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Original Research Article

PHYSICOCHEMICAL PROPERTIES OF NAPROXEN SODIUM IN DIFFERENT SOLVENT SYSTEMS AT DIFFERENT TEMPERATURES

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Abstract: The study of the volumetric behavior of pain killers as electrolytes in solution provides information useful to elucidate ion–ion, ion–solvent, and solvent–solvent interactions. Apparent molar volumes (ϕ_v) and viscosity B-coefficients for naproxen sodium solutions in NS (Normal Saline), DNS (NS with dextrose), RL (Ringer lactate) and pure water system have been determined from density (ρ) and viscosity (η) measurements at 298.15 to 313.15 K using a pycnometer and Ubbelohde viscometer respectively. Various concentrations of naproxen sodium solutions ranging from 0.0060 to 0.0199 M were prepared. The apparent molar volumes were calculated from the density data. In addition, the concentration dependence of the apparent molar volumes was examined using Masson's equation. The Jones-Dole equation was used to analyze viscosity data to obtain viscosity 'A' and 'B' coefficients. The concentration dependence of the apparent and partial molar volumes can be used to study ion–ion interactions, whereas the partial molar volumes at infinite dilution provide information on ion–solvent interactions.

Keywords: Naproxen sodium, density, viscosity, B-coefficient.

Introduction:

It is well known that physicochemical characterization of drugs plays a crucial role in all the stages associated to design and development of pharmaceutical dosage forms, especially those intended to parenteral administration[1]. In this context, as a contribution to generation and systematization of physicochemical information about drugs' behavior in NS, DNS, RL and aqueous system, the main goal of this study was to evaluate the effect of concentration and temperature on the apparent molar volume of drugs in different solvent systems.

The partial molar volume and the related volumetric parameters of drug compounds in dilute aqueous solutions at different temperatures and pressures are studied by

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several authors [2-5]. Due to importance of non-steroidal anti-inflammatory drugs (NSAID), the study of its volumetric properties in various aqueous solutions may be helpful in investigating the molecular phenomenon. The apparent molar volumes of pain killers in different solvents systems as NS, DNS, RL and pure water at different temperatures T = (298.15, 303.15, 308.15, 310.15 and 313.15) K are reported in the present paper.

Non-narcotic analgesics have three important properties namely analgesics, antipyretics and anti-inflammatory (e.g. Aspirin and Paracetamol). The non-narcotics (salicylates) are called aspirin like or Non-steroidal Anti-inflammatory Drugs (NSAIDS). These drugs have common mechanism of inhibiting the cyclooxygenase (COX), the key enzyme responsible for biosynthesis of Prostaglandins (PG).

Bio-pharmaceutics is the study of factors influencing the extent and rate of absorption. The rate and amount of drug absorption depends on biological and physicochemical factors. During their way to site of action, drug molecules have to cross one or more membranous barrier, which are lipoidal in nature and have different size of pores. Physicochemical factors include lipid solubility, salt complexation, dissolution rate, Viscosity and drug stability in GIT. Lipid soluble drugs more unionized and easily absorbed Na and K salts of weak acid have higher absorption rate than acids.

All 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 there by affect the rapid absorption. E.g. 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[6].

The study of the volumetric behavior of electrolytes in solution provides information useful to elucidate ion–ion, ion–solvent, and solvent–solvent interactions. The concentration dependence of the apparent and partial molar volumes can be used to study ion–ion interactions, whereas the partial molar volumes at infinite dilution provide information on ion–solvent interactions. The data reported here were obtained by performing density measurements on solutions of naproxen sodium in NS, DNS, RL and pure water solvent systems.

Experimental:

Materials:

Naproxen sodium of high purity was obtained from Research Lab Fine Chemicals, Mumbai, recrystallized and then used. De-ionized 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 (6.0×10^{-3} to 1.99×10^{-2}) $mol.L^{-1}$. The precision of balance used was $\pm 1\times10^{-5}$g.

Density measurements:

The pycnometer was calibrated by measuring the densities of triple distilled water. The densities of distilled organic liquids like acetone, alcohol, benzene, carbon tetra chloride, aniline, and nitrobenzene were evaluated with respect to density of water. The densities of solution of naproxen sodium in NS, DNS, RL and pure water were measured by bicapillary pycnometer at different temperatures. The density was measured with an uncertainty of $\pm 1.48\times10^{-4}g.cm^{-3}$.

Viscosity measurements:

The different compositions (0.0199M to 0.0060M) of solutions of naproxen sodium were prepared in NS, DNS, RL and pure water solvent systems. The viscosities were measured at 298.15, 303.15, 308.15, 310.15 and 313.15K temperatures for seven different concentrations. The solution viscosities were measured with an uncertainty of ± 2.4×10^{-4} mPa.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.

Data Evaluation:

The apparent molar volumes, ϕ_v, were obtained from the density results using the following equation[7-10]

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

where M_2, C, ρ and ρ_0 are the molar mass of the naproxen sodium, 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[11]

$$\phi_v = \Phi_v^0 + S_v.C^{½} \qquad (2)$$

Where Φ_v^0 is the limiting apparent molar volume and S_v a semi-empirical parameter which depends on the nature of solvent, solute and temperature.

The viscosity results for the aqueous solutions of drugs were plotted in accordance with Jones-Dole equation[12]

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

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 (η_r - 1)/$C^{½}$ versus $C^{½}$ were obtained for the naproxen sodium. The B-coefficients were obtained from the linear plots using the least-square fitting method. The A- coefficient reflects solute-solute interaction[13] and the B-coefficient reflect the solute-solvent interactions. Since in general, A/B <<1, the Jones –Dole equation reduces to,

$$\eta_r = 1 + \beta C, \qquad (4)$$

The relative viscosity data of these solutions have also been fitted in Moulik equation,

$$\eta_r^2 = M + K C^2 \qquad (5)$$

The density data of these solutions have also been fitted in Root's equation,

$$(d- d_0) / C = R - SC^{½} \qquad (6)$$

where R and S are constants.

Results and Discussion:

The values of the densities (ρ) and apparent molar volumes (ϕ_v) of naproxen sodium solution in different solvent systems at different temperatures are shown in Table 1 and 2 respectively.The tables 1 and 2 reveal that densities of naproxen sodium solutions under investigation decrease with increase in temperature and increases with increase in concentration. Such observations were previously made by Comesana et al.[14], Lee et al.[15, 16] and Nikumbh et al.[17] for other solutions. The values of ϕ_v increases with increase in concentration in pure water system while decreases with concentration in NS, DNS and RL solvent systems.

The apparent molar volumes at infinite dilution ($\Phi_v^0 = V_2^0$ and slopes S_v , calculated using Masson equation (2) are given in Table 3. The Φ_v^0 values of naproxen sodium under investigation in NS, DNS, RL and in pure water solvent systems are large and positive suggests presence of strong solute-solvent interactions promotes structure making effect.[18] These interactions are in the following order

$$\Phi_v^0(DNS) > \Phi_v^0(RL) > \Phi_v^0(NS) > \Phi_v^0(pure\ water)$$

Table 1: Densities of naproxen sodium solution in NS, DNS, RL and distilled water at different temperatures.

Solvent system	Molar Conc. of Naproxen sodium (C) mol/dm^3	Temperatures				
		298.15K	303.15K	308.15K	310.15K	313.15K
NS	0.0100	1.00166	1.00024	0.99845	0.99772	0.99651
	0.0120	1.00249	1.00106	0.99926	0.99852	0.99734
	0.0140	1.00331	1.00191	1.00006	0.99935	0.99816
	0.0160	1.00415	1.00273	1.00085	1.00014	0.99895
	0.0180	1.00496	1.00346	1.00166	1.00095	0.99975
	0.0199	1.00560	1.00418	1.00246	1.00164	1.00049
DNS	0.0060	1.00761	1.00611	1.00438	1.00356	1.00244
	0.0080	1.00841	1.00682	1.00510	1.00428	1.00316
	0.0100	1.01106	1.00955	1.00775	1.00700	1.00580
	0.0120	1.01347	1.01195	1.01022	1.00939	1.00819
	0.0140	1.01673	1.01522	1.01333	1.01265	1.01137
	0.0160	1.01928	1.01760	1.01586	1.01503	1.01367
	0.0180	1.02204	1.02044	1.01861	1.01778	1.01656
	0.0199	1.02451	1.02283	1.02108	1.02032	1.01903
RL	0.0060	0.99967	0.99829	0.99667	0.99594	0.99485
	0.0080	1.00046	0.99907	0.99739	0.99662	0.99554
	0.0100	1.00128	0.99984	0.99811	0.99736	0.99621
	0.0120	1.00197	1.00048	0.99884	0.99804	0.99686
	0.0140	1.00272	1.00112	0.99955	0.99875	0.99755
	0.0160	1.00348	1.00186	1.00024	0.99940	0.99816
	0.0180	1.00421	1.00258	1.00084	1.00003	0.99888
	0.0199	1.00480	1.00315	1.00135	1.00059	0.99949
Distilled water	0.0060	0.99771	0.99631	0.99465	0.99389	0.99274
	0.0080	0.99788	0.99645	0.99482	0.99405	0.99288
	0.0100	0.99803	0.99660	0.99496	0.99419	0.99302
	0.0120	0.99816	0.99672	0.99509	0.99432	0.99317
	0.0140	0.99833	0.99688	0.99523	0.99446	0.99329
	0.0160	0.99844	0.99703	0.99540	0.99458	0.99340
	0.0180	0.99854	0.99717	0.99553	0.99472	0.99353
	0.0199	0.99871	0.99729	0.99564	0.99486	0.99364

Table 2: Apparent molar volumes of naproxen sodium in NS, DNS, RL and distilled water at different temperatures.

Solvent system	Molar Conc. of Naproxen sodium (C) mol/dm^3	Temperatures				
		298.15K	303.15K	308.15K	310.15K	313.15K
NS	0.0100	430.75	431.36	439.10	431.45	433.97
	0.0120	331.92	333.23	340.46	334.90	334.47
	0.0140	262.05	260.99	270.72	263.80	264.11
	0.0160	208.39	208.69	219.04	212.97	213.22
	0.0180	168.32	172.99	177.74	172.32	173.09
	0.0199	144.20	144.41	144.66	145.28	143.44
DNS	0.0060	2982.7	2959.8	2961.7	2973.7	2949.6
	0.0080	2200.9	2194.8	2194.9	2203.9	2185.8
	0.0100	1551.3	1538.2	1545.8	1545.9	1539.1
	0.0120	1137.8	1127.4	1127.7	1134.3	1128.3
	0.0140	783.11	773.21	784.33	779.32	779.60
	0.0160	560.42	561.95	562.30	567.01	572.02
	0.0180	375.84	372.65	377.64	381.73	378.40
	0.0199	242.30	243.19	243.60	243.78	244.09
RL	0.0060	847.81	867.18	853.67	839.36	835.29
	0.0080	600.28	616.01	613.32	607.57	603.24
	0.0100	448.78	466.31	469.11	462.49	466.01
	0.0120	358.57	377.32	372.13	370.77	376.20
	0.0140	289.87	313.76	304.30	303.12	309.18
	0.0160	237.71	259.85	254.67	256.13	263.93
	0.0180	198.81	219.03	221.07	220.69	222.61
	0.0199	174.28	193.56	198.41	195.56	194.77
Distilled water	0.0060	140.99	151.22	156.50	159.97	168.55
	0.0080	147.68	159.17	159.43	163.33	172.33
	0.0100	153.69	162.94	164.21	167.36	174.60
	0.0120	159.38	167.96	168.24	170.88	175.27
	0.0140	160.57	168.68	170.39	172.68	177.91
	0.0160	165.23	169.84	170.12	175.28	180.52
	0.0180	169.41	171.31	172.15	176.19	181.43
	0.0199	168.82	173.08	174.38	176.53	182.81

Table 3: Φ_v^0 ($cm^3.mol^{-1}$) and S_v ($cm^3 .mol^{-3/2} .L^{1/2}$) of naproxen sodium solutions in different solvent systems at different temperatures.

Masson's parameters	Temperature (K)	NS	DNS	RL	Pure water
$\boldsymbol{\Phi_v^0}$	298.15	1102	5996	1520	107.4
	303.15	1099	5954	1533	129.9
	308.15	1123	5956	1512	135.6
	310.15	1101	5977	1487	139.4
	313.15	1109	5926	1478	152.1
$\boldsymbol{S_v}$	298.15	-6946	-42537	-10045	452.8
	303.15	-6913	-42237	-9989	317.8
	308.15	-7058	-42225	-9826	278.9
	310.15	-6915	-42372	-9643	275.4
	313.15	-6979	-41980	-9540	219.3

Table 4: $\Delta\Phi_v^0$ (tr) ($cm^3.mol^{-1}$) of Naproxen sodium solution wrt NS, DNS and RL at different temperatures.

Masson's parameters	Temperature (K)	NS	DNS	RL
$\Delta\Phi_v^0$ (tr) ($cm^3.mol^{-1}$)	298.15	994.6	5888.6	1412.6
	303.15	969.1	5824.1	1403.1
	308.15	987.4	5820.4	1376.4
	310.15	961.6	5837.6	1347.6
	313.15	956.9	5773.9	1325.9

Table 5: Viscosities of naproxen sodium in NS, DNS, RL and distilled water at different temperatures.

Solvent system	Molar Conc. of Naproxen sodium (C) mol/dm^3	Temperatures				
		298.15K	303.15K	308.15K	310.15K	313.15K
NS	0.0100	0.91602	0.82179	0.74147	0.71213	0.67063
	0.0120	0.91894	0.82443	0.74451	0.71541	0.67316
	0.0140	0.92116	0.82675	0.74673	0.71914	0.67542
	0.0160	0.92410	0.82921	0.74893	0.72082	0.67735
	0.0180	0.92685	0.83195	0.75277	0.72334	0.67989
	0.0199	0.93029	0.83673	0.75665	0.72515	0.68544
DNS	0.0060	0.96619	0.85558	0.76785	0.73663	0.69302
	0.0080	0.98033	0.87105	0.78386	0.74762	0.70417
	0.0100	0.99183	0.88143	0.79384	0.75945	0.71896
	0.0120	1.00491	0.89299	0.80597	0.77453	0.72944
	0.0140	1.01738	0.90352	0.81616	0.79075	0.74004
	0.0160	1.03429	0.91586	0.83053	0.80268	0.74796
	0.0180	1.04296	0.92817	0.83839	0.81213	0.75957
	0.0199	1.05973	0.95100	0.85955	0.81947	0.77412
RL	0.0060	0.91081	0.81753	0.73826	0.70883	0.67007
	0.0080	0.91430	0.82154	0.74155	0.71136	0.67241
	0.0100	0.91855	0.82494	0.74396	0.71365	0.67451
	0.0120	0.92152	0.82753	0.74616	0.71595	0.67637
	0.0140	0.92581	0.82867	0.74787	0.71801	0.67815
	0.0160	0.92940	0.83181	0.75128	0.71986	0.67989
	0.0180	0.93420	0.83526	0.75376	0.72198	0.68145
	0.0199	0.93784	0.83849	0.75553	0.72410	0.68304
Distilled water	0.0060	0.90164	0.81045	0.73481	0.70449	0.66483
	0.0080	0.90364	0.81265	0.73711	0.70602	0.66645
	0.0100	0.90585	0.81476	0.73921	0.70796	0.66793
	0.0120	0.90851	0.81655	0.74145	0.70932	0.67016
	0.0140	0.91046	0.81805	0.74327	0.71165	0.6713
	0.0160	0.91203	0.81981	0.74576	0.71313	0.67342
	0.0180	0.91437	0.822	0.74821	0.7145	0.67462
	0.0199	0.91622	0.82522	0.74987	0.71723	0.67538

Table 6: Relative viscosities of naproxen sodium in NS, DNS, RL and distilled water at different temperatures.

Solvent system	Molar Conc. of Naproxen sodium (C) mol/dm^3	Temperatures				
		298.15K	303.15K	308.15K	310.15K	313.15K
NS	0.0100	1.00639	0.99888	1.00380	1.00287	1.00522
	0.0120	1.00960	1.00209	1.00792	1.00749	1.00901
	0.0140	1.01204	1.00491	1.01092	1.01275	1.01240
	0.0160	1.01527	1.00790	1.01390	1.01511	1.01529
	0.0180	1.01829	1.01123	1.01910	1.01866	1.01910
	0.0199	1.02207	1.01704	1.02435	1.02121	1.02742
DNS	0.0060	0.92946	0.91987	0.91619	0.91494	0.91699
	0.0080	0.94306	0.93650	0.93529	0.92859	0.93175
	0.0100	0.95412	0.94766	0.94720	0.94329	0.95132
	0.0120	0.96671	0.96009	0.96167	0.96202	0.96519
	0.0140	0.97870	0.97141	0.97383	0.98216	0.97921
	0.0160	0.99496	0.98468	0.99098	0.99698	0.98969
	0.0180	1.00331	0.99791	1.00036	1.00872	1.00505
	0.0199	1.01944	1.02246	1.02561	1.01784	1.02431
RL	0.0060	1.00689	0.99684	0.98143	0.97242	0.98300
	0.0080	1.01075	1.00173	0.98580	0.97590	0.98643
	0.0100	1.01544	1.00588	0.98901	0.97904	0.98951
	0.0120	1.01873	1.00903	0.99193	0.98219	0.99224
	0.0140	1.02347	1.01043	0.99420	0.98502	0.99485
	0.0160	1.02744	1.01425	0.99874	0.98756	0.99740
	0.0180	1.03274	1.01846	1.00203	0.99046	0.99969
	0.0199	1.03677	1.02240	1.00439	0.99337	1.00202
Distilled water	0.0060	1.00892	1.01215	1.01702	1.01412	1.01346
	0.0080	1.01115	1.01490	1.02021	1.01632	1.01593
	0.0100	1.01363	1.01753	1.02311	1.01912	1.01819
	0.0120	1.01661	1.01977	1.02621	1.02107	1.02158
	0.0140	1.01879	1.02164	1.02873	1.02443	1.02332
	0.0160	1.02054	1.02384	1.03218	1.02656	1.02655
	0.0180	1.02316	1.02658	1.03557	1.02853	1.02838
	0.0199	1.02523	1.03060	1.03787	1.03246	1.02954

Table 7: Different parameters of naproxen sodium solution in NS, DNS, RL and distilled water at different temperatures.

NS					
T	298.15K	303.15K	308.15K	310.15K	313.15K
A($dm^{3/2}mol^{-1/2}$)	-0.153	-0.315	-0.274	-0.253	-0.264
B($dm^3.mol^{-1)}$	2.179	3.029	3.120	2.925	3.128
M	1.003	0.986	0.994	0.997	0.996
K	104.5	117.6	135.8	121.8	141.5
R	-0.853	-0.849	-0.871	-0.848	-0.854
S	6.970	6.927	7.060	6.912	6.967
β	1.768	1.768	2.208	1.864	2.054
DNS					
A($dm^{3/2}mol^{-1/2}$)	-2.090	-2.315	-2.433	-2.552	-2.440
B($dm^3.mol^{-1)}$	16.01	17.48	18.60	19.65	18.78
M	0.859	0.841	0.836	0.833	0.839
K	469.8	560.5	543.3	564.5	545.2
R	-5.890	-5.837	-5.829	-5.845	-5.786
S	43.57	43.19	43.11	43.23	42.77
β	6.368	6.854	7.376	7.786	7.451
RL					
A($dm^{3/2}mol^{-1/2}$)	-0.119	-0.244	-0.536	-0.695	-0.474
B($dm^3.mol^{-1)}$	2.687	2.874	4.125	4.713	3.568
M	1.012	0.995	0.963	0.946	0.967
K	166.5	131.4	122.1	109.3	100.1
R	-1.272	-1.284	-1.260	-1.234	-1.223
S	10.07	10.01	9.829	9.638	9.524
β	2.150	1.727	1.634	1.481	1.349
DW					
A($dm^{3/2}mol^{-1/2}$)	0.035	0.092	0.154	0.120	0.120
B($dm^3.mol^{-1)}$	1.021	0.805	0.794	0.718	0.664
M	1.017	1.023	1.023	1.027	1.027
K	90.03	96.54	116.9	99.65	92.06
R	0.145	0.122	0.117	0.113	0.101
S	-0.451	-0.316	-0.277	-0.273	-0.217
β	1.178	1.244	1.509	1.285	1.206

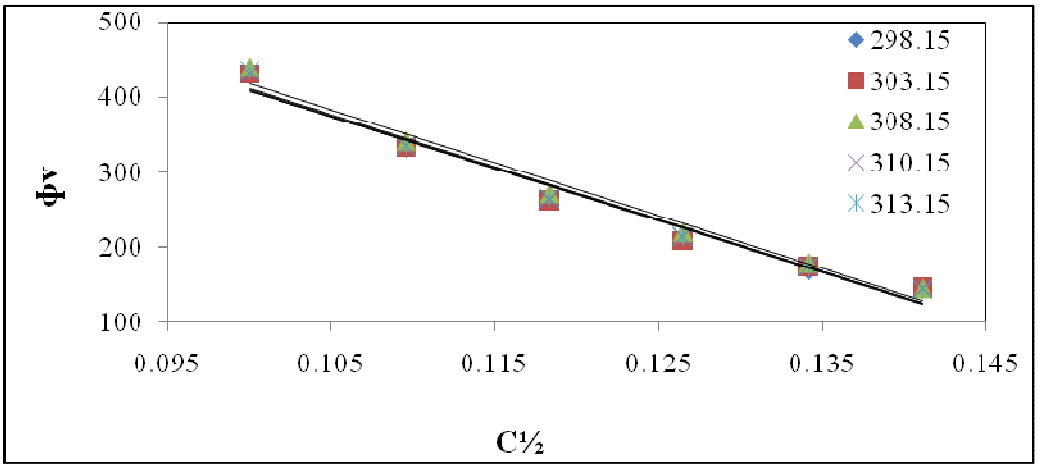

Fig.1: Plot of Φ_v ($cm^3.mol^{-1}$) Versus $C^{½}$ ($mol^{1/2}.dm^{-3/2}$) for naproxen sodium solutions in NS at temperature range T= (293.15 to 313.15K).

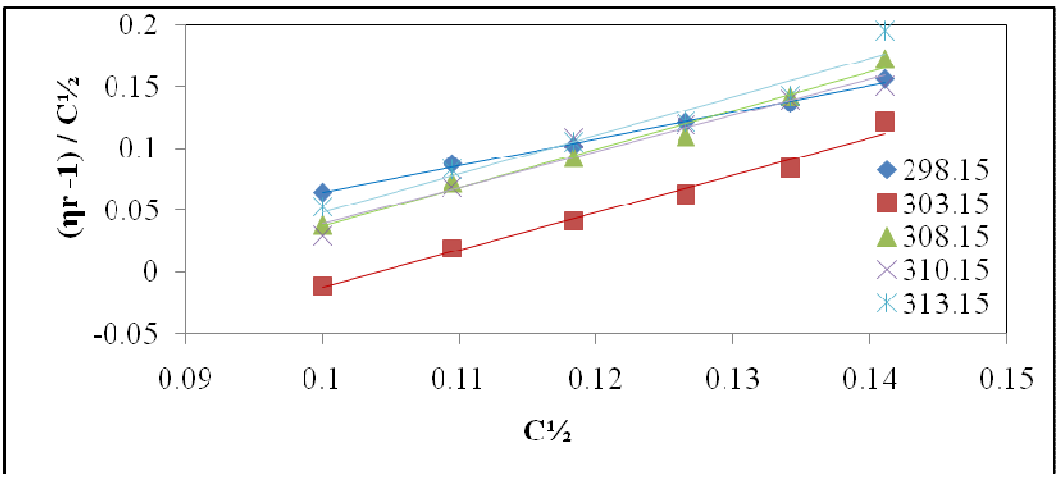

Fig.2: Plot of $(\eta_r-1)/C^{½}$ vs $C^{½}$ for naproxen sodium solutions in NS solvent system at different temperatures.

Fig. 1 is representative plot which represents variation of ϕ_v with $C^{½}$ in NS. It is observed that for lower concentration side the plot is linear but for higher concentration side, it slightly deviates from linearity due to strong solute- solvent interactions. Similar such behavior is observed in DNS, RL and pure water solvent systems.

It is interesting to note further that ϕ_v^0 value of pain killer solutions under investigation in pure water are further influenced by additives like NaCl, KCl, dextrose, sodium lactate in water. It is clear that the ϕ_v^0 values are much higher in NS, DNS and RL systems in comparison with that in pure water This indicates that the structure of water gets modified by pain killer and enhanced in the presence of ions of additives.

The slope S_v is negative for the naproxen sodium in NS, DNS and RL solvent

system while S_v is positive in pure water. The positive S_v values shows that naproxen sodium considerably associated in presence of ions. Since S_v is measure of solute-solute interactions[19, 20].These results indicate that there is presence of strong solute-solute interactions. S_v values do not change systematically with change in temperature, and hence it suggests that the solute-solute interactions are insensitive to change in temperature.

The table 4 includes the apparent molar volumes of transfer at infinite dilutions $\Delta \phi_v^{\circ}(tr)$ of naproxen sodium and are obtained from the relation

$\Delta \Phi_v^0$ (tr) = Φ_v^0 (pain killer in solvent system) – Φ_v^0 (DW)

Mishra, Prasad and Ahluwalia[21], using the model, observed that overlap of co-sphere of two ionic species shows an increase in volume where as overlap of hydrophilic-hydrophobic groups and ion hydrophobic groups show decrease in volume. The positive Φ_v^0 (tr) studied in the present investigation suggest that the ion-ion and ion-hydrophilic group interactions are stronger than the ion-hydrophobic interaction that results in an increase in volume.

The nature of interactions can be explained by involving co-sphere overlap model developed by Gurney [22]. The properties of water molecule in the hydration co-sphere depend on the nature of solute species[23, 24]. According to this model, NaCl, KCl all exist in the ionic form and thus overlap comes into play, because of the following types of interactions occur between solute and co-solute (NaCl, KCl).

1. Interactions between the ions of co-solutes and hydrophilic sites of pain killers.
2. Interactions between the co-solutes and hydrophobic groups of pain killers.

The first type of interactions contribute positively where as second type of interactions contribute negatively to $\Delta\Phi_v^0$ (tr) values. Therefore presently obtained positive values of $\Delta\Phi_v^0$ (tr) for naproxen sodium aqueous solutions in presence of NaCl, KCl etc. This suggest that the ionic hydrophilic interactions are dominating over ionic hydrophobic interactions.

The values of the viscosity and relative viscosities of naproxen sodium in NS, DNS, RL and pure distilled water at 298.15, 303.15, 308.15, 310.15 and 313.15K temperature are given in Table 5 & 6. In all sets the viscosities of solutions increases with increase in concentration of solution, while viscosity decreases with increase in temperature. This is in accordance with the observation made earlier by Comesana et al.[14], Lee et al.[15, 16] and Nikumbh et al.[17]. For each temperature relative viscosity increases with increase in concentration. The linear plots of $(\eta_r - 1)/C^{1/2}$ vs $C^{1/2}$ are obtained at all temperatures with regression coefficients higher than 0.99 and only representative plot is shown in Fig. 2 for NS solvent system.

Jones-Dole, Moulik, Roots and Jones-Dole reduced equation parameters are tabulated in Table 7. The present system obeys Jones-Dole, Moulik, Roots and Jones-Dole reduced equation. The linear Plots obtained show the applicability of these equations. 'A' is constant independent of concentration and 'B' is Jones-Dole coefficient represents measure of 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 ions on the structure of water[25]. The positive values of 'B' at all temperatures indicate water structuring[26].

The B values of naproxen sodium solutions in all the systems studied are positive; the (dB/dT) is negative in pure water system. Thus positive B and negative (dB/dT) values make naproxen sodium as structure promoter in pure water system. In the present investigation, 'B' values are found to be higher in DNS and follow the trend as,

$$B_{DNS} > B_{RL} > B_{NS} > B_{D.W}.$$

The positive β values and negative dβ/dT values in RL solvent system predict structure making tendency of naproxen sodium. The Moulik parameters are positive in all solvent systems. The Root's parameters, 'R' values are positive in pure water, while negative in other solvent systems. However, 'S' values are negative in pure water system and positive in NS, DNS and RL solvent systems.

The viscosities, relative viscosities and different parameters reported shows the expected variation of pain killer's w. r. t. selected concentrations and temperatures as that for electrolytes and non-electrolytes in pure and binary solvent systems including at body temperature.

Conclusions:

In the present report, physicochemical properties of solutions of naproxen sodium in NS, DNS, RL and pure water at different temperatures are systematically presented. It has been observed that there exist strong solute–solvent interactions in these systems, which increases with increase in drug concentration.

The values of ϕ_v^0 are positive suggest strong ion-solvent interactions. The positive values of Jones-Dole coefficient 'B' indicates structure promoting tendency and strong interactions between solute and solvent. Positive values of 'B' suggesting strongly hydrated solute indicating structure promoting tendency i.e. kosmotropes (structure makers). The Jones-Dole, Moulik, Roots and Jones-Dole reduced equation are verified to the naproxen sodium solutions in these solvent systems.

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