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Effects of Concentration and Relative Permittivity on the Transport Properties of Sodium Chloride in Pure water and Ethanol-Water Mixed Solvent Media

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Abstract

The measurements on the conductivity of Sodium Chloride in pure water and ethanol-water mixed solvent media containing 0.10, 0.20, 0.30, 0.40 and 0.50 volume fractions of ethanol at room temperature are reported. The concentrations were varied from ~ 0.025 to~0.10 mol.L^{-1}. The results showed a sharp increase in the conductivity with increasing electrolyte concentration. The effects of relative permittivity of the medium on the conductivity are also investigated.

Keywords: Mixed solvent media, relative permittivity, conductivity, sodium chloride

Introduction

It is well known that precise conductivity measurements provide important information on ion-ion and ion-solvent interactions[1]. The effect of ion association on the conductance behaviour of electrolytes has been a subject of extensive investigation. Although numerous conductance measurements have been reported in the literature, such studies in mixed solvents are relatively rare[2]. In recent, several studies have reported that the nature of the spherical ions, having a large variation in size in aqueous mixtures of the alcohols, has received considerable attention[3].

It was reported in the previous work[4] that potassium halides are structure breakers in ethanol-water mixtures and the maximum in breaking power occurs at 0.1 mole fraction of ethanol. It has been found in the literature[5] that the conductance of sodium nitrate in ethanol - water mixtures at 308.15 K. But no work has been done earlier on the effects of concentration, relative permittivity on the transport properties of sodium chloride in ethanol-water mixed solvent media. This paper deals with the conductance behaviour of Sodium Chloride in pure water and ethanol-water mixtures covering a range of dielectric constant values at room temperature (303.15 K).

Material and Methods

Ethanol (E. Merck, India) was used for the experimental works. The purified solvent had a density of 0.78097 g.cm^{-3} and a co-efficient of viscosity of 0.9490 mPa.s at 303.15 K; these values are in good agreement with the literature values[6,7]. Distilled water with a specific conductance less than 10^{-6} S.cm^{-1} at 303.15 K was used for the preparation of the mixed solvents. The physical properties of ethanol-water mixed solvents used in this study at 303.15K are shown in table 1 and those values are also matched with the published works[3,8,9]. sodium chloride (NaCl) employed in these investigations was purchased from Ranbaxy chemical company, inc. India. Conductance measurements were carried out on a Pye-Unicam PW 9509 conductivity meter at a frequency of 2000 Hz using a dip-type cell with a cell constant of 1.15 cm^{-1} and having an uncertainty of 0.01%. The cell was calibrated by the methods[10], using aqueous potassium chloride solution. The measurements were made at room temperature. The details of the experimental procedure have been described earlier[11,12]. Solutions were prepared and runs were performed to ensure the reproducibility of the results. Due correction was made for the specific conductance of the solvent by subtracting the specific conductance of the relevant solvent medium from those of the electrolyte solutions. In order to avoid moisture pickup, all solutions were prepared in a dehumidified room with utmost care. In all cases, the experiments were performed in three replicates.

Results and Discussion

The structures of liquid alcohols are much simpler than that of water. They associate much less strongly and form polymeric H-bonded chains, rather than large cluster, which rarely contain 5 to 7 molecules for sterically hindered alcohols[13]. When alcohol and water are mixed there is a minute but measurable heat of solution that is evident. The hydrogen bonding and closer packing of the molecules by the attraction allows a larger number of molecules of the hydrated alcohol to fit into the same space, thus decreasing the overall volume. The density is decreased with the increase of alcohol content for the ethanol-water mixed solvent system (table 1). This behaviour has been found to be similar in the literatures[14,15,16]. As a liquid becomes warmer, the molecules spread out more. When the molecules are more spread out, the substance is less dense, as the specific gravity is lower (table1).

Table-1
Properties of Pure water, Ethanol-Water Mixtures Containing 0.10, 0.20, 0.30, 0.40, 0.50 and pure ethanol at 303.15 K

T/*K*	ρ_0 /g.cm^{-3}	η_0 / mPa.s	D
Pure water			
303.15	0.99568	0.7975	76.54
0.10 volume fraction of ethanol			
303.15	0.98405	1.1262	72.00
0.20 volume fraction of ethanol			
303.15	0.97126	1.4031	67.32
0.30 volume fraction of ethanol			
303.15	0.95556	1.6731	62.07
0.40 volume fraction of ethanol			
303.15	0.93856	1.8816	56.89
0.50 volume fraction of ethanol			
303.15	0.91915	1.9912	51.48
Pure ethanol			
303.15	0.78097	0.9490	23.89

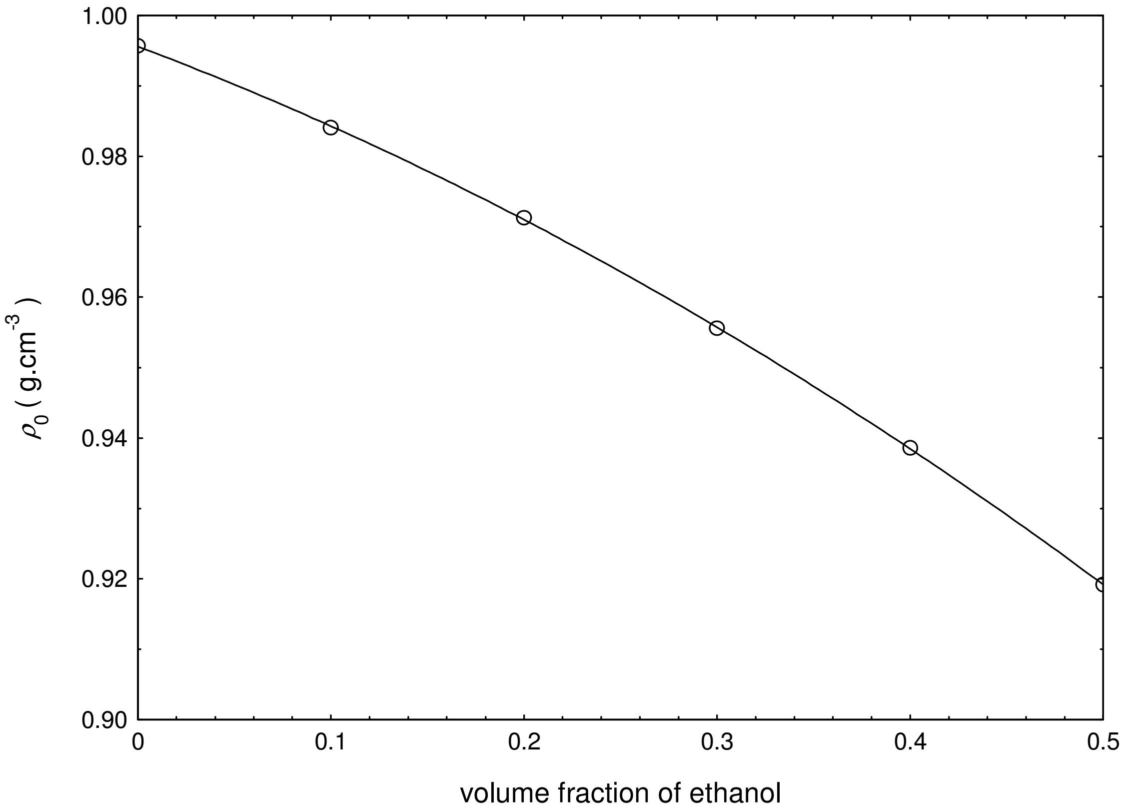

Figure-1
Density of ethanol-water mixtures at 303.15 K

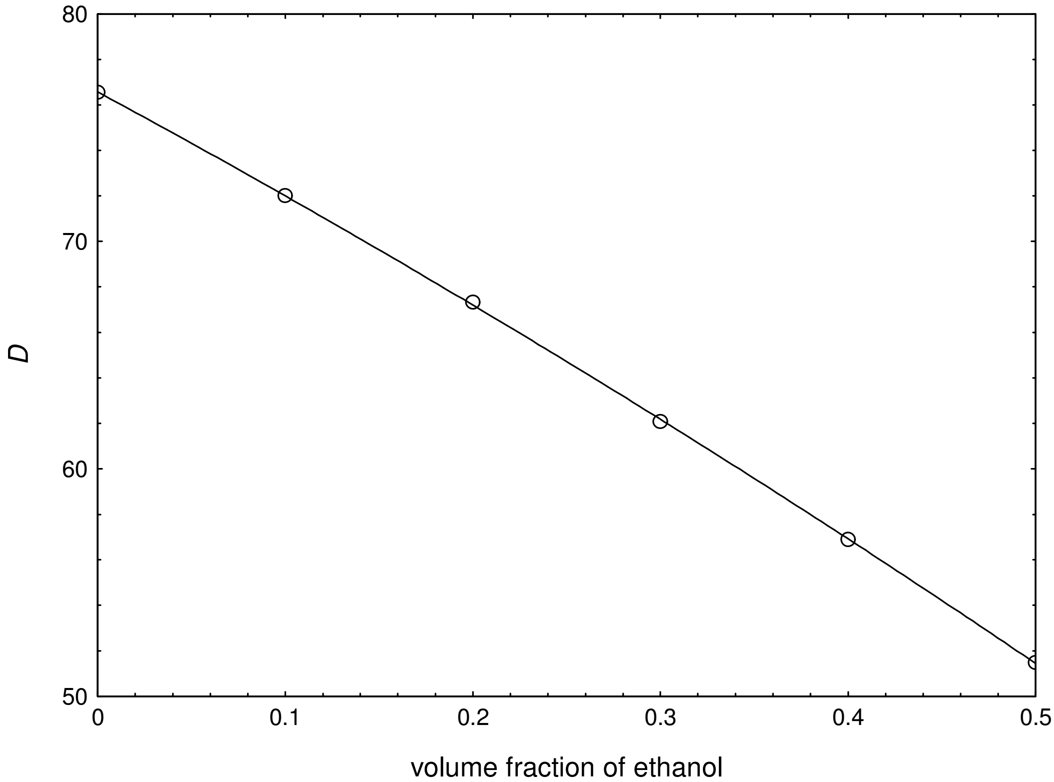

Figure-2
Dielectric constant of ethanol-water mixtures at 303.15 K

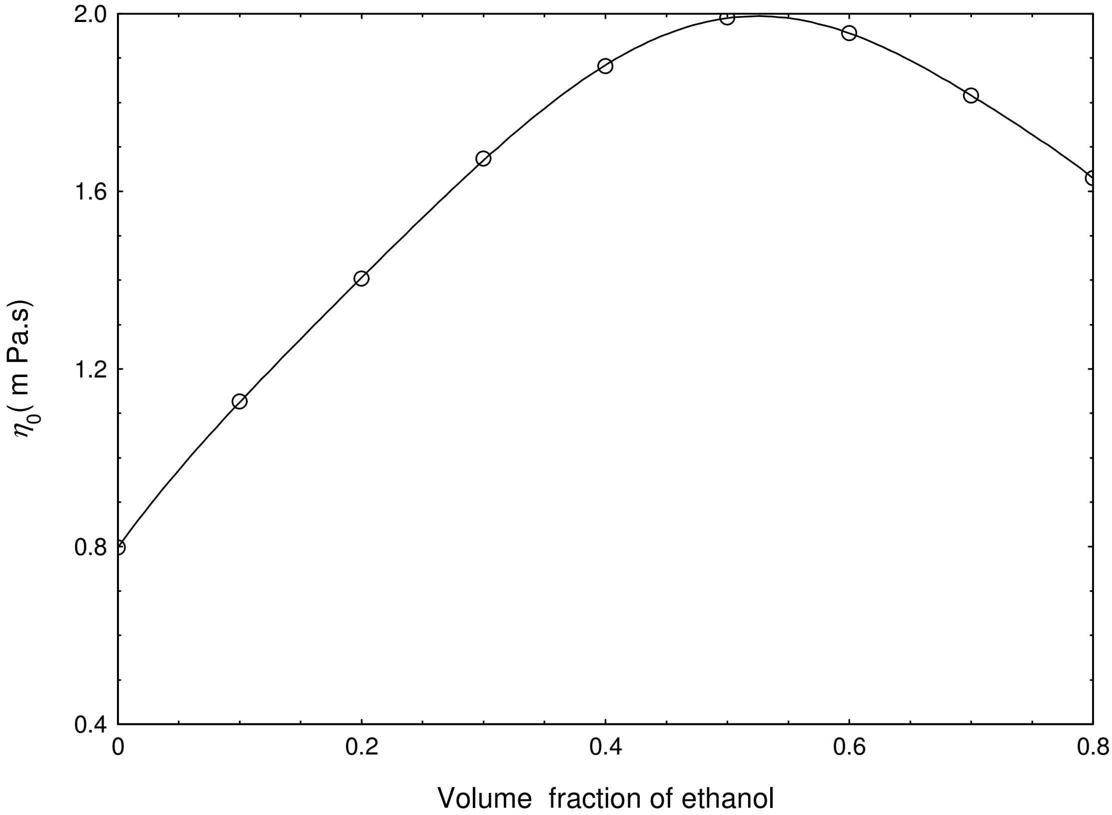

Figure-3
Viscosity of ethanol-water mixtures at 303.15 K

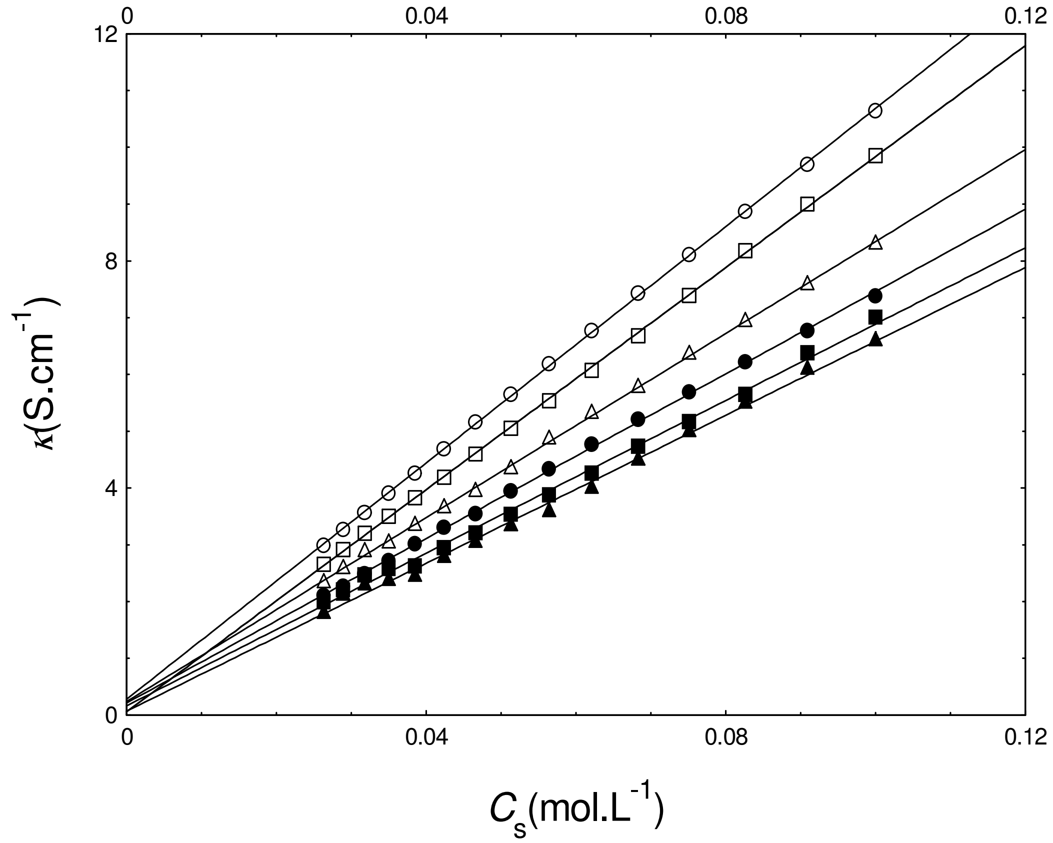

Figure-4

Specific conductivities of Sodium Chloride as a function of the salt concentration (c_s) in 303.15 K. Circle symbols represent experimental values at pure water, square symbols represent experimental values at 0.10 volume fractions of ethanol, triangle symbols represent experimental values at 0.20 volume fractions of ethanol, closed circle symbols represent experimental values at 0.30 volume fractions of ethanol, closed square symbols represent experimental values at 0.40 volume fractions of ethanol and closed triangle symbols represent experimental values at 0.50 volume fractions of ethanol respectively

In ethanol-water mixtures, solvent-solvent interactions play a considerable part and properties of these mixtures cannot always be interpreted on the basis of continuous miscibility of the components in all mixtures. These mixtures possess also pronounced structures which vary with temperature and ethanol content.

The plots of figures (1, 2 and 3) show the variation in the density, dielectric constant and viscosity with ethanol content. It is found that the density and dielectric constant decrease with the increase of ethanol (figures 1 and 2). In the case of viscosity, variation with ethanol shows different behaviour (figure 3). It is observed that by increasing ethanol, the viscosity values increase slowly and reach maxmimum between 0.4 to 0.6 volume fractions of ethanol and then again decrease with further addition of ethanol. It has been described in the literature[17] that about 0.4 to 0.6 volume fractions of ethanol, the water structure has broken down completely and the free volume is minimum and then, hole formation in the activation process of viscous flow will require maximum energy at this composition.

The experimental specific conductivities of sodium chloride as a function of the salt concentration (c_s) at 303.15 K of pure water and five different ethanol-water mixtures (containing 0.10, 0.20, 0.30, 0.40 and 0.50 volume fractions of ethanol) are depicted in figure 4 and shows the specific conductivities exhibit a sharp increase with increasing concentration within the concentration range investigated. Obviously, the concentration dependence of the specific conductivity follows the same pattern at all solvent composition investigated. The relative permittivity of the medium decreased at a given temperature with increasing in the ethanol content and this trend has also been seen in the conductivity study[18,19,20] of methanol content in water.

Conclusion

Experimental results for the specific conductivity of solution of sodium chloride in pure water and ethanol-water mixed solvent media have been presented as a function of salt concentration and different percentage composition of (ethanol + water) mixed solvent media. The specific conductivities are found to increase with increasing concentration over the entire concentration range investigated whereas the specific conductivities of sodium chloride decrease with decreasing dielectric constant of solvent composition at temperature 303.15 K.

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