 2, 4 and 6 weight % of aqueous mannitol solutions at temperatures 303.15, 308.15, 313.15 and 318.15K by measuring ultrasonic velocity, density and viscosity have been studied. From the speed of sound, various acoustical and thermodynamic parameters have been computed from the experimental data with a view to investigate the nature of molecular interaction between the components of liquid mixture.

II. MATERIALS AND METHODS

Fresh double distilled water with specific conductance in the range of 0.1×10^{-6} to 1.0×10^{-6} $\Omega^{-1}cm^{-1}$ has been used for preparation of the solutions. Nickel sulphate and mannitol (AR grade) were dried under vacuum for 24 hours before use. Water of crystallization was estimated by the standard method [19]. All the solutions were prepared by weight and conversions of molality to molarity were done by using the standard expression [20]. The concentration range for nickel sulphate was 0.01 m to 0.12 m and solvents were 2, 4 and 6% aqueous mannitol. The density and velocity of sound were measured with the help of DSA (Density and Sound Analyser) 5000, Antor Paar, GmbH Garz, Austria. All measurements were made at 303.15, 308.15, 313.15 and 318.15K. Repeatability of the instrument for density is 1.0×10^{-6} gcm^{-3}, for sound velocity 1.0×10^{-2} ms^{-1} and for temperature is 1.0×10^{-3} K.

III. THEORY AND CALCULATION

Adiabatic compressibility can be calculated from the speed of sound (U) and density of medium using the Newton-Laplace equation [21] as :

$$\beta = 1/U^2\rho \qquad ... (1)$$

Intermolecular free length (L_f) can be determined [22] as :

$$L_f = K\beta^{1/2} \qquad ... (2)$$

where K values for different temperatures were taken from the work of Jacobson [23].

The acoustic impedance (Z) is the product of the velocity of ultrasound in a medium and its density and can be calculated by the relation [24] as:

$$Z = U\rho \qquad ... (3)$$

Solvation number (S_N), can be obtained by the relation [25-26] as :

$$S_N = (n_1/n_2)(1 - \beta/\beta_0) \qquad ... (4)$$

The relaxation time can be calculated by the relation [27-29] as :

$$\tau = (4\eta/3\rho U^2) \qquad ... (5)$$

where η is viscosity.

Gibb's free energy is calculated from the relation [30] as :

$$\Delta G^* = kT \ln(kT\tau/h) \quad ... (6)$$

where τ is the viscous relaxation time, k is the Boltzmann's constant, T is absolute temperature and h is the Plank's constant.

IV. RESULT AND DISCUSSION

The values of density, viscosity and ultrasonic velocity of nickel sulphate in water, 2, 4 and 6 wt. % aqueous mannitol solutions at 303.15, 308.15, 313.15 and 318.15 K are presented in Table-1. The acoustical parameters such as adiabatic compressibility, Intermolecular free length, acoustic impedance, solvation number, relaxation time and Gibb's free energy are presented in Table-1.

Table 1 : Densities (ρ), viscosities (η), ultrasonic velocities (U), adiabatic compressibility (β), intermolecular free length (L_f), specific acoustic impedance (Z), solvation number (S_N), relaxation time (τ) and Gibb's free energy of activation (ΔG^*) for nickel sulphate in different solents at different temperatures.

$C \times 10^2$ ($mol\ lit^{-1}$)	ρ (gcm^{-3})	η (cP)	U ($m\ s^{-1}$)	β ($10^{-10}\ Pa^{-1}$)	L_f ($10^{-11} m$)	Z ($10^6\ kg\ m^{-2}s^{-1}$)	S_N	τ ($10^{-13}s$)	ΔG^* ($10^{-21}\ J\ mol^{-1}$)
				$NiSO_4$ in water					
303.15 K									
ρ_0 = 0.995670 gcm^{-3}			η_0 = 0.79730 cP		U_0 = 1509.62 ms^{-1}			β_0 = 4.4071 : 10^{-10} Pa^{-1}	
0.9946	0.997435	0.80162	1511.10	4.3907	4.3491	1.5072	20.6886	4.6929	4.5440
1.9872	0.999175	0.80699	1511.60	4.3801	4.3439	1.5104	16.9909	4.7130	4.5619
3.9659	1.002608	0.81721	1513.81	4.3524	4.3301	1.5178	17.2357	4.7424	4.5879
5.9359	1.005986	0.82823	1515.81	4.3263	4.3171	1.5249	16.9645	4.7776	4.6188
7.8972	1.009321	0.83899	1517.89	4.3002	4.3041	1.5320	16.8368	4.8105	4.6476
9.8496	1.012614	0.84979	1520.02	4.2742	4.2911	1.5392	16.7455	4.8429	4.6757
11.7932	1.015879	0.86114	1521.79	4.2506	4.2792	1.5460	16.4382	4.8805	4.7080
308.15K									
ρ_0 = 0.994060 gcm^{-3}			η_0 = 0.71900 cP		U_0 = 1520.26 ms^{-1}			β_0 = 4.3526 10^{-10} Pa^{-1}	
0.9930	0.995807	0.72209	1521.68	4.3369	4.3614	1.5153	20.0921	4.1770	4.1934
1.9839	0.997535	0.72623	1522.23	4.3262	4.3561	1.5185	16.8367	4.1906	4.2072
3.9593	1.000947	0.73528	1524.36	4.2995	4.3426	1.5258	16.9661	4.2166	4.2335
5.9260	1.004314	0.74461	1526.29	4.2742	4.3298	1.5329	16.6809	4.2450	4.2620
7.8841	1.007645	0.75448	1528.26	4.2491	4.3171	1.5399	16.5161	4.2761	4.2930
9.8333	1.010934	0.76412	1530.32	4.2239	4.3043	1.5471	16.4317	4.3050	4.3216
11.7738	1.014203	0.77431	1532.03	4.2009	4.2925	1.5538	16.1403	4.3386	4.3548
313.15 K									
ρ_0 = 0.992240 gcm^{-3}			η_0 = 0.65260 cP		U_0 = 1529.24 ms^{-1}			β_0 = 4.3096 10^{-10} Pa^{-1}	
0.9912	0.993973	0.65503	1530.66	4.2941	4.3787	1.5214	19.9712	3.7503	3.8653
1.9803	0.995690	0.65875	1531.27	4.2832	4.3732	1.5247	16.9594	3.7621	3.8789
3.9520	0.999092	0.66698	1533.35	4.2571	4.3598	1.5320	16.9099	3.7859	3.9061
5.9151	1.002456	0.67523	1535.2	4.2326	4.3473	1.5390	16.5383	3.8106	3.9342
7.8696	1.005794	0.68428	1537.09	4.2082	4.3347	1.5460	16.3380	3.8394	3.9667
9.8154	1.009095	0.69283	1539.06	4.1837	4.3221	1.5531	16.2283	3.8647	3.9952
11.7525	1.012375	0.70166	1540.75	4.1610	4.3103	1.5598	15.9619	3.8928	4.0264
318.15 K									
ρ_0 = 0.990250 gcm^{-3}			η_0 = 0.59720 cP		U_0 = 1536.49 ms^{-1}			β_0 = 4.2776 10^{-10} Pa^{-1}	
0.9892	0.991982	0.59901	1538.04	4.2615	4.4008	1.5257	20.8723	3.4036	3.5706
1.9763	0.993699	0.60211	1538.82	4.2498	4.3947	1.5291	18.0177	3.4118	3.5812
3.9441	0.997102	0.60958	1540.88	4.2240	4.3814	1.5364	17.3927	3.4332	3.6086
5.9034	1.000469	0.61733	1542.63	4.2002	4.3690	1.5434	16.7386	3.4573	3.6393
7.8540	1.003803	0.62510	1544.46	4.1764	4.3566	1.5503	16.4283	3.4809	3.6692
9.7961	1.007112	0.63289	1546.31	4.1527	4.3442	1.5573	16.2177	3.5043	3.6986
11.7295	1.010395	0.64097	1548.01	4.1301	4.3324	1.5641	15.9585	3.5297	3.7303

$NiSO_4$ in 2% Aqueous Mannitol

303.15 K

ρ_0 = 1.002160 gcm^{-3} η_0 = 0.84128 cP U_0 = 1516.50 ms^{-1} β_0 = 4.3389 10^{-10} Pa^{-1}

1.0013	1.004095	0.84636	1517.55	4.3245	4.3162	1.5238	18.0453	4.8802	4.7077
2.0007	1.005950	0.85193	1518.46	4.3114	4.3097	1.5275	17.2876	4.8973	4.7224
3.9934	1.009558	0.86381	1520.71	4.2833	4.2956	1.5352	17.4801	4.9333	4.7530
5.9774	1.013019	0.87483	1522.97	4.2560	4.2819	1.5428	17.3729	4.9644	4.7793
7.9528	1.016428	0.88747	1525.03	4.2303	4.2689	1.5501	17.0729	5.0057	4.8140
9.9188	1.019727	0.89846	1526.96	4.2059	4.2566	1.5571	16.7184	5.0385	4.8413
11.8751	1.022932	0.90969	1528.45	4.1846	4.2458	1.5635	16.1688	5.0756	4.8720

308.15 K

ρ_0 = 1.000390 gcm^{-3} η_0 = 0.75668 cP U_0 = 1525.80 ms^{-1} β_0 = 4.2937 10^{-10} Pa^{-1}

0.9995	1.002350	0.76106	1527.90	4.2736	4.3295	1.5315	25.6242	4.3366	4.3528
1.9973	1.004240	0.76592	1528.79	4.2606	4.3229	1.5353	21.0757	4.3510	4.3669
3.9867	1.007876	0.77611	1530.95	4.2332	4.3090	1.5430	19.2224	4.3806	4.3957
5.9675	1.011342	0.78622	1533.97	4.2021	4.2931	1.5514	19.4012	4.4050	4.4194
7.9394	1.014722	0.79631	1535.13	4.1818	4.2828	1.5577	17.7787	4.4400	4.4530
9.9022	1.018017	0.80638	1537.02	4.1580	4.2706	1.5647	17.2444	4.4706	4.4822
11.8552	1.021218	0.81616	1538.72	4.1358	4.2591	1.5714	16.7194	4.5006	4.5107

313.15 K

ρ_0 = 0.998176 gcm^{-3} η_0 = 0.68143 cP U_0 = 1534.78 ms^{-1} β_0 = 4.2531 10^{-10} Pa^{-1}

0.9974	1.000186	0.68541	1536.72	4.2338	4.3479	1.5370	24.7012	3.8692	4.0001
1.9930	1.002110	0.68959	1537.55	4.2211	4.3414	1.5408	20.4891	3.8811	4.0134
3.9785	1.005799	0.69841	1539.63	4.1943	4.3275	1.5486	18.8508	3.9058	4.0408
5.9556	1.009319	0.70716	1541.77	4.1680	4.3140	1.5561	18.1731	3.9300	4.0675
8.8067	1.014241	0.71879	1543.67	4.1376	4.2982	1.5657	18.5091	3.9654	4.1063
9.8832	1.016070	0.72458	1545.52	4.1203	4.2892	1.5704	17.0302	3.9806	4.1228
11.8325	1.019261	0.73295	1547.16	4.0987	4.2779	1.5770	16.5010	4.0055	4.1498

318.15 K

ρ_0 = 0.996586 gcm^{-3} η_0 = 0.62318 cP U_0 = 1542.82 ms^{-1} β_0 = 4.2156 10^{-10} Pa^{-1}

0.9958	0.998615	0.62678	1544.03	4.2004	4.3691	1.5419	19.6141	3.5103	3.7061
1.9899	1.000577	0.63034	1544.82	4.1879	4.3626	1.5457	17.9102	3.5197	3.7179
3.9726	1.004309	0.63762	1546.83	4.1615	4.3488	1.5535	17.4957	3.5379	3.7406
5.9472	1.007906	0.64460	1548.91	4.1355	4.3352	1.5612	17.2675	3.5543	3.7609
7.9127	1.011305	0.65174	1550.77	4.1117	4.3228	1.5683	16.7975	3.5730	3.7839
9.8691	1.014615	0.65912	1552.56	4.0889	4.3107	1.5753	16.3961	3.5934	3.8089
11.8159	1.017832	0.66622	1554.16	4.0675	4.2995	1.5819	15.9617	3.6131	3.8329

$NiSO_4$ in 4 % Aqueous Mannitol

303.15 K

ρ_0 = 1.009241 gcm^{-3} η_0 = 0.88601 cP U_0 = 1523.50 m s^{-1} β_0 = 4.2689 10^{-10} Pa^{-1}

1.0083	1.011169	0.89279	1524.98	4.2525	4.2802	1.5420	20.5808	5.0622	4.8610
2.0147	1.013022	0.89900	1525.85	4.2399	4.2738	1.5457	18.2047	5.0823	4.8775
4.0212	1.016585	0.91052	1528.27	4.2117	4.2596	1.5536	17.9560	5.1131	4.9028
6.0188	1.020036	0.92307	1530.28	4.1864	4.2468	1.5609	17.2538	5.1525	4.9349
8.0067	1.023313	0.93526	1532.42	4.1614	4.2340	1.5681	16.8689	5.1893	4.9647
9.9852	1.026552	0.94665	1534.25	4.1383	4.2223	1.5750	16.3829	5.2234	4.9921
11.9537	1.029701	0.95856	1536.23	4.1151	4.2104	1.5819	16.0865	5.2594	5.0208

308.15 K									
ρ_0 = 1.007513 gcm^{-3}			η_0 = 0.79488 cP		U_0 = 1533.60 ms^{-1}			β_0 = 4.2201 10^{-10} Pa^{-1}	
1.0066	1.009472	0.80094	1535.03	4.2041	4.2942	1.5496	20.3463	4.4896	4.5002
2.0114	1.011353	0.80641	1535.86	4.1917	4.2878	1.5533	18.0113	4.5070	4.5167
4.0147	1.014950	0.81648	1538.19	4.1642	4.2738	1.5612	17.7299	4.5333	4.5415
6.0091	1.018391	0.82754	1540.1	4.1399	4.2612	1.5684	16.9716	4.5679	4.5737
7.9940	1.021701	0.83801	1542.19	4.1153	4.2486	1.5757	16.6291	4.5982	4.6019
9.9693	1.024921	0.84792	1543.93	4.0931	4.2371	1.5824	16.1167	4.6275	4.6289
11.9344	1.028039	0.85833	1545.89	4.0704	4.2253	1.5892	15.8369	4.6583	4.6571
313.15 K									
ρ_0 = 1.005566 gcm^{-3}			η_0 = 0.72049 cP		U_0 = 1542.16 ms^{-1}			β_0 = 4.1815 10^{-10} Pa^{-1}	
1.0047	1.007553	0.72584	1543.52	4.1659	4.3129	1.5552	19.9756	4.0317	4.1779
2.0076	1.009449	0.73089	1544.32	4.1538	4.3066	1.5589	17.7562	4.0479	4.1953
4.0073	1.013069	0.73983	1546.57	4.1269	4.2926	1.5668	17.4835	4.0709	4.2198
5.9982	1.016535	0.74951	1548.42	4.1030	4.2802	1.5740	16.7557	4.1003	4.2508
7.9795	1.019836	0.75857	1550.46	4.0790	4.2676	1.5812	16.4146	4.1256	4.2774
9.9509	1.023030	0.76760	1552.13	4.0575	4.2564	1.5879	15.8826	4.1527	4.3057
11.9126	1.026165	0.77689	1554.06	4.0350	4.2446	1.5947	15.6301	4.1797	4.3338
318.15 K									
ρ_0 = 1.003215 gcm^{-3}			η_0 = 0.65431 cP		U_0 = 1549.25 ms^{-1}			β_0 = 4.1530 10^{-10} Pa^{-1}	
1.0024	1.005228	0.65900	1550.56	4.1377	4.3364	1.5587	19.7511	3.6357	3.8602
2.0030	1.007149	0.66365	1551.31	4.1258	4.3302	1.5624	17.5379	3.6508	3.8785
3.9984	1.010822	0.67156	1553.52	4.0991	4.3161	1.5703	17.3697	3.6704	3.9020
5.9850	1.014305	0.67964	1555.31	4.0757	4.3038	1.5776	16.6246	3.6933	3.9293
7.9621	1.017621	0.68739	1557.28	4.0521	4.2913	1.5847	16.2648	3.7139	3.9536
9.9297	1.020845	0.69485	1558.85	4.0312	4.2802	1.5913	15.7107	3.7348	3.9783
11.8874	1.023991	0.70255	1560.77	4.0089	4.2684	1.5982	15.4850	3.7553	4.0024
$NiSO_4$ in 6 % Aqueous Mannitol									
303.15 K									
ρ_0 = 1.016660 gcm^{-3}			η_0 = 0.94130 cP		U_0 = 1531.22 ms^{-1}			β_0 = 4.1952 10^{-10} Pa^{-1}	
1.0157	1.018585	0.94984	1532.54	4.1800	4.2435	1.5610	18.9633	5.2938	5.081
2.0295	1.020434	0.95669	1533.7	4.1661	4.2365	1.5650	18.1773	5.3143	5.0643
4.0504	1.023979	0.96898	1535.91	4.1398	4.2230	1.5727	17.3444	5.3485	5.0911
6.0621	1.027363	0.98280	1538.24	4.1137	4.2097	1.5803	17.0176	5.3905	5.1239
8.0638	1.030615	0.99520	1540.14	4.0906	4.1979	1.5873	16.3789	5.4279	5.1528
10.0556	1.033794	1.00677	1542.27	4.0667	4.1856	1.5944	16.0889	5.4590	5.1766
12.0372	1.036900	1.01913	1544.10	4.0449	4.1744	1.6011	15.6817	5.4965	5.2053
308.15 K									
ρ_0 = 1.014906 g cm^{-3}			η_0 = 0.84176 cP		U_0 = 1541.00 m s^{-1}			β_0 = 4.1492 10^{-10} Pa^{-1}	
1.0140	1.016852	0.84925	1542.29	4.1344	4.2584	1.5683	18.8276	4.6815	4.6782
2.0261	1.018715	0.85536	1543.40	4.1209	4.2514	1.5723	17.9595	4.6998	4.6948
4.0437	1.022280	0.86640	1545.52	4.0953	4.2382	1.5800	17.0947	4.7309	4.7228
6.0523	1.025715	0.87767	1547.74	4.0698	4.2250	1.5875	16.7613	4.7626	4.7513
8.0508	1.028955	0.88882	1549.63	4.0471	4.2132	1.5945	16.1656	4.7962	4.7812
10.0398	1.032170	0.89918	1551.61	4.0242	4.2013	1.6015	15.8324	4.8247	4.8064
12.0179	1.035235	0.90947	1553.47	4.0027	4.1900	1.6082	15.4646	4.8538	4.8319

313.15 K

ρ_0 = 1.012967 gcm^{-3} η_0 = 0.75504 cP U_0 = 1549.30 ms^{-1} β_0 = 4.1128 10^{-10} Pa^{-1}

1.0121	1.014948	0.76154	1550.52	4.0983	4.2777	1.5737	18.5076	4.1613	4.3147
2.0223	1.016824	0.76718	1551.6	4.0850	4.2708	1.5777	17.7215	4.1786	4.3326
4.0364	1.020430	0.77680	1553.65	4.0599	4.2576	1.5854	16.9013	4.2049	4.3597
6.0414	1.023860	0.78634	1555.78	4.0352	4.2447	1.5929	16.5219	4.2307	4.3861
8.0364	1.027119	0.79579	1557.61	4.0129	4.2330	1.5999	15.9451	4.2579	4.4139
10.0217	1.030310	0.80496	1559.51	3.9908	4.2212	1.6068	15.5890	4.2832	4.4394
11.9962	1.033365	0.81434	1561.31	3.9698	4.2101	1.6134	15.2234	4.3104	4.4667

318.15 K

ρ_0 = 1.010743 gcm^{-3} η_0 = 0.68798 cP U_0 = 1556.16 ms^{-1} β_0 = 4.0856 10^{-10} Pa^{-1}

1.0099	1.012742	0.69379	1557.30	4.0715	4.3016	1.5771	18.0488	3.7664	4.0153
2.0179	1.014645	0.69876	1558.35	4.0584	4.2946	1.5812	17.4565	3.7812	4.0325
4.0279	1.018278	0.70706	1560.35	4.0336	4.2815	1.5889	16.7159	3.8026	4.0574
6.0289	1.021748	0.71555	1562.37	4.0095	4.2687	1.5963	16.3076	3.8253	4.0835
8.0198	1.024992	0.72392	1564.16	3.9877	4.2570	1.6033	15.7410	3.8490	4.1105
10.0015	1.028230	0.73205	1565.98	3.9659	4.2454	1.6102	15.3958	3.8710	4.1356
11.9724	1.031315	0.74012	1567.73	3.9452	4.2343	1.6168	15.0472	3.8932	4.1607

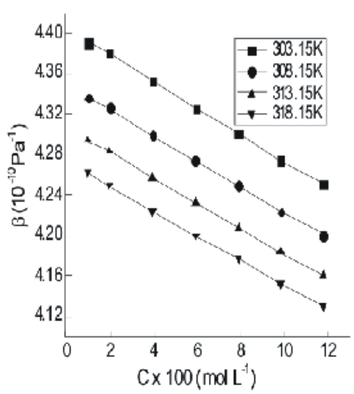

Fig. 1. Plots of adiabatic compressibility (β) Vs molar concentration (C) for nickel sulphate in water at different temperatures.

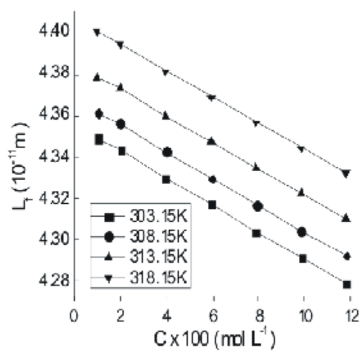

Fig. 3. Plots of intermolecular free length (L_f) Vs molar concentration (C) for nickel sulphate in water at different temperatures.

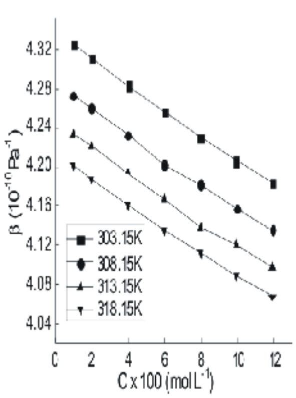

Fig. 2. Plots of adiabatic compressibility (B) Vs molar concentration (C) for nickel sulphate in 2% aqueous mannitol at different temperatures.

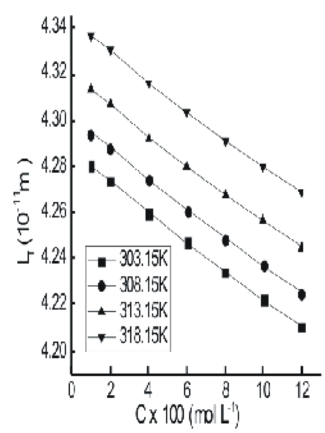

Fig. 4. Plots of intermolecular free length (L_f) Vs molar concentration (C) for nickel sulphate in 4% aqueous mannitol at different temperatures.

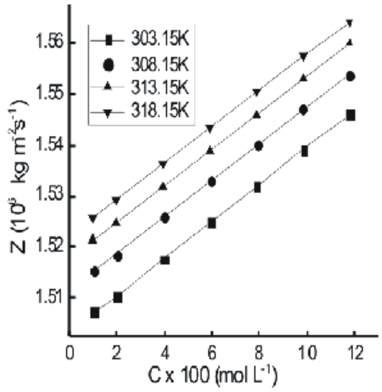

Fig. 5. Plots of specific acoustic impedence (Z) Vs molar concentration (C) for nickel sulphate in water at different temperatures.

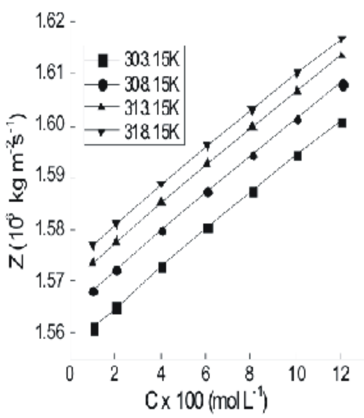

Fig. 6. Plots of specific acoustic impedence (Z) Vz molar concentration (C) for nickel sulphate in 6% aqueous mannitol at different temperatures.

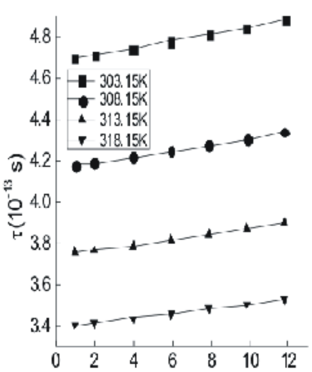

Fig. 7. Plots of relaaxation time (τ) Vs molar concentration (C) for nickel sulphate in water at different temperatures.

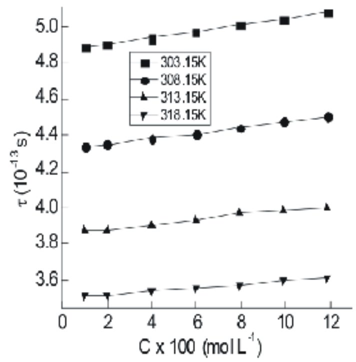

Fig. 8. Plots of relaxation time (τ) Vs molar concentration (C) for nickel sulphate in 2% aqueous mannitol at different temperatures.

At all temperatures, the density, viscosity and ultrasonic velocity of the solutions increase with increasing nickel sulphate and mannitol concentrations as shown in Table-1. The gradual increase in density, viscosity and ultrasonic velocity with solute concentration at all temperatures may be due to association between solute and solvent molecules. A rise in temperature leads to less ordered structure and more spacing between the molecules. The decrease in density, viscosity and increase in ultrasonic velocity with temperature indicates decrease in intermolecular forces due to increase in the thermal energy of the system, which causes increase in volume expansion and hence, increase in free path length.

From Table-1, it is found that the adiabatic compressibility decreases with increasing concentration of the solute as well as temperature in all the systems. The decrease in adiabatic compressibility is attributed to the influence of the electrostatic field of ions (Ni^{+2}, SO_4^{-2}) on the surrounding solvent molecules.

Intermolecular free length (L_f), denotes the magnitude of either the ion-ion interaction or the ion-solvent interactions or both of the system. In the present investigation intermolecular free length decreases with molar concentration of solute, but it increases with temperatures in all systems. The decrease in free length with the increase in concentration may be due to increase in number of ions in a given volume or due to increase in compressibility. This indicating that there is a significant interaction between solute and solvent molecules [31], suggesting a structure promoting behaviour on the addition of solute.

When the sound wave travels through a solution certain part of it travels through the medium and rest gets reflected by the ion [32-34] *i.e.* restriction for free flow of sound velocity by the ions. The character that determines this restriction/backward movement of sound waves is known as acoustic impedance. The acoustic impedance increases with increasing solute concentrations as well as temperatures. The higher impedance indicates the presence of bulkier/

solvated ion due to ion-solvent/solvent-solvent interactions which restricts the free flow of sound waves.

Solvation number is the number of solvent molecules associated and taking part in the formation of primary shell with the central ion [35]. In present case solvation numbers decreases with increase in solute concentration as well as with increase in temperature for all solvents systems.

The values of τ and ΔG^* increases as concentration of the solute increases, but the same show reverse trend for increase in temperature in all the studied systems. The relaxation time shows the presence of molecular interaction by addition of solute concentration at a given temperature and the same is confirmed by Gibb's free energy parameter. The increasing values of Gibb's free energy suggest that the closer approach of unlike molecules is due to hydrogen bonding. The reduction of ΔG^* with temperature in all the solvent system indicates the need for smaller time for the cooperative process or the rearrangement of molecules in the mixtures decreases the energy that leads dissociation.

V. CONCLUSION

Ultrasonic method is a powerful probe for characterising the physico-chemical properties and existence of molecular interaction in the mixtures. In addition the density, viscosity and the derived acoustical and thermodynamic parameters provide evidence of confirmation.

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