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Short Communication

Conductometric Studies of Salt Treated Sugar

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ABSTRACT

The electrical conductivity behavior of hygroscopic salts deposits containing Ca^{++}, Mg^{++} ,K^{+}, Na^{+}, *ion was measured in sucrose solution to find preferential salvation in the sugar water solution .This behavior is explained in term of the solute - solvent interaction involved in electrolyte – solvent – non electrolyte solvents systems and their complex forming nature with sucrose molecule, and the hydrogen bonding capabilities of sucrose and the solvent water .It is evident that both ion solvents and electrolytes are predominant in these systems and the hydration of ion and the bonding tendency of sucrose and water play an important role. In view of the fact that above salts are routinely used in sugar industry as well as food additive.*

Keywords: Electrical conductivity; Sucrose solution; hygroscopic salts, Food additive.

INTRODUCTION

Many carbohydrates are known to have the capability of combing with the metal ion, especially with those of the alkali and alkaline earth metal group **[1]** .Formation of adduct between D-Glucose and hydroxide of the alkaline –earth metal has been reported elsewhere [2]. The interaction of sucrose with symmetrical tetra alkyl ammonium iodide in N, N – dimethyl formamide [3] has been studied by employing conductance measurement .A systematic study on electrolyte solvent – non-solvent interaction employing conductance [4 – 9] and viscosity measurement reported elsewhere. Whereas an only uni-univalent electrolyte has been studied earlier the conductance behavior of different multivalent ions (both cation and anion) in sucrose solution is reported [10]. These electrolytes were chosen for the study on conductance basis of their characteristic feature, e.g., a glass - forming tendency [11] and their molecular complex – foaming nature with molecules [12]. Sucrose, like many other polyhydroxy compounds, is known to interact with electrolytes in solution [13-14]. Besides this, conductance behavior of same tetra alkyl ammonium halide in aqueous sucrose solution has been investigated, and data on the conductance of these salts in water saturated by sucrose at 50 ^{O}C are separated [15].Although previous studies indicated that the presence of salt may affect important property of aqueous sugar system related to their protective role [16-17]. Conductance of various electrolytes in solution of D- glucitol, D- glucose, glycerol, D- mannitol, and sucrose was measured [18]. In present paper, the results of further measurement have been analyzed in the light of extended, conductivity theory. The carbohydrate –salt complexation in solution has been quantitatively estimated with the help of the theory.

MATERIALS AND METHODS

General: $CaCl_{2,}$ $MgCl_{2,}$ KCl, and NaCl salts obtained from (E .Merck) and recrystallize from suitable solvents or their mixture .They were used without further purification, after drying in a vacuum desiccator. The sucrose used was of analytical reagent grades (Sigma).

Method: For the conductivity measurement a glass cell with platinized platinum electrode was employed. The resistance, R, of the solution was measured with an AC Bridge (Wayne Kerr 6425) in the frequency range w = 500 Hz –5 KHz, and the true resistance was obtained by extrapolation of R vs w^{-1} at infinite frequency .A thermo stated ethylene glycol / water bath was used to the control the temperature of the super cooled solution with in the ± 0.05 K; and a kerosene /oil bath was used to control the temperature for the measurement at 298.15 K within the = 0.02K; The cell constant was determined as a function of temperature employing the separated electrical conductivity of solution of known concentration ,aqueous KCl at temperature above 273.15K [19] and ethanol solution of KI for temperature below 273.15 K [20]. The cell constant was various from 0.1002 cm^{-1} at 278K down to 0.0957 cm^{-1} 323 K , and the volume at 298.15K was 0.0968 = 0.0006 cm^{-1} .In all cases specific conductivity of pure sugar in water was determined to correct the measured the specific conductivity by the contribution of ionic impurities of the disaccharides.

RESULTS AND DISCUSSION

Production of electrical conductivity: A comparative study of the electrical conductivity producing ability of various salts is summarized in Table 1. Only $CaCl_2$ was found to generates higher values of electrical conductivity when dissolved in sucrose solution .The electrical conductivity generating potential of $CaCl_2$ was comparable to well known conducting salts like, $MgCl_2$, KCl, NaCl.

Dose response studies:

Table 1. A comparison of compounds tested for electrical conductivity

S. No.	Salts	Electrical conductivity production
1	$CaCl_2$	+ + + +
2	$Mg\ Cl_2$	+ + + +
3	KCl	+ + + +
4	NaCl	+ + +

*Concentration (0.01 M)

+ + + + = Very strong, + + + = strong.

The generation of electrical conductivity from $CaCl_2$ was found to be concentration dependent .A linear relation was found between the concentration of $CaCl_2$ (0.01M) and the value of electrical conductivity produced (Fig 1.) .The relationship between electrical conductivity and concentration of test compounds was observed in dilute solution only. At higher concentration the linearity was disturbed due to low solubility of $CaCl_2$.

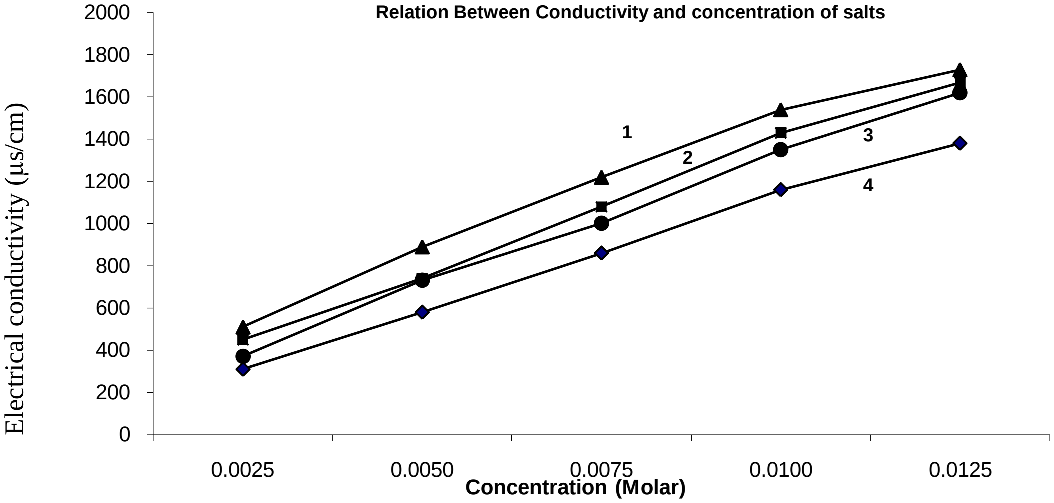

Fig. 1: Determination of electrical conductivity production (0.0025 to 0.0125 M) of the following test compounds. 1. Calcium Chloride; 2.Magnesium chloride; 3.Potassium Chloride; 4.Sodium Chloride.

Another experiment showing relationship between electrical conductivity and concentration of various salts, viz; $MgCl_2$, KCl , NaCl (Fig 1.)

Measurement of electrical conductivity of salts with sucrose solution: 0.0918 gram of calcium chloride (electrolytes) was uniformly dissolved in one liter of water at 20 ^{O}C. To prepare sodium chloride water solution having concentration of about 0.01 mol L^{-1} .One liter of the calcium chloride water was poured into a glass vessel having a capacity of 1L and a pair of electrode of an electric conductivity meter was dipped into the calcium chloride water solution.

Next, 10 g of sucrose powder was added to the calcium chloride water solution in the vessel to that concentration of sucrose was set to about 10 g L^{-1} in a mixed water solution of the calcium chloride and the sucrose, that is about 10 g sucrose was added to 1L of the calcium chloride water solution, and the sucrose and the water were stirred to be uniformly mixed together. On the other hand, an electrical conductivity was detected there by electric conductivity meter of the mixed solution of the calcium chloride and sucrose. As shown in fig.2, although the electrical conductivity of the mixed water solution lowered at first time elapsed by the addition of the sucrose, it took a constant value after a predominant period of time had elapsed.

Thereafter, another 10 g of sucrose were added two more times (that is, the concentration of the sucrose was set to about 20 g L^{-1} and about 30 g L^{-1} and the electric conductivity of the mixed water solution was measured .As shown in fig.2, although the electrical conductivity of the mixed water solution also lowered at first as time elapsed, it had a constant value after a predetermined period of time had elapsed.

It was found from fig.2 that as additive amount of the sucrose increases, the electrical conductivity of the mixed water solution lowers. Fig .2 shows the relationship between the additive amount of the sucrose, i.e. the concentration of sucrose and the electrical conductivity of the mixed water solution of the calcium chloride and the sucrose, wherein it is found that a fixed correlation, i.e. a linear correlation exits between the concentration of the sucrose and the electrical conductivity. Similarly same exercise was carried out for $MgCl_2$, KCl, and NaCl mixed sucrose solution and the observation comes out from fig.2 depicting the same as in $CaCl_2$

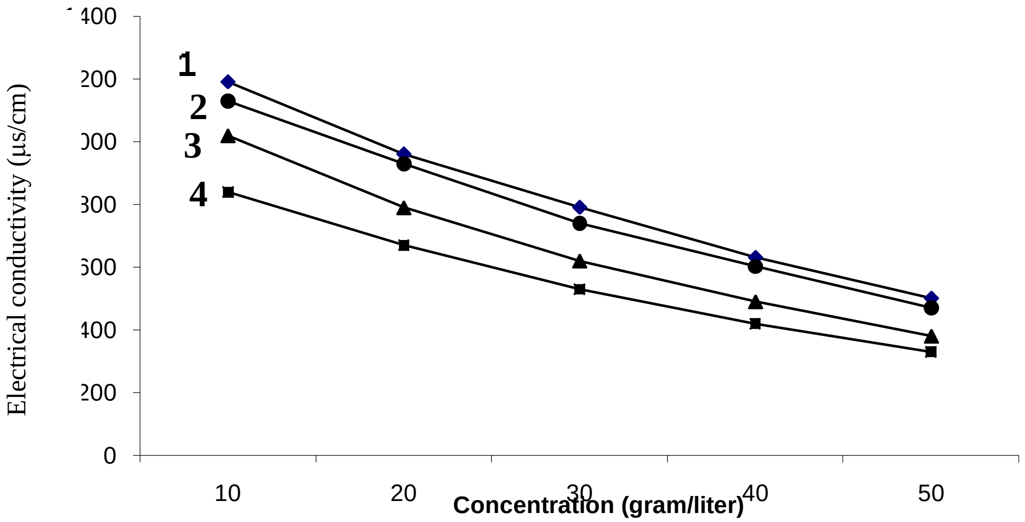

Fig. 2: Relationship between the additive amount of sucrose and the electrical conductivity of the mixed water solution (0.01M) of 1.Calcium Chloride; 2.Magnesium chloride; 3. Potassium Chloride; 4.Sodium Chloride.

Selected salts $CaCl_2$, $MgCl_2$, KCl, NaCl; most commonly used in sugar industry as well as food additive were examine for their ability to produce electrical conductivity in sucrose solution under normal condition with a view of investigate the possible water – salts interaction. $CaCl_2$, $MgCl_2$, KCl, NaCl; were found to produce electrical conductivity of salts depending upon the concentration of the salts (0.01M). At higher concentration, the linearity was disturbed due to low solubility of salts and various other unknown factors. The effect of various alkali halides on the structure of aqueous sucrose solution already has been discussed [4]. The concept that the structure making properties of alkali halides decreases with an increases in their – radii [21] is further supported. It had earlier been established that the divergence of the pair of straight line in these ternary system increase with increases in the structure breaking properties of the electrolytes. For ions of an alkali metal having nitrate and sulphate anions attached, divergence of the pair of straight line is more pronounced in the case of potassium (K^+) ions that of Na^+ ions. Departure of the lines for sulphates were comparatively more pronounced than for nitrates, and this may also be attributed to the structure-breaking breaking properties of SO_4^{--}ions.

For considering the system alkaline - earth chlorides –sucrose –water, divergence a pair of straight lines is found in the order $Ba^{++} > Sr^{++} > Ca^{++} > Mg^{2+}$ .To attribute structure – breaking behavior to the larger alkaline –earth cations appear at, least superficially, to be in conflict with conclusion drawn for other measurements. These viscosity B coefficients are for these ions are positives. Therefore, it would have been stated that they would behave as structure makers.

Results may be further explained by taking into account structural features, solvent –water, hydrogen bonding capabilities and hydration characteristics of sucrose molecule, and the structural behavior of various ions in aqueous system. Water is known to be highly associated liquid .The presence of non electrolytes in sucrose tend to strengthen the hydrogen bonds between the water molecules near the large solute, and a relatively “iceberg ‘is effectively formed around them. Structure –making /-breaking properties of various electrolytes influence model to different extent and that explains the variation in the divergence of straight line for different systems.

A final aspect of such a transition concerns the possibility of cooperative in the solvent structure induced by the solute [22]**.**The physical evidence of changes consists in relatively abrupt changes in the slope or curvature of the various properties .It is evident that both ion solvent and the electrolyte – non-electrolytes are predominant in these systems, and the hydration of ions and the bonding tendency of sucrose and water also play an important role.

Studies shows that there is photonic conduction in sucrose and may be attributed to protons hydrogen bond (HB) – C-H-/-O$<_{H}^{H}$ network present in sucrose crystal.There are several considerations, which strongly favor proton of hydrogen bond network as charge carriers. The fact that when hydrogen bonded protons can take part in charge transport within ice, proteins, and resins [23], then there is no reason why this system should not be involved in transporting charge in the sucrose crystal which is also a good candidate of hydrogen bonding or where the existence of HB are well understood.

A very interesting elucidation can be had from the neutron diffraction structure [24] of sucrose, which revealed two strong intra molecular hydrogen bonds (O-2^{g}...HO-1^{f}, O-5^{g}...HO...6^{f}), which serve to hold the molecule in a well-ordered, rigid conformation in which two rings are approximately at right angles. Apart from HO-4, all the –OH groups are inter molecularly hydrogen bonded. A comparative study with the conductivity of octa-methyl sucrose [25] where there is no hydrogen bonds has revealed that octa-methyl sucrose crystals have no electrical conductivity, which confirms the participation of hydrogen bonds as charge carrier, which is thought to be responsible for the observed conductivity in sucrose crystal. A comparative study with the sugar alcohols, which have infinite chains of –O-H...O-H...O-H- bonds, as an ice would provide an additional evidence of hydrogen bond network as charge carrier in $C_{12}H_{22}O_{11}$. However, this is beyond the scope of present investigation.

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