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Densitometric and Viscometric Study of Diclofenac Sodium in Aqueous Solution in Presence and Absence of Additives at Different Temperatures.

Arun B. Nikumbh*[a], Ganesh K. Kulkarni[a] and Ravindra C. Bhujbal[b]

a = P. G. Department of Chemistry, S. S. G. M. College, Kopargaon-423601. (M. S.) India

b = Department of Chemistry, Hon. B. J. College, Ale, Pune-412411. (M. S.) India

University of Pune, Maharashtra State, India.

Abstract:

The measurement of density and viscosity of diclofenac sodium in aqueous solution have been measured and analyzed in presence of additives viz. NaCl, dextrose, KCl, sodium lactate in a range of molarity, m= (4×10^{-3} to 1.99×10^{-2}) $mol.L^{-1}$, at T = (298.15 to 313.15)K using a pycknometer and Ubbelohde viscometer. The density results were used to evaluate the apparent molar volumes. Viscosity results were used to calculate Jones-Dole viscosity B-coefficient. The simple physical properties like density and viscosity are used to explain the molecular interaction in aqueous solutions as well as in presence of additives. Drug therapy now forms a major aspect of therapeutics. The drug interact with various ions, molecules, biological membranes present in the biological system is an important phenomenon.

Keywords: Diclofenac sodium, density, viscosity, apparent molar volume, B-coefficient.

1. INTRODUCTION

In solution chemistry the interpretation of molecular interactions are understood with apparent molar volumes, Jones-Dole and Moulik parameters. It is based on theories like Van't Hoff, Gibbs, Debye-Huckel and Onsagar. The simple physical properties like density and viscosity are used to evaluate the molecular interaction in aqueous solutions. Drugs which alter the pain sensitivity or removes pain from body parts are called pain killers or analgesics. Which meet the health needs of majority of the population? They must be effective, safe, and cost effective and meet the medical need of local people.

The drugs in any solid dosage form or suspension when administered will first change into drug solution in body fluids. So, dissolution rate is important factor affecting the rate of absorption. When a drug is more rapidly or completely absorbed from solution, it is very likely that its absorption will be dissolution limited. Viscosity limits the dissolution rate and thereby affects the rapid absorption. Aqueous solution of Na-Salicylate showed its rapid appearance in plasma while the same drug in suspension form failed to reach the target as quickly as with aqueous solution[1].

The parameters like apparent molar volume, density, viscosity and Jone-Dole parameters are useful to focus the solute-solvent interactions and to understand different biochemical reactions at 310.15 K i.e. at body temperature. It also enables to enrich the data at various composition and temperatures.

1.1 EXPERIMENTAL:

1.1.1 Materials:

Diclofenac sodium of high purity was obtained from Research lab fine chemicals and was used as received. Deionized water with a specific conductance of $< 10^{-6}$ $S.cm^{-1}$ was used for the preparation of solutions at room temperature in a molarity range (5.5×10^{-3} to 1.99×10^{-2}) $mol.L^{-1}$. The precision of balance used was $\pm 1 \times 10^{-5}$g.

1.1.2 Density measurements:

The pycknometer was calibrated by measuring the densities of triple distilled water. The densities of distilled organic liquids like acetone, alcohol, benzene, carbon tetra chloride, aniline, nitrobenzene were evaluated with respect to density of water as a standard. The density was measured with an uncertainty of $\pm$ 1.48 $\times 10^{-4} g.cm^{-3}$.

1.1.3 Viscosity measurements:

The solution viscosities are measured with an uncertainty of ± 1.48 $\times 10^{-4}$ m.Pa.s by using Ubbelohde viscometer. The temperature of thermostat is maintained to desired temperature, by using demerstat with an accuracy of ± 0.1 K. The flow time will be measured at the accuracy of ± 0.01 s.

The different compositions (0.0055 to 0.0199 M) of solutions of pain killers were prepared in NS, DNS, RL and D.W. The densities and viscosities were measured at T = (298.15, 303.15, 308.15, 310.15 & 313.15) K for nine different concentrations. The solvent compositions used are as under,

NS = (0.9g NaCl)/100 ml D.W.

DNS = (5% Dextrose + 0.9 g NaCl)/100 ml D.W.

RL = (0.320 g Sodium Lactate + 0.600 g NaCl + 0.040 g KCl

+ 0.035 g $CaCl_2.2H_2O$) / 100 ml D.W.

D.W. = Pure distilled water.

1.1.4 DATA EVALUATION

The apparent molar volume, ϕ_v, was obtained from the density results using the following equation[2, 3, 4]

$$\phi_v = \frac{1000(\rho_0 - \rho)}{C\rho_0} + \frac{M_2}{\rho} \qquad (1)$$

Where M_2, C, ρ and ρ_0 are the molar mass of the DS, concentration (mol.L^{-1}), and the densities of the solution and the solvent, respectively.

The apparent molar volumes (ϕ_v) were plotted against the square root of concentration ($C^{½}$) in accordance with the Masson's equation[5]

$$\phi_v = \phi v^{o} + S_v.C^{½} \qquad (2)$$

Where ϕv^{o} is the limiting apparent molar volume and S_v a semi-empirical parameter which depends on the nature of solvent, solute and temperature. Its (S_v) value for large organic solutes is not of much significance[6].

The viscosity results for the aqueous solutions of drugs were plotted in accordance with Jones-Dole equation[7]

$$\frac{\eta_r - 1}{C^{½}} = A + BC^{½} \qquad (3)$$

Where $\eta_r = (\eta/\eta_o)$ and η, η_o are viscosities of the solution and solvent respectively, C is the molar concentration. The linear plots for $(\eta_r - 1)/C^{½}$ versus $C^{½}$ were obtained for the DS. The B-coefficients were obtained from the linear plots using the least-square fitting method. The A- coefficient reflects solute-solute interaction[8] and the B-coefficient reflect the solute-solvent interactions. The interactions can also be evaluated from Moulik[9] and Root[10] equations,

$$\eta_r^2 = M + KC^2 \qquad (4)$$

$$(d - d_0)/C = A - B\,C^{½} \qquad (5)$$

1.2 RESULTS AND DISCUSSION

The values of the density, apparent molar volume and viscosity of DS in NS, DNS, RL and pure distilled water are listed in table-1. In all sets the densities and viscosities of solutions increases with increase in concentration of solution[11]. At higher temperatures the values of densities and viscosities are smaller. The apparent molar volumes (ϕ_v) were calculated by using equation (1). The plots of ϕ_v with square root of concentration are linear for all the concentrations investigated. Figure-1 shows plots of apparent molar volume ϕ_v of DS against square

root of concentration over the temperature range 298.15 K to 313.15K for NS. Similar such plots were observed for DNS, RL and DW solvent systems.

The limiting apparent molar volumes (ϕv^0) have been calculated from the intercept of linear plots using equation (2). They are listed in table-2. The ϕv^0 values provide information regarding the solute-solvent interactions, drug hydrophobicity and hydration properties. Inspection of table-2, shows the positive values of Φ_v^0 for all sets. The positive values of ϕv^0 suggests strong solute-solvent interactions[12, 13]. The negative values of S_v obtained from the slope indicate weak solute-solute interactions.

The viscosities (η) of solutions are listed in table-1. The η values increases with concentration and decreases with rise in temperature. This suggests the existence of molecular interactions occurring in the system. The viscosity data have been analyzed by using Jones –Dole equation (3). Where η and η_o are the viscosities of solute and solvent respectively. Figures-2 shows the variation of $(\eta_r-1)/C^{1/2}$ against square root of concentration over the temperature range 298.15 K to 313.15K for different concentrations for NS. Similar such plots were observed for DNS, RL and DW solvent systems. 'A' is constant independent of concentration and 'B' is Jones-Dole coefficient represents measure of

Table 1: Density, apparent molar volume and viscosity of diclofenac sodium in NS, DNS, RL and pure distilled water at different temperatures.

SET 1 in NS					SET 2 in DNS				
T /K	C/mole/lit	ρ/(gm/cc)	η/ mPa.s	ϕ_v/cm^{3}mol^{-1}	T /K	C/mole/lit	ρ/(gm/cc)	η/ mPa.s	ϕ_v/cm^{3}mol^{-1}
298.15	0.008	0.99938	0.90717	24.959	298.15	0.008	1.00613	0.95606	-823.43
	0.01	1.00026	0.91046	-4.9086		0.01	1.00892	0.97112	-876.21
	0.012	1.00137	0.91401	-44.21		0.012	1.01179	0.98393	-918.39
	0.014	1.00223	0.91703	-54.393		0.014	1.01463	1.00254	-946.62
	0.016	1.00336	0.91965	-79.108		0.016	1.01757	1.02120	-974.3
	0.018	1.00419	0.92209	-81.599		0.018	1.0207	1.04089	-1006.7
	0.0199	1.0052	0.92395	-94.783		0.0199	1.02429	1.0545	-1062.8
303.15	0.008	0.99792	0.81235	40.0947	303.15	0.008	1.00502	0.85476	-853.49
	0.01	0.99879	0.81557	8.18097		0.01	1.00785	0.86878	-904.59
	0.012	0.99982	0.81767	-26.629		0.012	1.01056	0.88020	-928.88
	0.014	1.00071	0.82138	-41.498		0.014	1.01362	0.89124	-971.67
	0.016	1.00155	0.82365	-49.566		0.016	1.01635	0.90844	-983.19
	0.018	1.0026	0.82526	-67.684		0.018	1.01942	0.92292	-1011.4
	0.0199	1.00363	0.82699	-83.234		0.0199	1.02281	0.93748	-1057.2
308.15	0.008	0.99606	0.73446	69.1545	308.15	0.008	1.00337	0.76936	-852.37
	0.01	0.99685	0.73655	39.4769		0.01	1.00605	0.78267	-888.93
	0.012	0.99788	0.73897	-0.5881		0.012	1.00863	0.79379	-905.16
	0.014	0.99881	0.74119	-22.082		0.014	1.0115	0.80844	-937.91
	0.016	0.99966	0.74345	-33.221		0.016	1.01431	0.81592	-958.9
	0.018	1.00079	0.74496	-57.682		0.018	1.01728	0.82981	-984.41
	0.0199	1.00163	0.74713	-64.553		0.0199	1.02105	0.84107	-1052.3
310.15	0.008	0.99532	0.70476	69.2055	310.15	0.008	1.00285	0.74073	-880.76
	0.01	0.99611	0.70678	39.5056		0.01	1.00545	0.75193	-903.73
	0.012	0.99705	0.70895	6.98968		0.012	1.00815	0.76243	-927.73
	0.014	0.99805	0.71165	-20.655		0.014	1.01107	0.77587	-961
	0.016	0.99902	0.71409	-39.571		0.016	1.01363	0.78425	-963.42
	0.018	0.99978	0.71598	-42.539		0.018	1.01644	0.79715	-979.53
	0.0199	1.00047	0.71742	-43.223		0.0199	1.02023	0.81059	-1049
313.15	0.008	0.99411	0.66431	83.1746	313.15	0.008	1.00146	0.69792	-845.12
	0.01	0.995	0.66662	40.5595		0.01	1.0041	0.70599	-879.46
	0.012	0.99581	0.6691	18.799		0.012	1.00653	0.71570	-884.93
	0.014	0.99674	0.67034	-5.495		0.014	1.00917	0.72921	-904.24
	0.016	0.99777	0.6718	-30.12		0.016	1.01235	0.73546	-953.1
	0.018	0.99859	0.6754	-37.521		0.018	1.01524	0.74826	-974.99
	0.0199	0.99947	0.67845	-48.369		0.0199	1.01885	0.75951	-1035.9

Table 1: Continued……

SET 3 In RL					SET 4 In D.W.				
T /K	C/mole/lit	ρ/(gm/cc)	η/ mPa.s	ϕ_v/cm^3mol^{-1}	T /K	C/mole/lit	ρ/(gm/cc)	η/ mPa.s	ϕ_v/cm^3mol^{-1}
298.15	0.0055	1.00064	0.90862	-338.56	298.15	0.006	0.9975	0.90112	242.033
	0.007	1.0016	0.91392	-335.74		0.008	0.99776	0.90307	228.577
	0.0085	1.00254	0.91906	-331.66		0.01	0.99809	0.90531	213.427
	0.01	1.00346	0.92146	-326.87		0.012	0.99847	0.90726	199.097
	0.0115	1.00439	0.92523	-324.29		0.014	0.99887	0.90943	187.388
	0.013	1.00529	0.92757	-320.04		0.016	0.9992	0.91214	182.984
	0.0145	1.00615	0.93314	-313.96		0.018	0.99958	0.91507	176.734
303.15	0.0055	0.99927	0.81332	-333.53	303.15	0.006	0.99621	0.80708	233.973
	0.007	1.00022	0.81749	-330.44		0.008	0.99645	0.8089	225.109
	0.0085	1.00116	0.81924	-327.37		0.01	0.99689	0.81042	199.609
	0.01	1.00208	0.82423	-323.29		0.012	0.99715	0.81279	197.684
	0.0115	1.00299	0.82799	-319.47		0.014	0.99755	0.81421	186.198
	0.013	1.0039	0.83023	-316.6		0.016	0.99787	0.81621	182.598
	0.0145	1.00475	0.83406	-310.21		0.018	0.99826	0.8192	175.848
308.15	0.0055	0.9976	0.7361	-326.75	308.15	0.006	0.99459	0.72885	232.677
	0.007	0.99855	0.73897	-325.23		0.008	0.99487	0.73052	219.174
	0.0085	0.99947	0.7419	-320.79		0.01	0.99527	0.73276	198.926
	0.01	1.00039	0.74429	-317.76		0.012	0.99554	0.73453	196.324
	0.0115	1.00128	0.74888	-312.97		0.014	0.99593	0.73648	185.78
	0.013	1.00218	0.75203	-310.13		0.016	0.99625	0.73866	182.265
	0.0145	1.00302	0.75612	-303.75		0.018	0.99665	0.73932	175.011
310.15	0.0055	0.99683	0.70716	-321.5	310.15	0.006	0.99392	0.70027	221.082
	0.007	0.99776	0.70956	-318.26		0.008	0.99416	0.70224	215.552
	0.0085	0.99867	0.71223	-313.9		0.01	0.99457	0.70382	195.034
	0.01	0.99958	0.7152	-310.93		0.012	0.99487	0.7056	190.575
	0.0115	1.00049	0.71837	-308.82		0.014	0.99521	0.70686	184.474
	0.013	1.00136	0.72254	-304.14		0.016	0.99552	0.70789	181.768
	0.0145	1.0022	0.72519	-298.4		0.018	0.99592	0.70944	174.578
313.15	0.0055	0.99572	0.66576	-320.02	313.15	0.006	0.99283	0.66076	219.644
	0.007	0.99665	0.66875	-317.17		0.008	0.99308	0.66215	213.265
	0.0085	0.99757	0.67161	-314.25		0.01	0.99351	0.66358	191.206
	0.01	0.99847	0.67219	-310.27		0.012	0.99378	0.66468	189.943
	0.0115	0.99936	0.67578	-306.52		0.014	0.99412	0.66579	183.955
	0.013	1.00026	0.67798	-304.48		0.016	0.99445	0.66669	180.069
	0.0145	1.00111	0.68379	-299.43		0.018	0.99483	0.66776	174.208

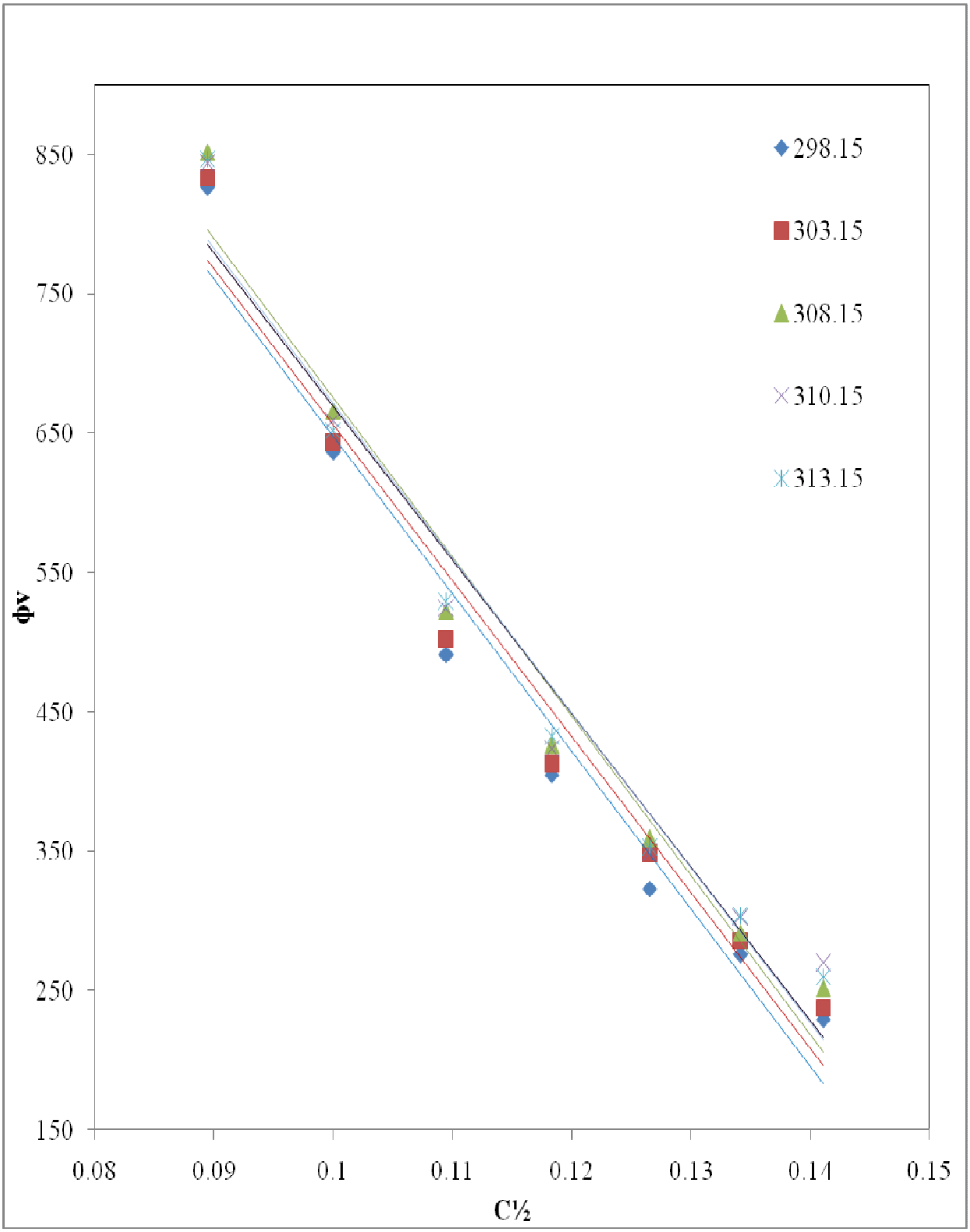

Figure- 1: Plot of ϕ_v Versus C½ of DS in NS at different temperatures.

Table 2: The interaction parameters of diclofenac sodium solutions at various temperatures.

Sets	T /K	**Masson equation**		**Roots equation**		**Jone-Dole equation**		**Moulik equation**	
		Φ_v^0	S_v	A	B	A	B	M	K
Set 1	298.15	1777	-11301	11.31	-1.462	-0.277	2.801	0.990	109.8
	303.15	1774	-11181	11.18	-1.456	-0.435	3.439	0.972	105.1
	308.15	1817	-11418	11.39	-1.496	-0.307	3.791	0.984	101.6
	310.15	1770	-11012	10.98	-1.448	-0.358	3.129	0.980	109.5
	313.15	1781	-11097	11.05	-1.456	-0.315	3.038	0.985	121.1
Set 2	298.15	6077	-41834	32.79	-5.897	-2.625	19.54	0.816	560.0
	303.15	5922	-40818	41.68	-5.728	-2.515	18.33	0.818	508.5
	308.15	5902	-40537	41.32	-5.697	-2.468	17.89	0.823	481.6
	310.15	5819	-39930	40.67	-5.608	-2.459	17.87	0.823	490.0
	313.15	5871	-40256	40.95	-5.654	-2.372	17.16	0.827	469.6
Set 3	298.15	1614	-11594	14.18	-1.448	-0.173	3.25	1.006	280.2
	303.15	1646	-11772	14.38	-1.480	-0.443	4.411	0.978	276.3
	308.15	1630	-11633	14.19	-1.459	-0.733	5.794	0.950	290.3
	310.15	1613	-11503	14.02	-1.439	-0.891	6.394	1.028	301.9
	313.15	1612	-11506	14.01	-1.437	-0.730	5.521	1.023	286.2
Set 4	298.15	333.8	-1200	-0.02	1.24	0.008	1.219	1.012	114.2
	303.15	313.3	-1049	-0.008	1.169	0.010	1.154	1.012	107.7
	308.15	306.6	-1001	-0.003	1.134	0.022	1.175	1.014	113.5
	310.15	285.0	-836.5	0.027	0.89	0.037	0.918	1.014	97.5
	313.15	280.4	-808.8	0.031	0.866	0.043	0.687	1.012	81.14

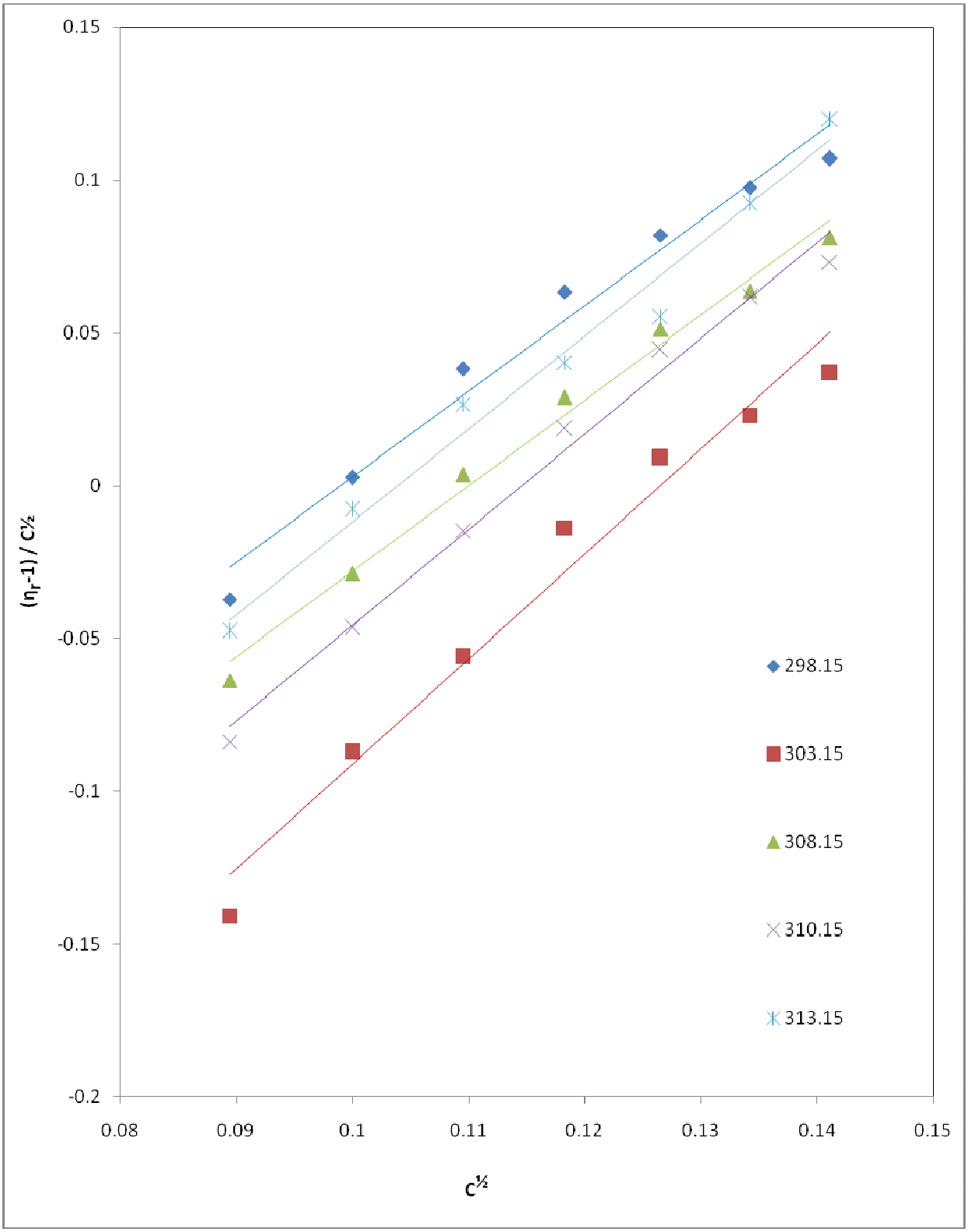

Figure- 2: Plot of $(\eta_r-1)/C^{½}$ Versus C½ of DS in NS at different temperatures.

order and disorder introduced by solute into the solution; positive B-coefficient shows strong alignment of solvent towards solute and is related to the effect of the solute on the structure of water [14, 15]. The strong interaction immobilizes the neighboring solvent molecules and presents large obstruction to viscous flow of solution thereby increasing viscosity. Thus the present system behaves as structure maker.

The parameters are obtained from Masson equation, Root equation, Jone-Dole equation and Moulik equation. The 'A' coefficients of Root's equation for set 1 to 3 are positive; while for set 4 are positive as well as negative. The positive values show strong solute-solute interactions with additives, while negative values show weak interactions. The 'B' coefficients are negative for set 1 to 3 and are positive for set 4. M and K coefficients are positive in all solvent systems & at all temperatures. M values are of low magnitudes & K values are of higher magnitudes. These models satisfy the investigated systems.

1.3 CONCLUSIONS:

From densitometric and viscometric studies of aqueous solutions of DS and in presence of additives as NaCl, KCl, Dextrose, Sodium lactate etc. at different temperatures shows,

1. All the values of ϕv^0 at all temperatures are positive and higher; suggest the strong solute-solvent interactions in aqueous solution, that may have the implication for the permeation of those molecules through biological membranes. All the S_v values are negative and are very small, suggesting weak solute-solute interactions.

2. The positive values of Jones-Dole coefficient 'B' at all temperatures indicates water structuring. Positive values of B suggesting strongly hydrated solute. Which indicates structure promoting tendency. (i. e. kosmotropes).

3. In aqueous solution (set-4) the values of apparent molar volume are positive and decrease with the extent of hydrogen bonding. Lower the apparent molar volume values, stronger are the hydrogen bonds.

4. Root's & Moulik equations are found to be obeyed for DS in presence and absence of additives.

REFERENCES:

1. Surender Singh, Essentials of Pharmacology, Academa Publishers, First Edition, Section- I, Chapter 1.2, (2004), PP 10.

2. Andreu A M, Ernesto V and Penna M P, *J. Chem. Eng. Data*, 44 (1999) 86.

3. Ernesto V, Francisco J R and Andreu A M, *J. Chem. Eng. Data*, 44 (1999) 1212.

4. P S Nikam and A B Nikumbh, *J. Chem. Eng. Data*, 47 (2002) 400-404.

5. Masson D O, Solute molecular volumes in relation to the solvation and ionization, *Philos. Mag*, 8 (1929) 218.

6. M J Iqbal, M A Choudhry, Thermodynamic Study of Three Pharmacologically Significant Drugs: Density, viscosity and refractive index measurements at different temperatures, J. Chem. Thermodynamics, 41 (2009) 221-226.

7. G. Jones, M. Dole, The viscosity of aqueous solutions of strong electrolytes with special reference to barium chloride, *J. Am. Chem. Soc*,. 51 (1929) 2950-2964.

8. H Falkenhagen, M Dole, Viscosity of electrolyte solutions and its significance to the Debye theory, *Zeitschrift Fur Physik*, 30 (1929) 611-616.

9. Moulik Satya P, Proposed viscosity-concentration equation beyond Einstein region, *J. Phy. Chem*, 72 (1968) 4682-84.

10. Root W C, An equation relating density and concentration, *J. Am. Chem. Soc.*, 55 (1933) 850-51.

11. M J Iqbal, M Siddiquah, Partial molar volumes of meteneric acid in alcohol at temperatures between T= 293.15 and T = 313.15 K, *J. Braz Chem. Soc.*, 17 (2006) 851.

12. A. Ali, A. K. Nain, N. Kumar, M. Ibrahim, Density and viscosity of magnesium sulphate in formamide + ethylene glycol mixed solvents, *J. Chem. Sci.*, 114 (5) (2002) 495.

13. A. Ali, Shahjahan, Volumetric, viscometric and refractive index behavior of some α- amino acids in aqueous tetra propyl ammonium bromide at different temperatures, *J.Iranian Chem. Soc.*, 3 (2006) 340.

14. R. A. Robinson, R. H. Stokes, Electrolytic solutions, Butterworth scientific publications, London,1959.

15. B.Haribar, N.T.Southall, V. Vlachy, K. A. Dill, How ions affect the structure of water, *J. Am. Chem. Soc.*, 124, issue 41 (2002) 12302-12311.