Apparent molar volumes and viscosity B-coefficients of sodium salicylate in different solvent systems at different temperatures.

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Abstract-Apparent molar volumes (ϕv) and viscosity B-coefficients for Sodium salicylate solutions in NS (Normal Saline), DNS (NS with dextrose), RL (Ringer lactate) and pure water solvent systems have been determined from density (ρ) and viscosity (η) measurements at 298.15 to 313.15 K using a bicapillary pycnometer and Ubbelohde viscometer respectively. The data were analyzed using Masson's equation to obtain limiting apparent molar volumes (ϕv°) and experimental slope (Sv). The Jones-Dole equation have been used to analyze viscosity data to obtain viscosity 'A' and 'B' coefficients. The drug interacts with various ions or molecules or biological membrane present in the biological system is an important phenomenon. The parameters derived from these equations have been interpreted in terms of solute-solute and solute-solvent interactions.

Keywords: Apparent molar volume, B-coefficient, density, Sodium Salicylate, viscosity,

1. INTRODUCTION

Drugs of the analgesics, antipyretics, and anti-inflammatory class include a heterogeneous group of compounds. Many of these agents affect pain, fever and inflammation and are referred to as the non-steroidal anti-inflammatory drugs (NSAIDs).

The principle mechanism of action for all NSAIDs appears to be inhibition of prostaglandin synthesis by blocking the activity of the precursor enzyme, cyclooxygenase (COX). Their actions on the prostaglandins likely account for many of the side effects of the NSAIDs. Although, in general, there is little difference between the efficacies of different NSAIDs, some patients may respond to one agent better than another. This is difficult to predict and often necessitates trial and error to find the most suitable drug.

The discovery that NSAIDs inhibit prostaglandin biosynthesis was made by John Vane and coworkers[1] in 1970. Tissue injury activates an enhanced conversion of arachidonic acid to prostaglandins via the COX pathway, this is so named because COX enzyme catalyzes the conversion. Because some prostaglandins amplify pain signals, inhibition of COX results in analgesia. NSAIDs have good analgesic efficacy, but less than that of opioids, a relatively rapid onset; well known adverse effects, including potentially fatal gastrointestinal bleeding and disturbance of salt and water balance.

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.
Eg. 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[2].

The parameters like apparent molar volume, density, viscosity 'A' and 'B' coefficient and Jones-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 compositions. The results are interpreted in terms of

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solute–solvent and solute–solute interactions in these systems.

2. EXPERIMENTAL

2.1 Materials:

Sodium salicylate of high purity was obtained from Loba Chemie Pvt Limited, Mumbai, recrystallized and then used. 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 (8.0×10^{-3} to 1.99×10^{-2}) $mol.L^{-1}$. The precision of balance used was $\pm1\times10^{-5}$g.

2.2 Density measurements:

The bicapillary 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 density was measured with an uncertainty of ± 1.48×10^{-4} $g.cm^{-3}$.

2.3 Viscosity measurements:

The solution viscosities were measured with an uncertainty of ± 2.4×10^{-4} mPa.s by using Ubbelohde viscometer. The viscosity measurements were performed at 298.15, 303.15, 308.15, 310.15 and 310.15K. 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 (0.0199M to 0.0080M) of solutions of Sodium salicylate were prepared in NS, DNS, RL and pure water. The viscosities were measured at different temperatures for seven different concentrations. The solvent system compositions used were as under,

- NS = (0.9 g 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.
- Distilled Water.

3. DATA EVALUATION

The apparent molar volumes, ϕv, were obtained from the density results using the following equation [3-6]

$$\Phi_V = \frac{1000(\rho_o-\rho)}{C\rho_o} + \frac{\mathcal{M}}{\rho} \qquad (1)$$

where M, C, ρ and ρ_0 are the molar mass of the Sodium salicylate, 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 [7]

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

Where ϕ_v^0 is the limiting apparent molar volume and Sv 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[8]

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

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 sodium salicylate. The B-coefficients were obtained from the linear plots using the least-square fitting method. The A- coefficient reflects solute-solute interaction[9] and the B-coefficient reflect the solute-solvent interactions.

4. RESULTS AND DISCUSSION

The values of the densities (ρ) and apparent molar volumes (ϕ_v) of sodium salicylate solution in NS, DNS, RL and pure water at 298.15, 303.15, 308.15, 310.15 and 310.15K temperature are shown in Table 1 and 2. In all sets the densities of solutions increases with increase in concentration of solution. The ϕv values decreases as drug concentration increases except in pure water system.

Fig 1 shows the linear plots of ϕ_v vs $C^{½}$ for sodium salicylate solutions in the NS solvent systems at different temperatures. Similar plots were obtained in DNS, RL and pure water solvent systems. Masson's parameters Φv0 and Sv were obtained from linear plots and are reported in table 3. The values of Φv0 obtained are positive for all the systems studied furnish important information regarding the drug hydrophobicity, hydration properties and solute-solvent interactions.

The Sv values are negative in NS, DNS and RL but in water system it is positive. The negative values of Sv for 0.08M NaCl as additive (-24443.8) were reported by Abdo Taher et. al[10]. Studies conducted on variety of compounds showed that negative values were associated with hydrophobic solutes[11]. The positive value indicates the presence of solute-solute interaction. The negative values of Sv for some solutes characterized by their water-structure promotion effects where the hydrophobic effect become dominant compared with hydrophilic effect, therefore the solvation around ionic moiety diminishes[12].

The values of the viscosity and relative viscosities of sodium salicylate in NS, DNS, RL and pure distilled water at 298.15, 303.15, 308.15, 310.15 and 310.15K are given in Table 4 and 5. In all sets the viscosities of solutions increases with increase in concentration of solution. Fig 2 shows the linear variation of $(\eta_r-1)/C^{½}$ against square

TABLE 1: DENSITIES AND APPARENT MOLAR VOLUMES OF SODIUM SALICYLATE SOLUTION IN NS AND DNS AT DIFFERENT TEMPERATURES.

Molar Conc. of Sodium salicylate (C) mol/dm^3	Temperatures				
	298.15K	303.15K	308.15K	310.15K	313.15K
NS					
Densities (ρ), (g.cm^{-3})					
0.0080	1.00065	0.99915	0.99751	0.99677	0.99566
0.0100	1.00135	0.99984	0.99820	0.99739	0.99633
0.0120	1.00218	1.00062	0.99892	0.99816	0.99712
0.0140	1.00274	1.00125	0.99953	0.99887	0.99778
0.0160	1.00338	1.00185	1.00015	0.99943	0.99825
0.0180	1.00404	1.00254	1.00090	1.00016	0.99897
0.0199	1.00475	1.00325	1.00154	1.00082	0.99965
Apparent molar volumes (Φ_v) (cm^3.mol^{-1})					
0.0080	509.59	520.29	511.18	502.85	493.43
0.0100	369.82	379.33	317.98	372.28	359.70
0.0120	265.85	277.87	276.68	272.73	260.54
0.0140	210.79	216.09	216.46	205.91	199.01
0.0160	164.53	171.62	170.67	165.18	164.75
0.0180	127.44	132.05	127.84	128.05	124.20
0.0199	94.947	99.094	98.762	94.317	93.423
DNS					
Densities (ρ), (g.cm^{-3})					
0.0080	1.00719	1.00578	1.00420	1.00351	1.00254
0.0100	1.00935	1.00824	1.00665	1.00602	1.00506
0.0120	1.01164	1.01019	1.00889	1.00854	1.00758
0.0140	1.01395	1.01228	1.01139	1.01100	1.01008
0.0160	1.01609	1.01443	1.01355	1.01345	1.01253
0.0180	1.01811	1.01672	1.01574	1.01564	1.01496
0.0199	1.02021	1.01875	1.01778	1.01762	1.01711
Apparent molar volumes (Φ_v) (cm^3.mol^{-1})					
0.0080	2259.9	2231.8	2214.8	2207.9	2171.4
0.0100	1628.3	1576.2	1563.3	1551.7	1521.3
0.0120	1196.7	1180.7	1146.0	1113.4	1087.8
0.0140	887.00	888.45	829.81	804.52	779.60
0.0160	665.10	665.58	613.46	573.49	551.52
0.0180	499.02	484.62	443.56	407.59	375.21
0.0199	363.28	353.56	315.78	286.46	248.36

Table 2: Densities and apparent molar volumes of Sodium Salicylate solution in RL and pure water at different temperatures.

Molar Conc. of Sodium salicylate (C) mol/dm^3	Temperatures				
	298.15K	303.15K	308.15K	310.15K	313.15K
RL					
Densities (ρ), (g.cm^{-3})					
0.0080	0.99996	0.99861	0.99692	0.99605	0.99494
0.0100	1.00062	0.99928	0.99758	0.99665	0.99554
0.0120	1.00127	0.99994	0.99819	0.99724	0.99618
0.0140	1.00190	1.00056	0.99882	0.99788	0.99672
0.0160	1.00245	1.00115	0.99943	0.99845	0.99732
0.0180	1.00300	1.00175	1.00007	0.99894	0.99786
0.0199	1.00359	1.00231	1.00053	0.99951	0.99832
Apparent molar volumes (Φ_v) (cm^3.mol^{-1})					
0.0080	570.74	581.44	579.94	586.67	586.07
0.0100	422.72	430.24	429.98	441.34	440.83
0.0120	324.87	330.27	334.17	345.29	340.67
0.0140	256.41	261.72	264.31	273.10	276.27
0.0160	210.04	212.18	213.16	223.35	224.22
0.0180	173.98	173.09	171.72	189.09	187.08
0.0199	143.05	143.73	147.50	157.67	161.37
Pure water					
Densities (ρ), (g.cm^{-3})					
0.0080	0.99775	0.99634	0.99464	0.99387	0.99277
0.0100	0.99792	0.99648	0.99475	0.99393	0.99285
0.0120	0.99807	0.99662	0.99487	0.99401	0.99294
0.0140	0.99823	0.99677	0.99498	0.99411	0.99301
0.0160	0.99839	0.99690	0.99509	0.99419	0.99308
0.0180	0.99852	0.99703	0.99520	0.99428	0.99315
0.0199	0.99866	0.99716	0.99530	0.99438	0.99325
Apparent molar volumes (Φ_v) (cm^3.mol^{-1})					
0.0080	71.562	80.446	89.38	93.222	93.325
0.0100	72.314	82.455	92.649	100.77	98.868
0.0120	74.487	83.794	93.991	104.13	101.72
0.0140	75.323	84.033	95.667	105.09	105.20
0.0160	75.950	85.467	96.925	107.06	107.81
0.0180	78.109	86.583	97.903	108.04	109.84
0.0199	78.927	87.108	98.877	108.06	109.70

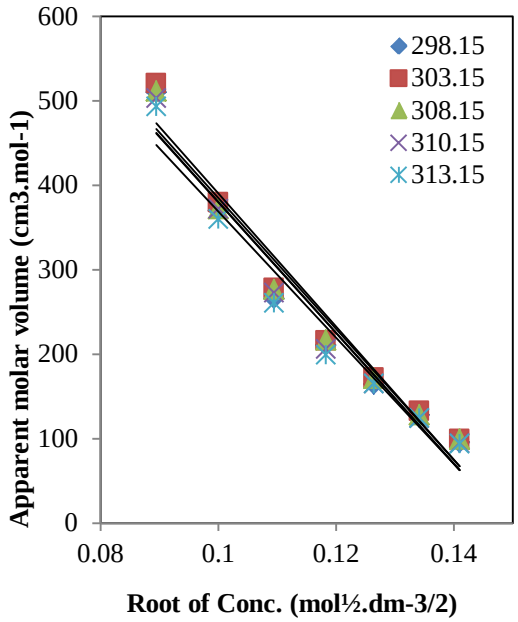

Fig 1: Plot of Φ_v ($cm^3.mol^{-1}$) Versus $C^{½}$ ($mol^{1/2}.dm^{-3/2}$) for sodium salicylate solution in NS at T= 298.15 to 313.15K.

root of concentration at different temperatures for different solvent systems performed. '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 [13]. The Jones-Dole parameters are given in Table 6. The positive values of 'B' at all temperatures indicate water structuring[14]. Increase in 'B' value shows increase in kosmotropicity and B values follows the trend

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

5. CONCLUSIONS

In the present report, from densitometry and viscometric study of aqueous solutions of sodium salicylate and in presence of additives as NaCl, KCl, Dextrose, Sodium lactate etc. 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 pain killer concentration.

The values of ϕv⁰ are positive suggest strong ion-solvent interactions. The Sv values are negative (except in pure water system) hydrophobicity is dominant over hydrophilic effect. The positive values of Jones-Dole coefficient 'B' indicates structure promoting tendency and strong interactions between solute and solvent. In aqueous solutions the values of partial molar volume are positive and decrease with the extent of hydrogen bonding. Lower the partial molar volume value, stronger is the hydrogen bond. Positive values of 'B' suggesting strongly hydrated solute indicating structure promoting tendency i.e. kosmotropes (structure makers). The Jones-Dole and Masson's equations are found to obey the sodium salicylate solutions in NS, DNS, RL and pure water system.

Table 3: Φ_v^0 ($cm^3.mol^{-1}$) and S_v ($cm^3.mol^{-3/2}.L^{1/2}$) of sodium salicylate solutions in NS, DNS, RL and pure water at different temperatures.

Masson's parameters	Temperature (K)	NS	DNS	RL	Pure water
Φ_v^0	298.15	1153	5261	1237	58.19
	303.15	1178	5170	1266	69.63
	308.15	1158	5204	1262	74.44
	310.15	1152	5240	1262	72.75
	313.15	1115	5211	1255	65.70
S_v	298.15	-7734	-35813	-8013	145.6
	303.15	-7875	-35182	-8223	125.0
	308.15	-7732	-35781	-8176	176.1
	310.15	-7724	-36311	-8084	265.0
	313.15	-7467	-36314	-8023	325.4

Table 4: Viscosities and relative viscosities of sodium salicylate solution in NS and DNS at different temperatures.

Molar Conc. Of	Temperatures

Sodium salicylate (C) mol/dm^3	**298.15K**	**303.15K**	**308.15K**	**310.15K**	**313.15K**
NS					
Viscosities (η) (Nm^{-3}.s)					
0.0080	0.90686	0.81175	0.73245	0.70603	0.66562
0.0100	0.91007	0.81401	0.73437	0.70805	0.66673
0.0120	0.91274	0.81612	0.73639	0.71017	0.66923
0.0140	0.91478	0.81846	0.73887	0.71242	0.6708
0.0160	0.91698	0.82061	0.74071	0.71412	0.67273
0.0180	0.91949	0.82283	0.74337	0.71628	0.67389
0.0199	0.92154	0.82477	0.74535	0.71785	0.67621
Relative viscosities (η_r)					
0.0080	0.99633	0.98668	0.99159	0.99428	0.99771
0.0100	0.99986	0.98942	0.99419	0.99713	0.99937
0.0120	1.00279	0.99199	0.99693	1.00011	1.00312
0.0140	1.00503	0.99483	1.00028	1.00328	1.00547
0.0160	1.00745	0.99745	1.00277	1.00567	1.00836
0.0180	1.01021	1.00015	1.00638	1.00872	1.01010
0.0199	1.01246	1.00250	1.00906	1.01093	1.01358
DNS					
Viscosities (η) (Nm^{-3}.s)					
0.0080	0.94989	0.85084	0.76948	0.73896	0.69586
0.0100	0.96348	0.86422	0.78118	0.74966	0.70425
0.0120	0.98026	0.87911	0.79194	0.76204	0.71486
0.0140	0.99497	0.89507	0.80492	0.77262	0.72219
0.0160	1.00865	0.90251	0.81538	0.78341	0.73222
0.0180	1.02055	0.91957	0.82429	0.79229	0.74111
0.0199	1.03375	0.92632	0.83287	0.79863	0.75004
Relative viscosities (η_r)					
0.0080	0.91378	0.91477	0.91813	0.91784	0.92075
0.0100	0.92685	0.92916	0.93210	0.93113	0.93186
0.0120	0.94299	0.94517	0.94493	0.94650	0.94589
0.0140	0.95714	0.96233	0.96042	0.95964	0.95559
0.0160	0.97030	0.97033	0.97290	0.97305	0.96886
0.0180	0.98175	0.98867	0.98353	0.98408	0.98063
0.0199	0.99445	0.99593	0.99377	0.99195	0.99244

Table 5: Viscosities of sodium salicylate solution in RL and pure water at different temperatures.

Molar Conc. of Sodium salicylate	**Temperatures**				
	298.15K	**303.15K**	**308.15K**	**310.15K**	**313.15K**

(C) mol/dm^3					
RL					
Viscosities (η) (Nm^{-3}.s)					
0.0080	0.91279	0.81792	0.73795	0.70964	0.66921
0.0100	0.91656	0.82095	0.74008	0.71125	0.67145
0.0120	0.91985	0.82362	0.74235	0.71407	0.67339
0.0140	0.92269	0.82569	0.74541	0.71674	0.67545
0.0160	0.92587	0.82953	0.74921	0.71958	0.67749
0.0180	0.92965	0.83266	0.7513	0.72139	0.68021
0.0199	0.93256	0.83511	0.75311	0.72332	0.68342
Relative viscosities (η_r)					
0.0080	1.00908	0.99732	0.98102	0.97354	0.98174
0.0100	1.01324	1.00101	0.98385	0.97574	0.98502
0.0120	1.01688	1.00427	0.98687	0.97961	0.98787
0.0140	1.02002	1.00679	0.99093	0.98328	0.99089
0.0160	1.02354	1.01147	0.99598	0.98717	0.99388
0.0180	1.02771	1.01529	0.99876	0.98966	0.99787
0.0199	1.03093	1.01828	1.00117	0.99230	1.00258
Pure water					
Viscosities (η) (Nm^{-3}.s)					
0.0080	0.90185	0.80945	0.73155	0.70289	0.66215
0.0100	0.90331	0.81106	0.73298	0.70433	0.66308
0.0120	0.90448	0.81219	0.7347	0.70538	0.66398
0.0140	0.90596	0.81369	0.73575	0.7066	0.66479
0.0160	0.90718	0.81536	0.73726	0.70818	0.66603
0.0180	0.90909	0.81668	0.73863	0.70966	0.66701
0.0199	0.91073	0.81795	0.73988	0.71098	0.66817
Relative viscosities (η_r)					
0.0080	1.00915	1.01903	1.01251	1.01182	1.00937
0.0100	1.01079	1.01291	1.01449	1.01389	1.01079
0.0120	1.01210	1.01432	1.01687	1.01540	1.01216
0.0140	1.01375	1.01620	1.01832	1.01716	1.01340
0.0160	1.01512	1.01828	1.02041	1.01943	1.01529
0.0180	1.01725	1.01993	1.02231	1.02156	1.01678
0.0199	1.01909	1.02152	1.02404	1.02346	1.01855

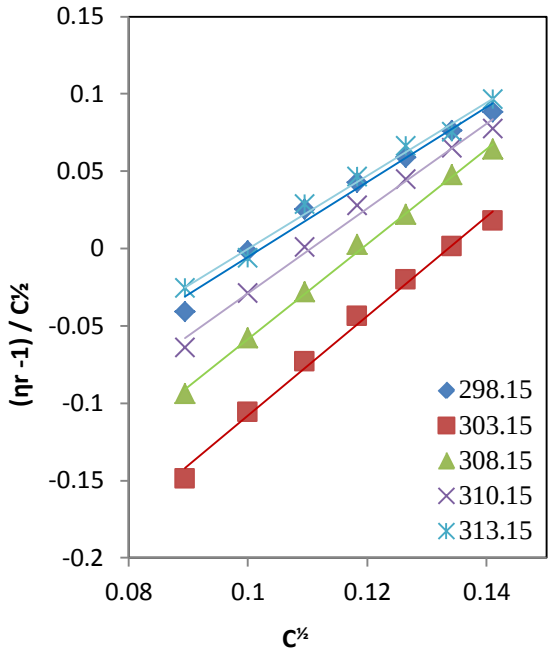

Fig 2: Plot of $(\eta_r - 1)/ C^{½}$ vs $C^{½}$ for sodium salicylate solutions in NS solvent system at different temperatures.

Table 6: Parameters of Jones-Dole equation of sodium salicylate in NS, DNS, RL and pure water.

NS					
T (K)	298.15	303.15	308.15	310.15	313.15
A($dm^{3/2}mol^{-1/2}$)	-0.247	-0.429	-0.365	-0.303	-0.236
B($dm^3.mol^{-1}$)	2.420	3.211	3.072	2.746	2.366
DNS					
A($dm^{3/2}mol^{-1/2}$)	-2.513	-2.510	-2.373	-2.370	-2.282
B($dm^3.mol^{-1}$)	17.83	18.0	16.85	16.81	15.99
RL					
A($dm^{3/2}mol^{-1/2}$)	-0.093	-0.301	-0.602	-0.715	-0.570
B($dm^3.mol^{-1}$)	2.227	3.079	4.411	4.775	4.159
Pure water					
A($dm^{3/2}mol^{-1/2}$)	0.045	0.067	0.087	0.071	0.056
B($dm^3.mol^{-1}$)	0.614	0.599	0.589	0.655	0.509

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