Conductometric Studies On Sodium Acetate And Sodium Benzoate in Ethanol –Water Mixed Solvent Media

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Abstract: Precise conductivity measurements for sodium acetate and sodium benzoate ethanol – water mixed media containing 5 %, 10%, 15%, 20% and 25% of ethanol at room temperature are reported. The results showed a sharp increase in the conductivity with increasing electrolyte concentration. The conductivity of the electrolyte decreases with increase in the amount of ethanol. These data have been used to study the nature of ion-solvent interactions and solvent- solvent interactions existing in the system.

Key words: Limiting molar conductance, sodium benzoate, sodium acetate, mixed solvent media.

I. INTRODUCTION:

Solvent blending or co solvency usually affects important characteristics of a solute in a solution. Some of these may include its solubility, stability and dissociation constants. Evidently, in the case of binary solvents, the composition is an additional variable that is usually expressed in terms of volume fractions of the solvent w or in molar fractions x.

The focus of conductivity measurements has shifted to various mixed-solvent systems in the current past. Numerous experimental and theoretical studies were devoted to the water-organic solvent and binary organic solvents media [1-4]. The added organic solvent may change the dielectric constant of the medium and may produce structural changes in the medium, like controlling the ion-association and predicting the solubility profile of a liquid mixture. Amongst mixed solvents, water and alcohol mixtures are of special interest because they are widely used both experimentally and theoretically. These mixtures also highlight the specific kind of interactions between aqueous and non aqueous solvent molecules through hydrogen bonding [5]. Systems like ethanol-water mixtures (amphiprotic hydroxylic solvents) are characterized by relatively large dielectric constants. These parameters have a great possibility to form a highly complex-hydrogen bonded structure in the liquid state. Ethanol is a very popular solvent in forming homogeneous mixtures with water.

Alcohols behave like water as they are strongly hydrogen-bonded self associated liquids. However unlike water they do not form open structures though the intermolecular bonding has a predominant effect on the physiochemical properties of the liquid. A close understanding of the structure of alcohol –water mixtures reveals the fact that the hydrophobic hydrocarbon chain in alcohols opposes the hydrophilic –OH group in its attempt to pull the molecule in solution [6]. Thus hydrogen bonding between the hydroxyl group and solvent molecules is possible in a binary liquid mixture.

The present study compares the conductivity behavior of sodium acetate and sodium benzoate at 303K. Studies on the conductance behavior of such salts in mixed solvents are highly essential for understanding the theory behind the changes related to the solvent structure. These investigations closely yielded important information about ion-ion and ion-solvent interactions under varied conditions. It involved determination from the experimental data λ vs concentration C, the limiting conductance of the electrolyte λ°, the equilibrium constant (association constant) K_A, and the interpretation of the ion-size parameter. The evaluation of these parameters were based on the different versions of the inter ionic attraction theory of charged spheres in a solvent continuum.

The limiting conductance λ° is a direct conclusion drawn over the size and the geometry of the ions in solution.

II. MATERIALS AND METHODS:

Sodium benzoate and sodium acetate used in the present study were of high purity and analytical grade. The salts employed in this investigation were purchased from Ranbaxy Chemical Company, Inc., India. The solvent ethanol was redistilled before use. The density of the purified solvent used was $0.7806 gcm^{-3}$ with a coefficient of viscosity of 0.9590mPa.s at room temperature. The density of the pure ethanol water mixtures was measured using a10ml specific gravity bottle. Sodium acetate and sodium benzoate are the salts of weak acids. Sodium benzoate is widely used as a preservative. Sodium acetate is practically useful in a lot of industrial applications. A highly precise digital conductivity meter, ModelCDM230 and a conductivity cell were used for conductance measurements. The cell constant of the cell used had an uncertainty of 0.01%.The instrument was calibrated by using freshly prepared KCl solutions. Triply distilled water (specific conductivity of the order of 1×10^{-7} Scm^{-1}) was used throughout this study.

To ensure better reproducibility of results several independent solutions were prepared and runs were performed. The experiments were also performed in triple replicates for accuracy.

III. RESULTS AND DISCUSSION:

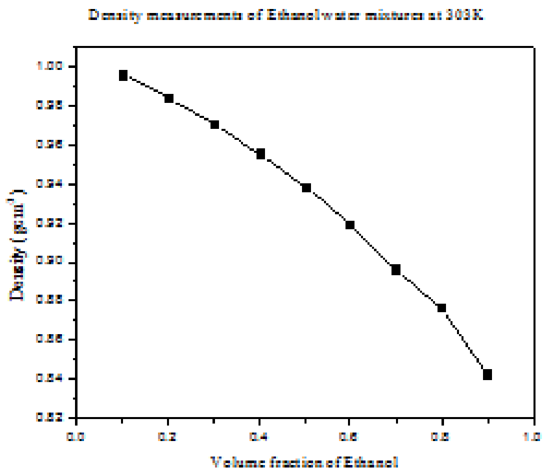
The density measurements of various proportions of pure ethanol water mixtures ranging from 0.1 to 0.9 volume fractions of ethanol were studied individually and are represented in Table 1.

Table1: Density measurements for pure Ethanol Water mixtures

Volume Fraction of Ethanol	Density (gcm^{-3})
0.1	0.9957
0.2	0.9842
0.3	0.9710
0.4	0.9554
0.5	0.9383
0.6	0.9194
0.7	0.8961
0.8	0.8765
0.9	0.8421

A graph is plotted between the density measurements of pure ethanol water mixtures Vs the volume fraction of Ethanol Content as seen in Figure 1.

Figure 1: Density measurements for Ethanol Water mixtures at 303K



The density studies from Figure 1 and Table 1 shows that the density decreases with the increase of alcohol content. An increased intermolecular interaction and an ionic hydration between the ethanol and water molecules are responsible for the decrease in density which is in coherence with the available literature values [7, 8 and 9]. It is also observed that on mixing ethanol and water the molecules start spreading out as the liquid becomes warmer.

A comparative analysis of K, λ, λ_∞ and α for the varied Sodium acetate and sodium benzoate solutions in ethanol water mixtures is studied individually and are presented in Table 2 and Table 3 .

Table-2: Comparative analysis of K, λ, λ_∞ and α for the varied Sodium acetate solutions in ethanol water mixtures

% of Ethanol	Conc	K=(Cond)(l/a) X $10^{-3}ohm^{-1}cm^{-1}$	λ=Kx 1000/c	α	Ka=$C\alpha^2/1-\alpha$	λ_0
5	0.01	0.4666	46.66	0.5677	0.00745	82.20
	0.008	0.3979	49.74	0.6051	0.00742	
	0.0066	0.3485	52.80	0.6423	0.00761	
	0.00565	0.3101	54.88	0.6676	0.00758	
	0.00494	0.2788	56.43	0.6865	0.00743	
	0.00439	0.2555	58.21	0.7081	0.00754	
	0.00395	0.2353	59.58	0.7248	0.00754	
	0.00359	0.2202	61.33	0.7461	0.00787	
10	0.01	0.4404	44.04	0.5695	0.00754	77.32
	0.008	0.3737	46.71	0.6041	0.00738	
	0.0066	0.3252	49.28	0.6373	0.00739	
	0.00565	0.2919	51.66	0.6682	0.00760	
	0.00494	0.2626	53.16	0.6875	0.00747	
	0.00439	0.2394	54.53	0.7052	0.00741	

	0.00395	0.2222	56.25	0.7275	0.00767	
	0.00359	0.2071	57.67	0.7459	0.00786	
15	0.01	0.4545	45.45	0.5463	0.00658	83.20
	0.008	0.3909	48.86	0.5872	0.00668	
	0.0066	0.3424	51.88	0.6235	0.00682	
	0.00565	0.3050	53.99	0.6489	0.00677	
	0.00494	0.2767	56.02	0.6733	0.00686	
	0.00439	0.2525	57.52	0.6913	0.00680	
	0.00395	0.2343	59.32	0.7130	0.00700	
	0.00359	0.2192	61.05	0.7338	0.00726	
20	0.01	0.431	43.53	0.5248	0.00638	80.44
	0.008	0.371	46.84	0.5647	0.00649	
	0.0066	0.328	50.19	0.6052	0.00683	
	0.00565	0.3	53.63	0.6466	0.00753	
	0.00494	0.264	53.98	0.6508	0.00676	
	0.00439	0.241	55.45	0.6685	0.00671	
	0.00395	0.223	57.02	0.6875	0.00682	
	0.00359	0.208	58.52	0.7055	0.00697	
25	0.01	0.3767	22.52	0.4889	0.00468	77.04
	0.008	0.3262	25.38	0.5293	0.00476	
	0.0066	0.2879	28.92	0.5660	0.00487	
	0.00565	0.2596	32.36	0.5963	0.00498	
	0.00494	0.2374	35.98	0.6236	0.00510	
	0.00439	0.2192	39.80	0.6480	0.00524	
	0.00395	0.2050	43.72	0.6737	0.00549	
	0.00359	0.1949	47.55	0.7047	0.00604	

Table-3: Comparative analysis of K, λ, λ_∞ and α for the varied Sodium benzoate solutions in ethanol water mixtures

% of Ethanol	Conc	K=(Cond)(l/a)x10^{-3} $ohm^{-1}cm^{-1}$	λ=K_sx 1000/c	α	Ka=$C\alpha^2/1-\alpha$	λ_0
5	0.001	0.0609	60.88	0.5781	0.00079	105.30
	0.0008	0.0505	63.10	0.5993	0.00072	
	0.0005	0.0329	65.72	0.6241	0.00052	
	0.0004	0.0278	69.38	0.6589	0.00051	
	0.00025	0.0213	85.28	0.8099	0.00086	
	0.0002	0.0174	86.78	0.8241	0.00077	
10	0.001	0.0575	57.53	0.5967	0.00088	96.41
	0.0008	0.0462	57.71	0.5985	0.00071	
	0.0005	0.0309	61.85	0.6415	0.00057	
	0.0004	0.0264	66.08	0.6854	0.00060	
	0.00025	0.0176	70.48	0.7310	0.00050	
	0.0002	0.0172	85.90	0.8910	0.00146	
15	0.001	0.0530	53.04	0.5967	0.00067	92.37
	0.0008	0.0445	55.61	0.5985	0.00063	
	0.0005	0.0277	55.33	0.6415	0.00039	

	0.0004	0.0232	57.93	0.6854	0.00036	
	0.00025	0.0167	66.64	0.7310	0.00039	
	0.0002	0.0168	84.22	0.8910	0.00121	
20	0.001	0.0460	45.99	0.6612	0.00129	69.55
	0.0008	0.0374	46.69	0.6714	0.00110	
	0.0005	0.0247	49.34	0.7094	0.00087	
	0.0004	0.0201	50.22	0.7220	0.00075	
	0.00025	0.0148	59.13	0.8502	0.00121	
	0.0002	0.0119	59.34	0.8531	0.00099	
25	0.001	0.0457	45.72	0.7100	0.00174	64.30
	0.0008	0.0367	45.92	0.7131	0.00142	
	0.0005	0.0234	46.87	0.7278	0.00097	
	0.0004	0.0187	46.69	0.7250	0.00076	
	0.00025	0.0147	58.85	0.9138	0.00242	
	0.0002	0.0110	60.01	0.8550	0.00101	

The experimental specific conductivities of sodium acetate and sodium benzoate as a function of the salt concentration at 303 K for the ethanol water mixtures are depicted in figures 2 and 3. Figure 2: Specific Conductivity of Sodium acetate as a Function of Salt Concentration in Ethanol Water mixtures from 5% to 25%

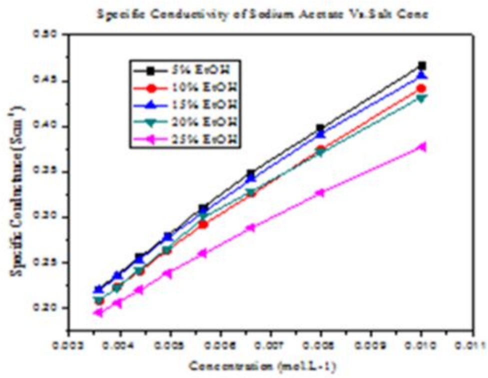
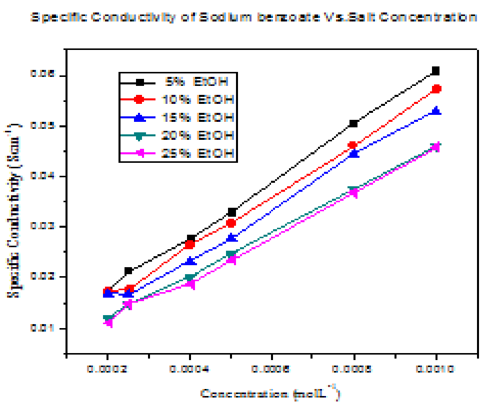


Figure 3: Specific Conductivity of Sodium benzoate as a Function of Salt Concentration in Ethanol Water mixtures from 5% to 25%



From these figures, it is proven that there is a sharp increase in specific conductivities with increasing concentration in all concentrations of the investigated range. As the number of ions per unit volume of the solution increases and there is also an increase in the specific conductivities with increase in concentration. However with increasing ethanol content, the conductivity decreases and the tendency for ion formation is enhanced as the added ethanol reduces the permittivity of the medium [10]. Evidently, the increase in specific conductivity is uniform for both sodium acetate and sodium benzoate at all solvent-mixture compositions investigated, complimenting with the similar trend in literature [11].

The λ_o value depends on the medium in each mixture. The λ_o values decreases with the increasing the percentage of alcohol [12].However the conductance decreases with the increase of alcohol content for the studied ethanol-water mixed solvent system. This aspect embraces the fact that the presence of ethanol reduces the dielectric constant of the solvent phase. This interaction also aids the formation of ion-pairs in the solution phase; thereby reducing the dielectric constant of the solvent phase. It is thus seen that the majority of the solutes are significantly influenced by the presence of solutes [13].

λ vs. $\sqrt{c}$ plots is drawn in figure 4 and figure 5 to find out the value of the equivalent conductance of sodium acetate and sodium benzoate at infinite dilutions for each of the water ethanol mixtures.

Fig. 4: The plot of equivalent conductance against the square root of concentration of Sodium acetate in Ethanol water mixtures

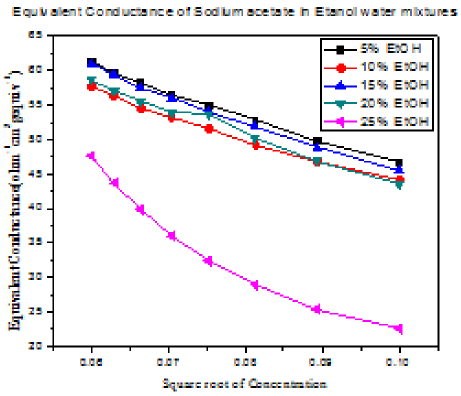
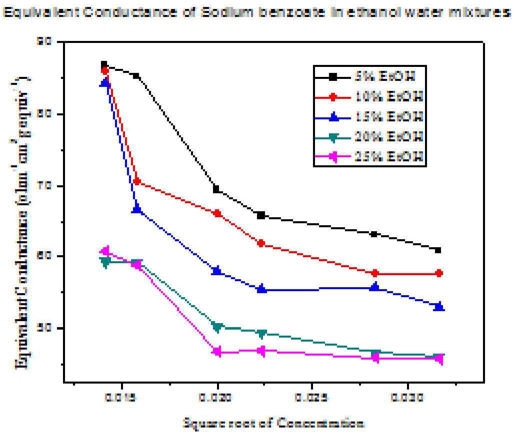


Fig. 5: The plot of equivalent conductance against the square root of concentration of Sodium benzoate in Ethanol water mixtures



With increasing ethanol content the trend explains a steady decrease accounting for an effect of ionic association. Further the variation in the conductivity values of sodium acetate seen in figure 4, support for an increased intermolecular interaction between the solute and solvent molecules. As seen in figure 5, the limiting conductance λ_{α} decreases as the weight percentage of ethanol increases. Ethanol starts dominating at higher alcohol proportions and structural changes are expected in the solution phase which is in perfect agreement with the published work from literature [14, 15 and 16].

It is seen from the (α) values that when the concentration of the salt is increased the α values also increased. This is in turn attributed to the fact that strong intermolecular association of the ethanol solute molecules take place at higher ethanol proportions [4] and [14].

IV. CONCLUSION:

Conductivity has been taken as a powerful medium to unravel the nature of intermolecular interactions providing useful information in the area of solution chemistry. This study also highlights the extent of dissociation, the solubility profile and the kinetics of a reaction in a binary liquid mixture.

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