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Acoustic and Viscometric studies of manitol with life-essential Co(II) and Cu(II) metal ions in aqueous medium at 298.15 K

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ABSTRACT

The ultrasonic velocity, density and viscosity of manitol in different concentration of aqueous solutions of Cu(II) and Co(II) metal ions at 298.15 K and one atmospheric pressures has been investigated to understand the molecular interactions of manitol with metal ions in aqueous medium. The acoustical parameters such as isentropic compressibility, intermolecular free length, specific acoustic impedance, relative association, free volume, internal pressure, viscous relaxation time, Gibb's free energy, attenuation coefficient, Rao's constant, and Wada's constant have been calculated from the experimental data. On the basis of the Jones-Dole equation, Falkenhagen coefficient A and Jones-Dole B-coefficient have been evaluated. The data have been interpreted in terms of molecular interactions and the variations in these parameters with solute concentration give the information about intermolecular interactions.

Keywords: Density, Viscosity, Ultrasonic velocity, Cu (II) and Co (II) metal ion, Manitol, Jones-Dole equation.

INTRODUCTION

Now a day's ultrasonic velocity, density and viscometric measurements have been frequently used to correlate the binding forces between the particles in liquid mixtures as well as evaluate a number of acoustic parameters of great relevance [1–3]. Although a lot of work has been done in this field, the basic processes are still needed to focus at a molecular level. From the previously reported literature reveals that acoustic properties of many organic, inorganic and biological compounds in different solvents have been carefully studied [4-7]. The molecular interaction of biomolecules such as amino acids, carbohydrates in aqueous solutions of metal ions at different experimental conditions has been continuously studied by many workers [8-14], however very few data available on their interactions with Co(II) & Cu(II) metal ions in aqueous medium prompted us to undertake the present study.

Cobalt and Copper are life essential trace elements and necessary for proper activity of many metalloenzymes in living systems. However, their imbalance is causes many types of diseases [15-17]. The literature provides immense data on the density, ultrasonic velocity and viscosity of liquid mixtures however combined studies of molecule with life essential metal ions in aqueous medium are very few.

In the present paper densities, viscosities and ultrasonic velocities of manitol (0.01–0.10 M) with Co(II) & Cu(II) metal ions (0.1, 0.05 and 0.025 M) in aqueous medium at 298.15 K have been measured. From these experimental data, a number of acoustic parameters namely, isentropic compressibility, intermolecular free length, specific acoustic impedance, relative association, free volume, internal pressure, viscous relaxation time, Gibb's free energy, attenuation coefficient, Rao's constant, Wada's constant, Falkenhagen coefficient A and Jones-Dole or viscosity *B*-coefficient have been calculated.

MATERIALS AND METHODS

Manitol (MW= 182.72 g/mol, Sigma-Aldrich chemicals Ltd), Cobalt chloride ($CoCl_2.6H_2O$, MW= 237.63 g mol^{-1}, CDH Chemicals) and Copper chloride ($CuCl_2.2H_2O$, MW=170.48 g mol^{-1}, CDH Chemicals) have been used as such to prepare the stock solutions. The weighing measurements were taken on a electronic digital balance (Model: Dhona 100 DS; Accuracy: ±0.01mg). Ultrasonic velocities have been determined by ultrasonic interferometer (Model M-84, supplied by M/S Mittal Enterprises, New Delhi; Accuracy: ±0.1$m \cdot s^{-1}$), at 298.15 K. The measuring cell of interferometer with digital thermostatic bath (Model SSI-03 Spl, supplied by M/S Mittal Enterprises, New Delhi), operating range −10°C to 85°C (Accuracy: ±0.1°C) has been used to providing desired temperature in the double-walled measuring cell containing the liquid mixtures. The densities measurements have been carried out using a specific gravity bottle of 25 cm^3 volume by relative measurement method (Accuracy: ±0.01 $kg \cdot m^{-3}$). The viscosity measurements were made using an Ostwald's viscometer (Accuracy: $3x10^{-6}$ $Nm^{-2}s$). The instrument has been calibrated with double distill deionized water at desired temperatures before taking measurements. The flow times have been measured with a stopwatch of 0.1s resolution and the average flow times were taken for each series of liquid solution.

Theoretical aspect: For understanding molecular interaction and structural changes, the ultrasonic velocity, viscosity and density data help to work out various parameters. These parameters have been computed using the following equations.

S. No.	Parameters	Formula
1.	Isentropic compressibility K_s	$K_s = \frac{1}{U^2 \times \rho}$
2.	Acoustic impedance Z	$Z = U \times \rho$
3.	Intermolecular free length L_f	$L_f = K \times K_s^{1/2}$ K {(93.875+0.375T) $x10^{-8}$} is temperature dependent constant
4.	Relative association R_A	$R_A = \frac{\rho}{\rho_o}.\left(\frac{u_0}{u}\right)^{1/3}$
5.	Free volume V_f	$V_f = \left[\frac{M_{eff}.u}{K\eta}\right]^{3/2}$ K the temperature independent constant (K = $4.281x10^9$)

6.	Internal pressure π_i	$\pi_i = bRT \left[\frac{k\,\eta}{u}\right]^{1/2} \left[\frac{\rho^{2/3}}{M_{eff}^{7/6}}\right]$ b is a constant stand for cubic packing factor which is assumed to be 2 for liquids
7.	Viscous relaxation time τ	$\tau = \frac{4}{3} K_s \eta$
8.	Gibb's free energy ΔG	$\Delta G = k\,T\,ln\left[\frac{k\,T\,\tau}{h}\right]$
9.	Attenuation Coefficient α	$\tau = \frac{4}{3} K_s \eta$
10.	Rao' constant R	$R_m = \left(\frac{M_{eff}}{\rho}\right) u^{1/3}$
11.	wada's constant w	$w = \frac{M_{eff}.K_s^{1/7}}{\rho}$

Where, u : ultrasonic velocity; ρ : density of mixture; η : viscosity; M_{eff} : effective molecular weight of mixture ($\sum M_i x_i$); R: the universal gas constant; T: the temperature in Kelvin; *k:* Boltzmaan's constant (1.23×10^{-23} JK^{-1}); *h:* the Planck's constant (6.63×10^{-34} Js); *f* : the frequency of the ultrasonic wave.

RESULTS AND DISCUSSION

The densities, viscosities and ultrasonic velocities of the aqueous Cu(II) and Co(II) metal ion solution with manitol as a third component have been determined at 298.15 K and are given in table 1.

Table 1 Measured value of ultrasonic velocity (*u*), density (*ρ*) and viscosity (*η*) of Manitol solution at 298.15 K.

Manitol con. (M)	Metal ion Concentration (M)								
	0.1M			0.05 M			0.025M		
	u (ms^{-1})	*ρ* (Kg m^{-3})	*η* (Nsm^{-2})	*u* (ms^{-1})	*ρ* (Kg m^{-3})	*η* (Nsm^{-2})	*u* (ms^{-1})	*ρ* (Kg m^{-3})	*η* (Nsm^{-2})
Cu(II) metal ion solution									
0	1548.2	1016.2	1.0160	1536.6	1012.6	0.9542	1518.4	1006.8	0.8964
0.01	1552.4	1016.8	1.0222	1537.4	1013.2	0.9696	1520.4	1006.6	0.9216
0.02	1552.8	1018.2	1.0384	1538.2	1014.4	0.9756	1521.2	1007.6	0.9846
0.03	1553.4	1020.2	1.0426	1540.4	1015.6	0.9988	1522.8	1008.8	1.0082
0.04	1554.6	1022.4	1.0730	1542.8	1016.2	1.0212	1524.2	1010.2	1.0098
0.05	1556.4	1024.8	1.0948	1543.8	1018.4	1.0668	1525.8	1014.8	1.0118

0.06	1557.2	1026.6	1.1312	1544.4	1020.2	1.0910	1526.2	1015.6	1.0418
0.07	1560.6	1027.4	1.1472	1546.0	1022.4	1.1088	1526.6	1016.8	1.0498
0.08	1561.4	1028.8	1.1512	1548.6	1025.6	1.1164	1529.2	1018.6	1.0644
0.09	1562.4	1030.6	1.1994	1549.6	1026.8	1.1522	1532.6	1022.6	1.0948
0.1	1564.2	1032.8	1.2258	1552.2	1028.4	1.1596	1534.2	1024.2	1.1246
				Co(II) metal ion solution					
0	1540.2	1016.6	0.9976	1528.2	1010.8	0.9688	1508.4	1004.6	0.9426
0.01	1542.2	1018.4	1.0048	1528.8	1011.4	0.9890	1508.6	1006.2	0.9846
0.02	1543.6	1019.6	1.0126	1529.6	1012.8	1.0042	1510.6	1006.4	0.9954
0.03	1544.8	1020.2	1.0414	1530.8	1014.2	1.0072	1512.2	1008.4	1.0036
0.04	1545.6	1020.8	1.0526	1531.6	1016.2	1.0292	1512.6	1010.8	1.0067
0.05	1546.8	1022.4	1.0938	1532.6	1016.8	1.0512	1514.6	1011.2	1.0264
0.06	1547.6	1025.2	1.1052	1534.0	1018.8	1.0812	1516.8	1012.2	1.0346
0.07	1548.8	1026.8	1.1282	1535.8	1019.2	1.0924	1517.8	1014.8	1.0684
0.08	1551.2	1027.8	1.1428	1536.6	1022.8	1.1046	1520.6	1016.2	1.0814
0.09	1552.8	1028.8	1.1512	1539.2	1024.6	1.1088	1522.8	1018.6	1.1040
0.1	1554.4	1030.6	1.1668	1542.4	1026.4	1.1204	1524.4	1020.8	1.1188

The acoustical parameters such as isentropic compressibility, K_s, intermolecular free length, L_f and specific acoustic impedance, Z, relative association, R_A, free volume, V_f, internal pressure, π_i, viscous relaxation time, τ and Gibb's free energy, ΔG, attenuation coefficient, α, Rao's constant, R_m, and Wada's constant, w of the mixture of manitol with Co(II) & Cu(II) metal ions in aqueous medium have been determined at 298.15 K and are given in tables 2-4.

Table 2 Calculated values of isentropic compressibility, K_s, intermolecular free length, L_f, specific acoustic impedance, Z and relative association, R_A for the mixtures at 298.15 K

Manitol con. (M)	Metal ion Concentration (M)											
	0.1M				0.05 M				0.025M			
	k_s (10^{-10} m^2N^{-1})	L_f (10^{-10} m)	Z (10^6 kg $m^{-2}s^{-1}$)	R_A	k_s (10^{-10} m^2N^{-1})	L_f (10^{-10} m)	Z (10^6 kg $m^{-2}s^{-1}$)	R_A	k_s (10^{-10} m^2N^{-1})	L_f (10^{-10} m)	Z (10^6 kg $m^{-2}s^{-1}$)	R_A
						Cu(II) metal ion solution						
0	4.1055	0.4317	1.5732	1	4.1825	0.4358	1.5559	1	4.3080	0.4423	1.5287	1
0.01	4.0809	0.4304	1.5784	0.9996	4.1757	0.4354	1.5576	1.0004	4.2976	0.4417	1.5304	0.9993
0.02	4.0732	0.4300	1.5810	1.0009	4.1664	0.4349	1.5603	1.0014	4.2888	0.4413	1.5327	1.0001
0.03	4.0620	0.4294	1.5847	1.0028	4.1496	0.4340	1.5644	1.0021	4.2747	0.4405	1.5362	1.0010

0.04	4.0470	0.4287	1.5894	1.0047	4.1342	0.4332	1.5677	1.0022	4.2609	0.4398	1.5397	1.0021
0.05	4.0282	0.4277	1.5949	1.0066	4.1200	0.4325	1.5722	1.0041	4.2327	0.4384	1.5483	1.0063
0.06	4.0170	0.4271	1.5986	1.0082	4.1095	0.4319	1.5755	1.0058	4.2272	0.4381	1.5500	1.0070
0.07	3.9964	0.4260	1.6033	1.0083	4.0922	0.4310	1.5806	1.0076	4.2200	0.4377	1.5522	1.0081
0.08	3.9869	0.4255	1.6063	1.0095	4.0657	0.4296	1.5882	1.0102	4.1982	0.4366	1.5576	1.0093
0.09	3.9748	0.4248	1.6102	1.0110	4.0557	0.4291	1.5911	1.0111	4.1632	0.4348	1.5672	1.0125
0.1	3.9573	0.4239	1.6155	1.0128	4.0359	0.4281	1.5962	1.0121	4.1481	0.4340	1.5713	1.0137
Co(II) metal ion solution												
0	4.1466	0.4339	1.5657	1	4.2361	0.4386	1.5447	1	4.3749	0.4457	1.5153	1
0.01	4.1285	0.4329	1.5705	1.0013	4.2303	0.4382	1.5462	1.0004	4.3668	0.4453	1.5179	1.0015
0.02	4.1162	0.4323	1.5738	1.0022	4.2200	0.4377	1.5491	1.0016	4.3544	0.4446	1.5202	1.0013
0.03	4.1074	0.4318	1.5760	1.0025	4.2076	0.4371	1.5525	1.0027	4.3365	0.4437	1.5249	1.0029
0.04	4.1007	0.4315	1.5777	1.0029	4.1949	0.4364	1.5564	1.0045	4.3240	0.4431	1.5289	1.0052
0.05	4.0879	0.4308	1.5814	1.0042	4.1870	0.4360	1.5583	1.0049	4.3108	0.4424	1.5315	1.0051
0.06	4.0726	0.4300	1.5865	1.0068	4.1711	0.4352	1.5628	1.0066	4.2941	0.4415	1.5353	1.0057
0.07	4.0599	0.4293	1.5903	1.0081	4.1597	0.4346	1.5652	1.0066	4.2775	0.4407	1.5402	1.0080
0.08	4.0434	0.4285	1.5943	1.0086	4.1408	0.4336	1.5716	1.0100	4.2558	0.4396	1.5452	1.0088
0.09	4.0312	0.4278	1.5975	1.0092	4.1196	0.4325	1.5770	1.0112	4.2336	0.4384	1.5511	1.0107
0.1	4.0159	0.4270	1.6019	1.0106	4.0953	0.4312	1.5831	1.0123	4.2156	0.4375	1.5561	1.0125

Table 3 Calculated values of Free volume, V_f, Internal Pressure, π_i, relaxation time, τ and Gibb's Free Energy, ΔG, for the mixtures at 298.15 K.

Manitol con. (M)	Metal ion Concentration (M)											
	0.1M				0.05 M				0.025M			
	V_f (10^{-6} m^3mol^{-1})	π_i (10^6 Nm^{-2})	τ (10^{-12} s)	ΔG (10^{-20} $KJmol^{-1}$)	V_f (10^{-6} m^3mol^{-1})	π_i (10^6 Nm^{-2})	τ (10^{-12} s)	ΔG (10^{-20} $KJmol^{-1}$)	V_f (10^{-6} m^3mol^{-1})	π_i (10^6 Nm^{-2})	τ (10^{-12} s)	ΔG (10^{-20} $KJmol^{-1}$)
Cu(II) metal ion solution												
0	524.60	0.9105	0.5561	0.5261	563.52	0.8914	0.5321	0.5076	604.49	0.8697	0.5149	0.49387
0.01	523.22	0.9107	0.5562	0.5261	551.93	0.8970	0.5398	0.5136	582.44	0.8794	0.5280	0.50445
0.02	512.46	0.9169	0.5639	0.5319	548.61	0.8985	0.5419	0.5153	529.16	0.9076	0.5630	0.53128
0.03	510.89	0.9180	0.5646	0.5325	532.04	0.9075	0.5526	0.5234	512.75	0.9169	0.5746	0.53982
0.04	491.08	0.9306	0.5790	0.5429	517.09	0.9155	0.5629	0.5312	513.49	0.9163	0.5736	0.53913
0.05	478.46	0.9391	0.5880	0.5494	485.94	0.9350	0.5860	0.5480	514.02	0.9178	0.5710	0.53718
0.06	457.00	0.9537	0.6058	0.5619	471.27	0.9447	0.5978	0.5563	493.37	0.9299	0.5871	0.54886
0.07	450.02	0.9581	0.6113	0.5657	461.80	0.9515	0.6049	0.5613	489.12	0.9323	0.5906	0.55135
0.08	449.09	0.9586	0.6119	0.5661	459.35	0.9541	0.6052	0.5615	481.48	0.9373	0.5958	0.55497
0.09	423.71	0.9775	0.6356	0.5820	439.59	0.968	0.6230	0.5737	464.23	0.9503	0.6077	0.56326
0.1	411.78	0.9872	0.6467	0.5893	437.54	0.9694	0.6240	0.5743	447.68	0.9618	0.6219	0.57297
Co(II) metal ion solution												

0	540.31	0.8979	0.5515	0.5226	549.05	0.8961	0.5472	0.5193	556.46	0.8917	0.5498	0.52135
0.01	536.85	0.8999	0.5531	0.5238	533.93	0.9039	0.5578	0.5274	522.62	0.9105	0.5732	0.53883
0.02	532.65	0.9020	0.5557	0.5258	523.53	0.9097	0.5650	0.5327	516.43	0.9133	0.5779	0.54220
0.03	512.53	0.9131	0.5703	0.5366	523.08	0.9098	0.5650	0.5327	512.17	0.9160	0.5802	0.54392
0.04	505.98	0.9164	0.5755	0.5404	508.02	0.9189	0.5756	0.5405	511.25	0.9170	0.5803	0.54399
0.05	479.36	0.9330	0.5961	0.5552	493.83	0.9270	0.5868	0.5486	498.80	0.9238	0.5899	0.55083
0.06	473.45	0.9376	0.6001	0.5580	475.22	0.9392	0.6013	0.5588	495.16	0.9257	0.5923	0.55254
0.07	460.68	0.9462	0.6107	0.5653	469.88	0.9420	0.6058	0.5619	473.46	0.9402	0.6093	0.56437
0.08	454.00	0.9504	0.6161	0.5690	463.59	0.9474	0.6098	0.5647	467.37	0.9442	0.6136	0.56731
0.09	450.80	0.9523	0.6187	0.5707	463.24	0.9478	0.6090	0.5641	455.17	0.9530	0.6231	0.57377
0.1	443.52	0.9576	0.6247	0.5748	458.58	0.9511	0.6117	0.5660	447.95	0.9584	0.6288	0.57757

Table 4 Calculated values of Attenuation Coefficient, α, Rao's constant, R_m, and Wada's constant, w, for the mixtures at 298.15 K.

Manitol con. (M)	Metal ion Concentration (M)								
	0.1M			0.05 M			0.025M		
	α (10^{-12} Hz)	R_m	w (10^{-6})	α (10^{-12} Hz)	R_m	w (10^{-6})	α (10^{-12} Hz)	R_m	w (10^{-6})
Cu(II) metal ion solution									
0	43.947	0.2080	823.96	42.049	0.2066	821.97	40.6878	0.2062	823.58
0.01	43.951	0.2084	824.81	42.658	0.2069	822.82	41.7299	0.2067	825.09
0.02	44.563	0.2085	824.51	42.826	0.2070	822.74	44.4915	0.2069	825.18
0.03	44.621	0.2084	823.73	43.668	0.2072	822.47	45.4081	0.2070	824.91
0.04	45.753	0.2083	822.82	44.482	0.2075	822.96	45.3338	0.2071	824.74
0.05	46.465	0.2083	821.72	46.308	0.2075	821.95	45.1229	0.2066	821.78
0.06	47.877	0.2083	821.10	47.238	0.2075	821.36	46.3998	0.2068	822.00
0.07	48.305	0.2086	821.55	47.806	0.2074	820.57	46.6765	0.2069	822.02
0.08	48.358	0.2087	821.30	47.823	0.2072	818.84	47.0815	0.2070	821.40
0.09	50.230	0.2087	820.76	49.235	0.2074	818.85	48.0230	0.2067	819.16
0.1	51.108	0.2087	819.92	49.309	0.2075	818.62	49.1504	0.2068	818.93
Co(II) metal ion solution									
0	43.584	0.2089	830.67	43.240	0.2073	827.22	43.4489	0.2066	828.03
0.01	43.707	0.2100	834.68	44.080	0.2086	832.26	45.3007	0.2076	832.28
0.02	43.915	0.2112	838.75	44.649	0.2097	836.17	45.6673	0.2091	837.23
0.03	45.067	0.2125	843.22	44.651	0.2109	839.92	45.8550	0.2101	840.67
0.04	45.478	0.2138	847.72	45.489	0.2119	843.35	45.8632	0.2110	843.66
0.05	47.111	0.2149	851.23	46.373	0.2132	847.83	46.6188	0.2124	848.20
0.06	47.423	0.2157	853.81	47.516	0.2142	851.05	46.8088	0.2137	852.59
0.07	48.260	0.2168	857.33	47.877	0.2156	855.60	48.1506	0.2146	855.44
0.08	48.685	0.2181	861.34	48.191	0.2162	857.58	48.4903	0.2158	859.34

0.09	48.895	0.2193	865.48	48.126	0.2173	861.06	49.2444	0.2167	862.43
0.1	49.369	0.2203	868.79	48.343	0.2185	864.28	49.6926	0.2177	865.72

The values of u, ρ and η increase with increase in concentration of manitol in all the ternary systems of metal ion under investigation (Fig. 1-3). As concentration (M) increases, the medium becomes denser due to the increasing number of molecules in the given region, this makes the lesser compressibility and hence sound velocity increases. It has also been supported by the fact that, the solute that increase the ultrasonic velocity values are structure makers and those decrease the sound velocity are structure breakers [18]. In addition the increasing number of molecules increases the fractional resistance between the layers of medium which results the viscosity coefficient increased. The values of ultrasonic velocity and their variation with molarities is almost same for all the mixture taken up the present study[19].

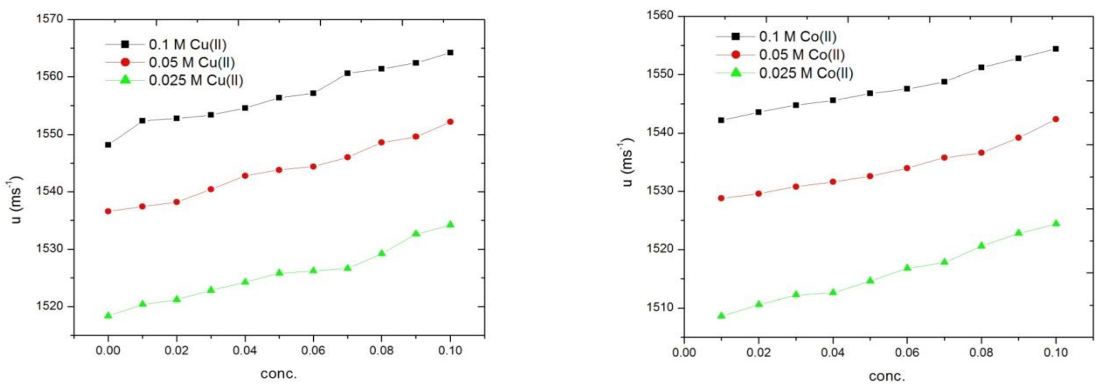

Fig.1 Variation of sound velocity (u) versus concentration (M) for different concentrations of Manitol solution with (a) 0.1 M, 0.05M and 0.025 M Cu (II) & (b) 0.1 M, 0.05M and 0.025 M Co(II) metal ion aqueous solution.

The increasing values of ultrasonic velocity with concentration may be due to the presence of interactions caused by the manitol and the hydrophilic nature of aqueous Cu(II) and Co(II) metal ions [20]. The increasing molecular associations in solutions may be due to water structure enhancement [21].

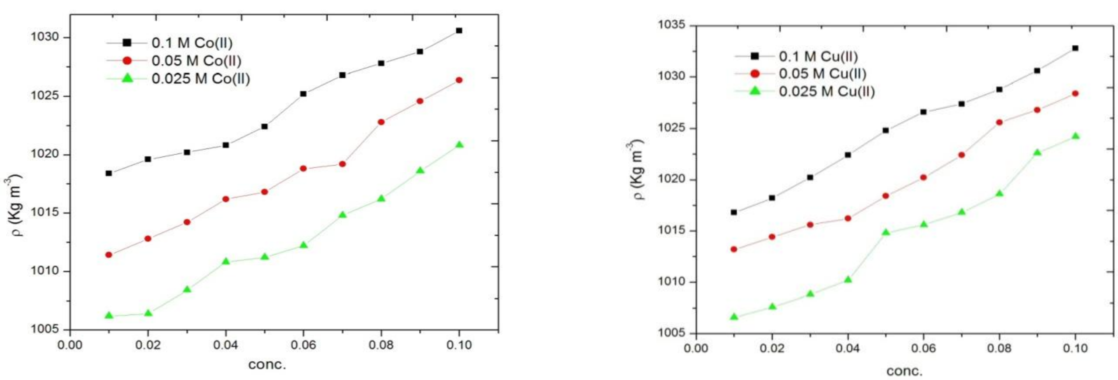

Fig.2 Variation of density (d) versus concentration (M) for different concentrations of Manitol solution with (a) 0.1 M, 0.05M and 0.025 M Cu (II) & (b) 0.1 M, 0.05M and 0.025 M Co(II) metal ion aqueous solution.

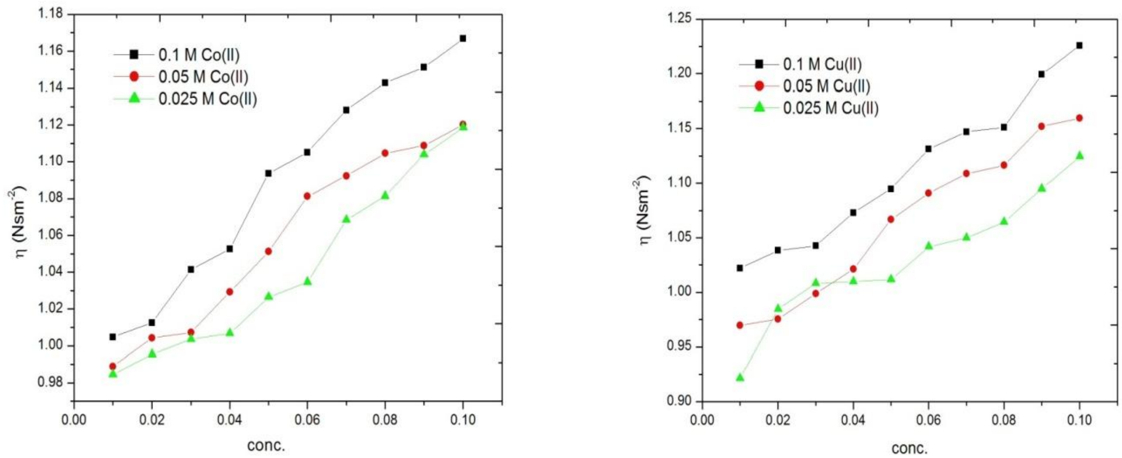

Fig.3 Variation of viscosity (*η*) versus concentration (M) for different concentrations of Manitol solution with (a) 0.1 M, 0.05M and 0.025 M Cu (II) & (b) 0.1 M, 0.05M and 0.025 M Co(II)

Density measurements also indicate the molecular interactions. As the density is increased with increasing solute concentration, the interaction between solvent–solvent and solute–solvent is also increased since available space for molecules is reduced, the larger number of solute particles occupy the free space in same region. This represents the structure-making capacity of the solute in solutions which depend on the hydrophobic or hydrophilic nature of the solute. [22]

To understand the structural changes and existing interactions between particles in solutions, the viscosity is another important parameter which influence to a certain extent, the change in structure of solvent or solution as compared to velocity and density.
The viscosity data were fitted into Jone-Dole equation:

$$\frac{(\eta_r-1)}{c^{1/2}} = A + Bc^{1/2} \quad \ldots\ldots\ldots\ldots..... (12)$$

Where η_r: relative viscosity (η / η_o), *A* : Falkenhagen coefficient and *B* : Jones-Dole coefficient.
These coefficients are calculated from linear plot of $(\eta_r - 1)/c^{1/2}$ versus $c^{1/2}$ for manitol in aqueous solution of Cu(II) and Co(II) metal ions at 298.15 K are listed in Table 5. [23-24].

The John-Dole equation generally describes the relative viscosity variation with concentration variation and observed values of viscosity coefficients support the structure making behavior. The A coefficient is negative or positive while the B coefficient is positive for all the systems indicating the strong ion solvent interaction. This may indicate that metal ions in the systems disturb the existing solvent structure and form a more stable arrangement. [25-27].

The values of isentropic compressibility (K_s) decrease with increasing concentration of manitol in aqueous solution of Cu(II) and Co(II) metal ions. [28] This may be due to the accumulation of solvent molecules around the solute molecules. Similar results obtained for intermolecular free length (L_f) suggest the strong interaction between solute and solvent. [29-30]. This can be explained as tight packing of molecules in the system which causes an increase in ultrasonic velocity [31]. This suggests a structure-making tendency of manitol with Cu(II) and Co(II) metal ions in aqueous solutions (Table 2). The behavior of acoustic impedance (Z) may be responsible for the propagation of ultrasonic waves [32]. The values of specific acoustic impedance increase with increase in concentration (Table 2) which is quite similar to the trends of ultrasonic velocity's variation.[33].

The relative association (R_A) is influenced either by breaking-up of solvent structures on addition of solutes or the solvation of solutes. The former results are seen in decreasing trend and the later results are seen in increasing trend in relative association (R_A). The R_A values show the positive change with increasing concentration and slightly greater than one. It may be suggested that the solvation of the solutes predominate over the breaking-up of the solvent structure. At very low concentration the observed decreasing trend is due to breaking up of the solvent on addition of manitol (Table 2). The increasing values of R_A with concentration suggest that solvation of solutes is more dominant over the breaking of the solvent structures. [34]

The values of free volume (V_f) decrease with increase in the solute concentration with slight deviations. The higher values of free volume indicate the weak solute-solvent interaction and vice-versa. The internal pressure (π_i) values decrease at lower concentration of solutes and increase at higher concentration of solutes. This decrease may be due to the loosening of cohesive forces leading to breaking up the structure of the solvent. The increasing value suggests the strengthening of cohesive forces, may be due to making up the solvent structure. The values of viscous relaxation time (τ) and Gibb's free energy (ΔG) increase with increase in solute concentration which shows the molecular interaction between solute-solvent molecules and stronger effect after increasing solute concentration [35]. The Gibb's free energy (ΔG) values suggest the denser system of the molecules due to the H-bond formation between different molecules in the solutions (Table 3) [32]. The Rao's constant (R_m), Wada's constant (w) and attenuation Coefficient (α) values also show an increasing trend with increase in solute concentration. This may be due to the presence of higher number of particles in same region which lead to a compact packing of the medium thus increasing the interactions (Table 4) [16,30,35].

Table 4. Coefficients of Jones–Dole equation for manitol in 0.1M, 0.05 M and 0.025 M aqueous solution of Cu(II) and Co(II) metal ions at 298.15 K

Metal ion concentration (M)	A	B
Manitol (0.01M-0.1M) + Cu(II) metal ion		
0.1	-0.257	2.78
0.05	-0.178	2.86
0.025	0.0594	2.24
Manitol (0.01M-0.1M) + Co (II) metal ion		
0.1	0.050	1.891
0.05	-0.739	4.74
0.025	-0.198	2.854

APPLICATIONS

The present acoustical data provides important information on solute-solvent interactions in solutions.

CONCLUSIONS

A systematic viscometric and acoustic studies of manitol - Cu(II) and Co(II) metal ion in aqueous medium has been carried out over whole concentration range. The acoustical data provides important information on solute-solvent interactions in solutions. From the experimental findings, various parameters, viz. K_s, L_f, Z, R_A, V_f, π_i, τ, ΔG, α, R_m, ,w, Falkenhagen Coefficient, A and Jones–Dole coefficient, B have been evaluated at 298.15 K. The results indicate the existence of solute– solvent interactions in these mixture, which increase with increasing solute concentration.

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