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The Study of Acoustic and Thermodynamic Properties of Solutions of Savlon in Acetone *i.e.* Non-Aqueous Medium

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Abstract: ***Viscosity (η), density (ρ), and ultrasonic velocity (V) in binary mixtures of savlon with acetone were measured at 30°C, 35°C, 40°C and atmospheric pressure by using a single-crystal interferometer at a frequency of 2 MHz. These parameters and concentrations were used to calculate adiabatic compressibility (β_s), intermolecular free length (L_f), specific acoustic impedance (Z), apparent molar compressibility (φ_k), solvation number (S_n) and relative association (R_A). The observed variation in these parameters with respect to the concentration highlights ion-solvent and ion-ion interactions were present, ion-solvent interactions were much depend the concentration of savlon in acetone.***

Keywords: Ultrasonic velocity, Savlon (antiseptic), Adiabatic compressibility, Viscosity, Ion-solvent interaction

1. Introduction

The savlon (antiseptic) organic compounds are essential chemicals for human beings, so emphasized the theoretical interpretation of these compound to discuss the molecular interaction of these compound with solvent medium. The solvents are selected dividing them as non-polar solvents. The solvation of antiseptic electrolyte will be more in polar solvents but less solvolysis takes place in non-polar solvents.

The study of molecular interactions has been a subject of extensive investigations by IR[1, 2], Raman[3], NMR[4, 5] and ultrasonic absorption[6, 7] measurements. Several workers[8-15] have used ultrasonic velocity measurements for studying the ion-solvent interaction and solvation of salts in non-aqueous solvents. The complementary use of adiabatic compressibility and apparent molar compressibility can provide interesting information on ion-solvent interaction.

In the present work ultrasound velocity, density and viscosity measured practically in the laboratory of the solvent and solute solutions in the solvents. The measured ultrasound velocity, density and viscosity were used for the determination of acoustic and thermodynamics properties like Isentropic Compressibility (β_s), Specific Acoustic Impedance (Z), Intermolecular Free Length (L_f), Molar Sound Velocity (*R*), Relative Association (R_A), Shears Relaxation Time (τ_s), Apparent Molal Compressibility (ϕ_k), Salvation Number (S_n), Viscosity (η), Specific Viscosity (η_{sp}) and Reduced Viscosity have been calculated. The above computed acoustic and thermodynamics parameter will decide nature and extent of interaction between solute and solvent molecules. The solvolysis depends on the interaction of solute molecules with the solvents.

2. Experimental

Density (ρ) and Viscosity (η): The densities of the solvent and solutions were measured with a double walled bi-capillary pyknometer. The viscosity of solvents and solution measured by suspended level canon-ubbelhode type viscometer is of special utility in observing the variation of viscosity with concentration. The viscometer was calibrated against distilled water, benzene and toluene. Viscosity (η) of liquid calculated by using formula

$$\eta_1 = \frac{\pi r^4 t_1 P_1}{8V}$$

and

$$\eta_2 = \frac{\pi r^4 t_2 P_2}{8V}$$

Therefore

$$\frac{\eta_1}{\eta_2} = \frac{t_1 P_1}{t_2 P_2} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where η_1 and η_2 is the viscosity of two liquids and P_1& P_2 are the hydrostatic pressure and t_1 & t_2 is the time flow of liquid in viscometer. We know that the hydrostatic pressure is the proportional to the density. Therefore,

$$\frac{\eta_1}{\eta_2} = \frac{t_1 \rho_1}{t_2 \rho_2} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where ρ & ρ are the density of liquids and η_2 is the viscosity of water. Specific Viscosity (η_{sp}) and Reduced Viscosity (η_r) were calculated as by following equation-

$$\eta_{sp} = \frac{\eta - \eta_0}{\eta} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

$$\eta_r = \frac{\eta_{sp}}{C} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Where η and η_0 are the viscosity of solution, solvent and C is the concentration of solution.

Ultrasonic Velocity: The ultrasonic velocity measurements were recorded on an ultrasonic interferometer (F-81, Mittal Enterprises, New Delhi) at 40.0 + 0.05 C using a crystal of 2 MHz frequency. Quartz crystal have different frequency of about 0.05%, the uncertainty of velocity measurements is 0.2%. The various acoustic parameters such as Isentropic Compressibility (β_s), Specific Acoustic Impedance (Z), Intermolecular Free Length (L_f), Molar Sound Velocity (*R*), Relative Association (R_A), Shears Relaxation Time (τ_s), Apparent Molal Compressibility (ϕ_k) and Salvation Number (S_n), have been calculated by using following relationship:

Isentropic Compressibility (β_s): The relation between the sound velocity and βs were written as

$$\beta_s = \frac{1}{V^2\rho} \quad \ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Where V is the ultrasound velocity and ρ is the density of liquid mixtures.

Intermolecular Free Length (L_f): Jacobson gave the empirical formula for the L_f as

$$L_f = K\sqrt{\beta_s} \quad \ldots\ldots\ldots\ldots\ldots\ldots (6)$$

Where is the temperature dependent constant which known as Jacobson's constant. The temperature dependent value of K at different temperature are given below

Temp (℃)	0	10	20	25	30	35	40	45
Value of K	588	604	618	625	631	636.5	642	652

Molar Sound Velocity (R): R may be expressed by this equation

$$R = \frac{\bar{M}}{\rho} V^{\frac{1}{3}} \quad \ldots\ldots\ldots\ldots\ldots\ldots (7)$$

Where $\bar{M}$ is the effective molecular weight which determined by following equation as

$$\bar{M} = \frac{n_1 M_1 + n_2 M_2}{n_1 + n_2} \quad \ldots\ldots\ldots\ldots (8)$$

Where n_1 and n_2 are the number of mole of solvent and solute, M_1 and M_2 are the molecular weight of solvent and solute.

Relative Association (R_A): R_A may be expressed by this equation

$$R_A = \left(\frac{\rho}{\rho_0}\right)\left(\frac{V_0}{V}\right)^{1/3} \quad \ldots\ldots\ldots\ldots (9)$$

Where ρ and ρ_0 are the density and V and V_0 are the ultrasonic velocity of solutions and solvent.

Shears Relaxation Time (τ_s): τ_s derived by this equation

$$\tau_S = \frac{4}{3}\eta\,\beta_S \quad \ldots\ldots\ldots\ldots\ldots (10)$$

Where η is the viscosity of solution.

Apparent Molal Compressibility (ϕ_k): ϕ_k expressed by this equation

$$\emptyset_K = \frac{1000}{C \times \rho_0}(\rho_0\beta_S - \beta_{S0}\rho) + \beta_{S0}\frac{M}{\rho_0} \quad \ldots\ldots (11)$$

Where ρ, ρ_0 & β_S, β_{S0}, are the density and adiabatic compressibility of solutions and solvent respectively.

Apparent Molar Volume ($\emptyset_V$): The $\emptyset_V$ is calculated by the following expression

$$\emptyset_V = \frac{1000}{C \times \rho}(\rho_0 - \rho) + \frac{M}{\rho_0} \quad \ldots\ldots\ldots (12)$$

Where M is the molecular weight of solute, C is the concentration.

Salvation Number (S_n): The expression used for calculation of S_n is due to passynsky

$$S_n = \frac{n_1}{n_2}\left(1 - \frac{\beta_S}{\beta_{S0}}\right) \quad \ldots\ldots\ldots\ldots (13)$$

Specific Acoustic Impedance (Z): It is defined as unit area Acoustic Impedance of a sound on a given surface and its value calculated by using formula

$$Z = V \times \rho \quad \ldots\ldots\ldots\ldots\ldots\ldots (14)$$

3. Results and Discussion

The measured parameters viz. ultrasonic velocity (V), density (ρ), viscosity (η) are given in the Table (1-3) at different temperatures. The table shows these three parameters increase with concentration of savlon-acetone. This indicates that strong interaction observed at higher concentrations of savlon-acetone and suggests more association between solute and solvent molecules in the system.

The ultrasonic velocity and various acoustical parameters for savlon-acetone have been evaluated (Table 1-3) at different temperatures. The variation of ultrasonic velocity (V), with savlon concentration C, can be expressed in terms of concentration derivatives of density ρ and adiabatic compressibility β, by the following relationship

$$\frac{dV}{dC} = -\frac{V}{2}\left[\frac{1}{\rho} \times \frac{d\rho}{dC} + \frac{1}{\beta_s} \times \frac{d\beta_s}{dC}\right]$$

The results indicate that the density increases while the adiabatic compressibility decreases with increasing savlon concentration. Therefore, the quantity dρ/dC (concentration derivative of density) is positive while the quantity $d\beta_s/dC$ (concentration derivative of compressibility), is negative. Since the values of $1/\beta_s \times d\beta_s/dC$ are larger than the values of $1/\rho \times d\rho/dC$ for these savlon solutions, the concentration derivative of velocity, (dV/dC) will be positive and so the velocity increases with increasing savlon concentration. This is an agreement with the result of several workers reported for electrolytic solutions[16-18]. The isentropic compressibility, β_s for the solution of savlon decrease with increase in solute concentration (Table 1-3). The decrease in isentropic compressibility is attributed to the fact that the solute molecules, in dilute solution ionize in simple cations and anions. These solutions are surrounded by a layer of solvent molecules, firmly bound, and oriented towards the ions. The orientation of solvent molecules around the ions is attributed to the influence of electrostatic field of ions and thus the internal pressure increases, which lowers the compressibility of solution i.e. the solutions become harder to compress[19]. The intermolecular free length (L_f), which is expected to decrease as a result of mixing of the two components, decreases with the increase in solute concentration. Rise in temperature generally increases the internal energy of the system by distorting the local structure, resulting in an increase in intermolecular free length and subsequently decreasing the ultrasonic velocity. In the present study, the elevation of temperature from 30°C, 35°C and 40°C shows the same trend.

The intermolecular free length (L_f) decrease while specific acoustic impedance (Z) increase with increase in solute concentration (Table-1-3), which can be explained on the basis of lyophobic interaction between the solute and solvent molecule which increases the inter molecular distance leaving relatively wider gaps between the molecules and thus becoming the main cause impediment to the propagation of ultrasound waves[20] and affects the structural arrangement. The specific acoustic impedance, a product of the density of the solution and the velocity, has shown the reverse trends to that of inter molecular free length. Thus the fact that increase of velocity, decrease of isentropic compressibility, decrease of intermolecular free length and increase of specific acoustic impedance with increase in molar concentration at all temperatures is an indicative of the increase in intermolecular forces with the addition of solute forming aggregates of solvent molecules around solute ions and supports the strong solute-solvent interactions, due to which structural arrangement is affected.

Relative association (R_A) is influence by two factors[21] (i) the breaking up of the solvent molecules on addition of electrolyte to it and (ii) the solvation of ion that are simultaneously present; the former resulting in a decrease and later increase of relative association .In the present investigation, it has been observed that relative association value increases with increase in concentration. Similar results have been reported in literature[22]. Solvation number (Sn) is calculated using Passynsky[23] equation and are listed in Table (1-3). The Sn values are found to increase with the increase in solute, which also suggested close association between solute and solvent.

The values of apparent molar compressibility (φ_k) are found to be negative and it increases negatively with increasing concentration of savlon. It is also found that molar compressibility varies linearly as the square root of molar concentration graph of φ_k *Vs* $\sqrt{C}$. The density, Shears Relaxation Time (τ_s) and ultrasound velocity of the solutions of savlon in foresaid solvent increases an increasing concentration of savlon solutions. The viscosity (η), specific viscosity (η_{sp}), and reduced viscosity (η_{red}) has been calculated for savlon-acetone system at different temperature (Table 1-3) is obvious that the value of η, η_{sp} and η_{red} increases with increase in molar concentration and density of the solution. The increases in viscosity may be due to increases tendency of savlon molecules to form aggregates with the increase in the savlon concentration in solution.

Table 1: System: Savlon + Acetone at 30°C (Isentropic Compressibility of Acetone = 95.60 × 10^{-12} dyne/cm^2)

Molar Conc. of Savlon (mole/L)	Density ρ (g/mL)	Viscosity η (c.p.)	Sp. Viscosity η_{sp} (c.p.)	Reduced Viscosity η_{red} (c.p.)	Ultrasound velocity (m/sec)	Isentropic Compressibility β_s (10^{12} × cm^2/dyne)	Lowering Compressibility β_{s0} - β_s (10^{12} × cm^2/dyne)
0.0550	0.7943	0.3322	0.0533	0.9684	1162	93.24	2.36
0.1101	0.8112	0.3491	0.1069	0.9713	1164	90.98	4.62
0.1651	0.8281	0.3660	0.1605	0.9722	1166	88.82	6.78
0.2202	0.8450	0.3829	0.2141	0.9727	1168	86.75	8.85
0.2752	0.8619	0.3998	0.2678	0.9730	1170	84.76	10.84
0.3302	0.8788	0.4167	0.3214	0.9732	1172	82.84	12.76
0.3853	0.8957	0.4336	0.3750	0.9733	1174	81.00	14.60
0.4403	0.9126	0.4505	0.4286	0.9734	1176	79.23	16.37
0.4954	0.9295	0.4674	0.4822	0.9735	1178	77.53	18.07
0.5504	0.9464	0.4843	0.5359	0.9736	1180	75.89	19.71

Sp. Acoustic impedance Z × 10^{-5}	Molar sound velocity R (m/sec)	Relative Association R_A	Solvation Number S_n	Inter molecular length L_f (Å)	β_s-β_{s0}/C (10^{12})	Apparent Molar Compressibility (φ_k) 10^2 ×cm^2/dyne	Shears Relaxation Time τ_s
0.9230	1016.45	1.0223	0.1661	0.6093	-42.87	-47.2532	41.2992
0.9442	1038.68	1.0447	0.3248	0.6019	-41.93	-22.2915	42.3501
0.9656	1060.92	1.0671	0.4770	0.5947	-41.05	-13.9142	43.3451
0.9870	1083.19	1.0894	0.6230	0.5877	-40.21	-9.6856	44.2876
1.0084	1105.49	1.1119	0.7632	0.5809	-39.40	-7.1183	45.1807
1.0300	1127.80	1.1343	0.8978	0.5743	-38.63	-5.3832	46.0275
1.0516	1150.15	1.1568	1.0273	0.5679	-37.89	-4.1247	46.8305
1.0732	1172.51	1.1793	1.1519	0.5617	-37.17	-3.1650	47.5925
1.0950	1194.90	1.2018	1.2718	0.5556	-36.48	-2.4053	48.3156
1.1168	1217.31	1.2243	1.3874	0.5497	-35.82	-1.7863	49.0021

Table 2: System: Savlon + Acetone at 35°C (Isentropic Compressibility of Acetone = 103.24 × 10^{-12} dyne/cm^2)

Molar Conc. of Savlon (mole/L)	Density ρ (g/mL)	Viscosity η (c.p.)	Sp. Viscosity η_{sp} (c.p.)	Reduced Viscosity η_{red} (c.p.)	Ultrasound velocity (m/sec)	Isentropic Compressibility β_s (10^{12} × cm^2/dyne)	Lowering Compressibility β_{s0} - β_s (10^{12} × cm^2/dyne)
0.0550	0.7755	0.2959	0.0633	1.1494	1132	100.63	2.61
0.1101	0.7924	0.3128	0.1240	1.1266	1134	98.14	5.10
0.1651	0.8093	0.3297	0.1848	1.1189	1136	95.75	7.49
0.2202	0.8262	0.3466	0.2455	1.1151	1138	93.46	9.78
0.2752	0.8431	0.3635	0.3063	1.1128	1140	91.27	11.97
0.3302	0.8600	0.3804	0.3670	1.1113	1142	89.16	14.08
0.3853	0.8769	0.3973	0.4277	1.1102	1144	87.14	16.10
0.4403	0.8938	0.4142	0.4885	1.1094	1146	85.19	18.05
0.4954	0.9107	0.4311	0.5492	1.1088	1148	83.32	19.92
0.5504	0.9276	0.4480	0.6100	1.1083	1150	81.52	21.72

Sp. Acoustic impedance $Z \times 10^{-5}$	Molar sound velocity R (m/sec)	Relative Association R_A	Solvation Number S_n	Inter molecular length L_f (Å)	β_s-β_{s0}/C (10^{12})	Apparent Molar Compressibility (φ_k) $10^2 \times cm^2$/dyne	Shears Relaxation Time τ_s
0.8779	983.78	1.0229	0.1701	0.6385	-47.4290	-70.3661	39.7017
0.8986	1005.81	1.0458	0.3326	0.6305	-46.3641	-33.4869	40.9294
0.9194	1027.87	1.0687	0.4882	0.6228	-45.3676	-21.1371	42.0912
0.9402	1049.95	1.0917	0.6373	0.6153	-44.4178	-14.9222	43.1914
0.9611	1072.05	1.1147	0.7803	0.6081	-43.5085	-11.1632	44.2338
0.9821	1094.18	1.1377	0.9176	0.6010	-42.6361	-8.6335	45.2219
1.0032	1116.33	1.1607	1.0495	0.5942	-41.7980	-6.8075	46.1589
1.0243	1138.51	1.1838	1.1763	0.5875	-40.9921	-5.4222	47.0478
1.0455	1160.71	1.2068	1.2983	0.5810	-40.2164	-4.3315	47.8914
1.0667	1182.93	1.2300	1.4157	0.5747	-39.4692	-3.4477	48.6923

Table 3: System: Savlon + Acetone at 40°C (Isentropic Compressibility of Acetone = 107.58×10^{-12} dyne/cm^2)

Molar Conc. of Savlon (mole/L)	Density ρ (g/mL)	Viscosity η (c.p.)	Sp. Viscosity η_{sp} (c.p.)	Reduced Viscosity η_{red} (c.p.)	Ultrasound velocity (m/sec)	Isentropic Compressibility β_s ($10^{12} \times cm^2$/dyne)	Lowering Compressibility β_{s0} - β_s ($10^{12} \times cm^2$/dyne)
0.0550	0.7659	0.2449	0.0737	1.3387	1116	104.83	2.75
0.1101	0.7828	0.2618	0.1478	1.3427	1118	102.20	5.38
0.1651	0.7997	0.2787	0.2219	1.3441	1120	99.69	7.89
0.2202	0.8166	0.2956	0.2961	1.3447	1122	97.28	10.30
0.2752	0.8335	0.3125	0.37102	1.3451	1124	94.96	12.62
0.3302	0.8504	0.3294	0.4443	1.3454	1126	92.75	14.83
0.3853	0.8673	0.3463	0.5184	1.3456	1128	90.62	16.96
0.4403	0.8842	0.3632	0.5925	1.3457	1130	88.57	19.01
0.4954	0.9011	0.3801	0.6667	1.3458	1132	86.60	20.98
0.5504	0.9180	0.3970	0.7408	1.3459	1134	84.71	22.87

Sp. Acoustic impedance $Z \times 10^{-5}$	Molar sound velocity R (m/sec)	Relative Association R_A	Solvation Number S_n	Inter molecular length L_f (Å)	β_s-β_{s0}/C (10^{12})	Apparent Molar Compressibility (φ_k) $10^2 \times cm^2$/dyne	Shears Relaxation Time τ_s
0.8547	967.00	1.0232	0.1718	0.6573	-49.9025	-62.5848	34.2316
0.8752	988.93	1.0464	0.3362	0.6490	-48.8422	-29.7284	35.6758
0.8957	1010.88	1.0696	0.4936	0.6410	-47.8039	-18.7079	37.0435
0.9162	1032.86	1.0929	0.6444	0.6332	-46.8031	-13.1494	38.3396
0.9369	1054.86	1.1161	0.7890	0.6256	-45.8408	-9.7781	39.5686
0.9576	1076.89	1.1394	0.9276	0.6183	-44.9158	-7.5023	40.7345
0.9783	1098.94	1.1628	1.0608	0.6111	-44.0262	-5.8538	41.8412
0.9991	1121.01	1.1861	1.1888	0.6042	-43.1704	-4.5986	42.8921
1.0200	1143.11	1.2095	1.3119	0.5975	-42.3465	-3.6064	43.8905
1.0410	1165.24	1.2329	1.4303	0.5909	-41.5528	-2.7993	44.8395

4. Conclusions

The ultrasonic velocity throws light on evaluation of various acoustical parameters of savlon in acetone i.e. non-aqueous medium mixture. These results confirm that there is a significant interaction between savlon-solvent molecules in dilute solutions.

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