Research Article

Densities and Refractive Indices of Potassium Salt Solutions in Binary {Ethanol + Water} Mixture of Different Compositions

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Densities and refractive indices of solutions of different concentrations of potassium salts, namely, KCl, KBr, and KI in 10%, 20%, 40%, and 60% (v/v) ethanol-water mixture were measured at 303.15 K. Specific refractions (R_D) and molar refractions (R_M) have been estimated from measured refractive indices and densities of solutions and interpreted in terms of interactions in salt solutions. Refractive indices increased with an increase in percentage of ethanol as well as with concentrations of potassium salts for given composition of binary solvent mixture.

1. Introduction

Refractive index is one of the important properties of liquid which can be measured easily with a high degree of accuracy. Theoretical and empirical equations are available for relating refractive index with other thermochemical or electronic properties. Refractive index is the ratio of velocity of light in a particular substance to velocity of light in vacuum.

Refractive indices of binary, ternary liquid solutions, and solutions of biologically important compounds have been studied [1–7]. Refractions of aqueous solutions of Co (III) complexes [8], aqueous salt solutions of Cu, Zn, Ag, and K [9] have been studied. Refractive indices and molar refraction of 1, 3-diarylcarbamides in different percentage of binary liquid mixture were studied by Ubarhande et al. [10]. Apparent specific refraction of poly(oxyethylene) glycols [11] and mono-, di-, tri-, and tetra(oxyethylene) glycol in aqueous, 1, 4-dioxane, and benzene solutions were studied by Rudan-Tasic and Klofutar [12]. Specific refractions of aqueous lithium iodate solutions were studied by Szweczyk, Sangwal [13].

Present paper reports densities and refractive indices data for solutions of different concentrations of potassium salts in {ethanol + water} mixtures of different composition at 303.15 K. Specific refractions and molar refractions for different systems are estimated.

2. Materials and Methods

Solutions of different concentrations of potassium salts in ethanol + water mixture of different percentage were prepared by adding accurately weighed potassium salts in respective solvent mixture. For each binary solvent mixture of given composition, three solutions of different concentrations of potassium salts were prepared. Density measurements were performed using single capillary pycnometer (borosilicate glass) having bulb volume of 10 mL [14]. It was calibrated with distilled water at 303.15 K. Weighing was done on the electronic balance (Denver Instrument, Denser instrument Germany). Electrolyte liquid-liquid ternary mixtures prepared as: (KCl + {ethanol + water}); (KBr + {ethanol + water}); (KI + {ethanol + water}). Solutions of 10, 20, 40, and 60% v/v ethanol were prepared by dissolving 10, 20, 40, and 60 mL ethanol in less than 90, 80, 60, and 40 mL of distilled water in 100 mL volumetric flask, and then total volume of the solution was brought to 100 mL by adding distilled water. For different concentrations of electrolytes in 10, 20, 40, and 60% (v/v) ethanol + water densities and refractive indices were measured.

Refractive indices of solutions were measured using Abbe's refractometer at constant temperature (303.15 K). Refractometer was calibrated with the glass piece provided with instrument. For each solution, three readings were taken

TABLE 1: Experimental densities (ρ) and refractive indices (n_D) of pure solvents and 10%, 20%, 40%, and 60% (v/v) ethanol + water binary mixtures at 303.15 K.

	ρ (g·cm ⁻³)	n_D
Ethanol	0.8054	1.362
Water	0.9957	1.333
10% (v/v) E-W	0.9851	1.332
20% (v/v) E-W	0.9702	1.343
40% (v/v) E-W	0.9430	1.352
60% (v/v) E-W	0.9063	1.360

TABLE 2: Experimental densities (ρ) and refractive indices (n_D) of potassium salt solutions in 10%, 20%, 40%, and 60% (v/v) ethanol + water (E-W) mixture at 303.15 K.

X_{KCl}	ρ (g·cm ⁻³) KCl + E-W	n_D	X_{KBr}	ρ (g·cm ⁻³) KBr + E-W	n_D	X_{KI}	ρ (g·cm ⁻³) KI + E-W	n_D
10% (v/v) E-W								
0.000579	0.9920	1.339	0.000573	0.9923	1.340	0.000571	0.9990	1.342
0.001123	0.9956	1.340	0.000971	1.0030	1.341	0.001116	1.0141	1.344
0.001596	1.0007	1.341	0.001745	1.0129	1.343	0.001730	1.0286	1.346
20% (v/v) E-W								
0.000645	0.9764	1.346	0.000605	0.9807	1.345	0.000618	0.9869	1.346
0.001224	0.9822	1.347	0.001255	0.9917	1.346	0.001184	0.9993	1.349
0.001876	0.9816	1.348	0.001877	1.0016	1.349	0.001848	1.0161	1.351
40% (v/v) E-W								
0.000748	0.9482	1.354	0.000733	0.9547	1.354	0.000737	0.9601	1.356
0.001502	0.9515	1.356	0.001453	0.9638	1.357	0.001480	0.9753	1.359
0.002218	0.9589	1.357	0.002241	0.9742	1.359	0.002232	0.9882	1.361
60% (v/v) E-W								
0.000926	0.9073	1.361	0.000888	0.9159	1.360	0.000914	0.9225	1.364
0.001850	0.9121	1.363	0.001818	0.9258	1.362	0.001824	0.9356	1.366
0.002777	0.9156	1.364	0.002771	0.9364	1.365	0.002738	0.9520	1.367

independently, and the average of these values were taken as final refractive index. Calculations of specific and molar refractions were performed over a personal computer.

3. Results and Discussion

Experimental densities and refractive indices of pure solvents and 10, 20, 40, and 60% (v/v) ethanol + water mixture at 303.15 K are reported in Table 1. And for that of potassium salt solutions in 10, 20, 40, and 60% (v/v) ethanol in {ethanol+water} mixture at 303.15 K are reported in Table 2.

Densities followed the order $KI > KBr > KCl$ for given percentage of ethanol and for approximately the same concentration of salt. This is due to relative solvation, corresponding resultant volumes of system and molar mass of these salts. Densities of all the salt solutions increased with increase in concentration in a given ethanol-water mixture which is because of strengthening of ion-solvent

interactions and decrease in volume of the system. And densities decreased with increase in the percentage of ethanol for approximately the same concentration of salt which may be due to the weakening of ion-solvent interactions in higher percentage of ethanol and increase in volume of system as ethanol percentage increases.

Refractive indices of all salt solutions for given composition of ethanol-water mixture are higher than corresponding ethanol-water binary mixtures. The refractive index of various solutions shows a linear relationship with concentration of potassium salts [15]. For given composition of binary ethanol + water mixture, refractive indices of potassium salt increase with their concentration. Also for approximately same concentration of salts, refractive indices increased with increase in percentage of ethanol in ethanol + water mixture which is due to the higher refractive index of ethanol than water.

Temperature independent quantity, *specific refraction* (R_D) that characterizes electronic polarizability of a substance

TABLE 3: Calculated specific refractions (R_D) and molar refractions (R_M) of potassium salt solutions 10%, 20%, 40%, and 60% (v/v) ethanol + water (E-W) mixture at 303.15 K.

X_{KCl}	R_D	R_M	X_{KBr}	R_D	R_M	X_{KI}	R_D	R_M
10% (v/v) E-W								
0.000579	0.2107	3.9982	0.000573	0.2112	4.0192	0.000571	0.2109	4.0099
0.001123	0.2105	4.0003	0.000971	0.2095	3.9993	0.001116	0.2089	3.9866
0.001596	0.2100	3.9964	0.001745	0.2086	4.0029	0.001730	0.2070	3.9510
20% (v/v) E-W								
0.000645	0.2181	4.4030	0.000605	0.2166	4.3535	0.000618	0.2158	4.3334
0.001224	0.2174	4.4228	0.001255	0.2147	4.3381	0.001184	0.2148	4.3315
0.001876	0.2181	4.4753	0.001877	0.2143	4.3479	0.001848	0.2123	4.3008
40% (v/v) E-W								
0.000748	0.2293	5.2654	0.000733	0.2277	5.2087	0.000737	0.2276	5.2002
0.001502	0.2296	5.3197	0.001453	0.2273	5.2255	0.001480	0.2257	5.1844
0.002218	0.2284	5.3333	0.002241	0.2260	5.2185	0.002232	0.2239	5.1649
60% (v/v) E-W								
0.000926	0.2439	6.6025	0.000888	0.2410	6.5011	0.000914	0.2416	6.5112
0.001850	0.2438	6.6535	0.001818	0.2396	6.4931	0.001824	0.2394	6.4811
0.002777	0.2434	6.6969	0.002771	0.2386	6.5010	0.002738	0.2359	6.4155

R_D and $R_M = \text{cm}^3 \cdot \text{mol}^{-1}$.

was calculated by Lorentz and Lorenz equation [16] as follows:

$$R_D = \frac{(n_D^2 - 1)}{(n_D^2 + 2)} \times \frac{1}{\rho}. \quad (1)$$

Lorentz-Lorenz molar refractions [17–19] were determined by using following equation:

$$R_M = \frac{(n_D^2 - 1)}{(n_D^2 + 2)} \times V_M = \frac{(n_D^2 - 1)}{(n_D^2 + 2)} \times \frac{\sum X_i M_i}{\rho}, \quad (2)$$

where, n_D = refractive index of solution; X_i = mole fractions of ethanol, water, and potassium salts; M_i = molecular weights of ethanol, water, and potassium salts; ρ = density of solution.

Calculated specific refractions and molar refractions are reported in Table 3. It can be observed from Table 3 that specific refractions decreased with increase in concentration of potassium salts for a given ethanol-water composition. While, for approximately same concentrations of potassium salts specific refractions have increased with increase in percentage of ethanol. Molar refractions are increased with increase in percentage of ethanol in ethanol-water mixture for approximately the same concentration of potassium salts. This increasing magnitude of molar refractions indicates strong solute-solvent interactions [20]. Changes in molar refractions with concentration of salts are negligible. In case of KI solutions molar, refractions are decreased with increase in concentration of KI in ethanol-water mixture.

4. Conclusion

Densities and refractive indices of solutions potassium salts in ethanol + water mixtures of different ethanol percentage have

been measured at 303.15 K. Specific refractions and molar refractions for different systems are estimated. Dissociation of ions and their interactions with other ions or solvent are recognized.

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