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Physico-chemical studies on interaction of aqueous solution of L-Alanine with Glucose, Sucrose, NaCl and KCl at T=293.15K

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Abstract

L-Alanine can be manufactured by the human body as it is a nonessential amino acid, hence need not be obtained directly through the diet. L-Alanine maintains a balance of glucose and nitrogen in the human body. It also performs a very important role in the glucose-alanine cycle taking place in the human body. In the present study the viscosity (η), surface tension (γ), density (ρ) and the specific conductance (κ) measurements have been carried out for amino acid L-Alanine, L-Alanine in aqueous glucose, sucrose, NaCl, and KCl at 293.15K for several concentrations. The experiment shows that there is an increase in the viscosity, surface tension, conductance and the density of the amino acid with an increase in the concentrations. And also there is an increase in viscosity, surface tension, density, and conductance with an increase in the concentration of the L-Alanine in Glucose, Sucrose, NaCl, and KCl. We have seen that the conductance of L-Alanine was small for NaCl and KCl to those obtained for Alanine itself and with Glucose, and Sucrose.

Keywords: Physico-chemical properties, L-Alanine, glucose, sucrose, sodium chloride and potassium chloride.

Introduction

Amino acids are organic compounds having biological significance which contain an amine (-NH_2) and carboxyl (-COOH) functional groups, along with an alkyl group (side chain) which is conspicuous to each amino acid[1]. Mainly, amino acids have carbon, hydrogen, oxygen, and nitrogen as key elements, though other elements are found in the side-chains of certain amino acids. The main function of amino acids is to supply nutrients for the nourishment of skin, hair, and nails from within the body. Amino acids are very important for protein synthesis and they are the second-largest component after water of human muscles, cells and other tissues[2]. Besides this, they perform critical roles in processes such as in neurotransmission and biosynthesis. Amino acids help to produce and repair cells and is mainly found in the tissues, organs, and glands of the body.

Amino acids are among the simplest biomolecules and are linked by intramolecular hydrogen bonds. They act as building blocks for most of the peptides and proteins. Amino acids have a unique hydration behavior to form dipolar ions in an aqueous medium which shows an importance in vital biological phenomenon. Due to this unique behavior of forming dipolar ions, their study seems to be very important in the biological system[3,4]. All the metabolic and control and coordination activities of the human body like memory, appetite control, and pain transmission were directly controlled by amino acids. Sometimes they are also used as food additives and also in the pharmaceutical industries. Studies shows that the thermo-dynamic properties of the aqueous amino acids solutions have been greatly affected by the varying amount of concentration of salt and temperature. These studies seem to be very useful in elucidating the various interactions that occur in these solutions. The nature of interactions operative in solution can be deduced by the volumetric and compressibility studies of amino acids in aqueous salt solution[5,6]. It has been confirmed that metal ions play a vital role in various biological processes such as regulation of enzymes, stabilization of structure of reactive molecules, and in membrane transport system[7].

Food industries are mainly concerned with sugar solutions and their co-solutes help in stabilizing biological macromolecules. Experimental findings indicate that this action is performed either as a result of direct interactions between them and/or through alteration of the water structure[8-11]. It is very difficult to directly estimate the protein-sugar interactions as the proteins are large complex molecules hence the unit of proteins that is the amino acid is mainly considered for the study of protein. With this view, a number of studies have been done by many researchers by using the different techniques to study the amino acid/peptide sugar interactions.

In the protein biosynthesis, Alanine (Ala) which is a α-amino acid plays an important role. Structurally, it contains a α-amino group (which is in the protonated $-NH^{3+}$ form under biological conditions), a α-carboxylic acid group (which is in the deprotonated −COO−), and a methyl group side chain. It is categorized as a non-essential amino acid in human being because the human body can synthesize this amino acid on its own. Alanine is mainly concentrated with meats although it may be found in variety of food items.

There are 20 amino acids encoded by the human genetic code and L-isomer (left-handed) of alanine is one of them. With the regard to occurrence L-Alanine is second only to leucine, and accounting about 7.8% of the primary structure in a sample of 1,150 proteins [12]. The right-handed form is the D-Alanine which is mainly found in bacterial cell walls and in some peptide antibiotics. In the present work, we studied the interaction of Glucose, Sucrose, NaCl, and KCl with the L-Alanine at different concentrations. To see these interactions, we have determined the viscosity (η), density (ρ), surface tension (γ), and the conductance (κ) of L- Alanine and L-Alanine with Glucose, Sucrose, NaCl, and KCl at different concentrations of L-Alanine.

Materials and methods

Materials: L-Alanine (Ala) (Batch no.-CN510) was purchased from Qualikems, India. 4.4545g L-Alanine was weighted to make a 250mL stoke solution of 0.2M by using distilled water. By using the stock solution, eight samples of L-Alanine of different concentrations (0.02, 0.04, 0.06, 0.08, 0.1, 0.12, 0.14, and 0.16M) were prepared. To check the intermolecular interactions with L-Alanine, 20mL of each 0.2M Glucose (Glu) (Batch No.-G8270, Company Name-Qualikems), 0.2M Sucrose (Batch No.-IK1030BC01, Qualikems, India), 0.02M Sodium Chloride (Batch No.-0981, Reidel India Chemicals) and 0.02 M Potassium Chloride (Batch No. 090514, Central drugs house, India) were prepared.

Methods: Determination of Viscosity: Ostwald viscometer was used to determine the viscosity. It consists of a U-shaped vertical glass tube. Liquid sample was filled in viscometer using rubber bulb up to the mark and allowed to flow through its capillary tube between two etched marks. The time of flow of the liquid sample was measured using a stopwatch. The viscometer was first be calibrated with a liquid of known viscosity such as pure (deionized) water. Viscosity was calculated using the formula as given below:

$$\frac{\eta_l}{\eta_w} = \frac{d_l t_l}{d_w t_w} \quad (1)$$

Where: Mη_l=Coefficient of the viscosity of liquid, η_w= Coefficient of the viscosity of water, d_l=Liquid density, d_w= Water density, t_l=Time of flow with the liquid, t_w=Time of flow with the water.

Determination of Density: To calculate the density of samples, we weighted the RD bottle with and without a sample. Then we subtracted the weight of empty RD bottle from filled one and got the weight of the sample. After that, we divided the sample weight by its taken volume.

$$\rho = \frac{m}{v} \quad (2)$$

Where: ρ =Density, m =Mass of sample, v =Volume of sample.

Determination of Surface Tension: Stalagmometer was used to determine the surface tension. It consists of three parts, a glass tube as the upper portion, a bulb in the middle and a capillary tube as the lower portion. The stalagmometer was clamped vertically in a clamp stand. Pressure was adjusted according to 15-20 drops per minute with the help of pinch cook using distilled water. A clean empty weighing bottle was weighted and10 drops of water were allowed to fall into it. The weight of the weighing bottle along with the drop was also taken. After this, the apparatus was rinsed with acetone and then allowed to dry completely. Now, the sample was sucked into the stalagmometer and allowed to fall drop wise as done before with water The surface tension was calculated by the following formula.

$$\frac{\gamma_l}{\gamma_w} = \frac{n_w d_l}{n_l d_w} \quad (3)$$

Where: γ_l= surface tension of the liquid, γ_w= surface tension of the water, n_l= no. of drops of the liquid, n_w= no. of drops of the water, d_l= density of liquid, d_w= density of water.

Determination of Electrical Conductivity: Conductivity meter (LT-16, Labtronics) having cell constant 0.97cm^{-1} is used for determining the conductivity of all Alanine samples. To measure conductance, firstly by using distilled water the conductivity cell was rinsed and then wiped with tissue paper before applying sample. After cell cleaning, cell was dipped in a small beaker containing Alanine sample. After setting constant, conductance reading was noted down. The same process was repeated for the other samples.

Results and discussion

Density, surface tension, viscosity and the conductivity of aqueous L-Alanine with Glucose, Sucrose, NaCl and KCl at 293.15K have shown in Table-1. The viscosity values for the system (Salt+amino acid+water) have been found to be increasing with an increase of amino acid (L-Alanine) in solution as shown in Figure-1. This may be attributed to an increase in the solute-solvent (Zwitter-ion) interaction with a successive increase in the number of amino acid molecules/Zwitter ions in the solution. Some decrease in the viscosity is due to the error present in the solution. The viscosity of Sucrose is highest in comparison to all and smallest for Alanine (Figure-1).

The viscosity and density of a solution of L-Alanine in water with and without glucose were measured showing in Figure-1 and Figure-2 respectively. The Figure-1 and Figure-2 show that there exists strong solute-solvent (hydrophilic-ionic group and hydrophilic-hydrophilic group) interaction in this system, which increase with an increase in glucose concentration. Also, increase in density with the concentration suggests a solute-solvent interaction exists between the L-Alanine and water. In the other word, the increase in density may be interpreted to the structure maker of the solvent due to H-bonding.

Table-1: Density, surface tension, viscosity and the conductivity at 293.15K.

M (mole/l)	P (g/cm^3)	γ (dyne/cm)	η (mpa.S)	K (S/m)
L-Alanine				
0.02	0.61	47.90	0.69	27.26
0.04	0.62	56.72	0.72	28.71
0.06	0.63	57.04	0.72	29.49
0.08	0.63	58.91	0.71	25.02
0.1	0.64	62.50	0.77	35.21
0.12	0.64	62.61	0.79	40.93
0.14	0.65	64.83	0.79	42.68
0.16	0.67	67.76	0.88	51.10
L-Alanine + NaCl				
0.02	0.61	72.35	0.69	1.23
0.04	0.61	74.37	0.71	0.58
0.06	0.61	78.87	0.74	1.11
0.08	0.62	80.27	0.77	1.36
0.1	0.62	82.88	0.77	0.85
0.12	0.63	83.68	0.80	1.23
0.14	0.63	83.78	0.84	1.20
0.16	0.64	87.82	0.90	0.92
L-Alanine + KCl				
0.02	0.61	58.48	0.69	1.47
0.04	0.62	60.51	0.71	3.29
0.06	0.63	62.84	0.74	0.63
0.08	0.64	63.82	0.77	1.28
0.1	0.64	67.95	0.83	2.44
0.12	0.65	66.07	0.84	3.35
0.14	0.65	66.38	0.84	2.37
0.16	0.66	68.99	0.84	2.17

M (mole/l)	P (g/cm^3)	γ (dyne/cm)	η (mpa.S)	K (S/m)
L-Alanine + Glucose				
0.02	0.61	58.33	0.69	39.77
0.04	0.62	60.56	0.74	42.87
0.06	0.63	61.48	0.76	37.54
0.08	0.64	73.91	0.78	46.66
0.1	0.64	74.07	0.79	49.76
0.12	0.65	81.49	0.81	53.45
0.14	0.66	84.58	0.86	54.32
0.16	0.67	85.81	0.91	67.22
L-Alanine + Sucrose				
0.02	0.61	49.69	0.85	22.69
0.04	0.62	53.60	0.86	27.26
0.06	0.63	57.68	0.89	30.65
0.08	0.64	59.94	0.91	30.65
0.1	0.65	60.37	0.92	34.05
0.12	0.65	73.26	0.97	45.49
0.14	0.67	78.85	1.01	46.56
0.16	0.67	79.10	1.03	60.24

The surface tension increases with concentration of L-Alanine in all cases. On the other hand, the surface tension is found to be highest when we interact NaCl solution with L-Alanine solution while smallest in the case of L-Alanine solution itself. L-Alanine solution containing glucose has higher surface tension than obtained for sucrose (Figure-3).

The conductance also increases with increase in concentration as shown in Figure-4 because of conductivity changes with the concentration of the electrolyte. The number of ions per unit volume carrying the current decreasing on dilution, so conductivity always decreases with a decrease in concentration and increase with an increase in concentration. Greater the number of ions in the solution the greater is the conductance. The strong electrolytes (NaCl and KCl) dissociate almost completely into ions in solution and therefore their solutions have high conductance. On the other hand, weak electrolyte dissociates to small extents and give the lesser number of ions.

Therefore, the solution of weak electrolytes has low conductance. In our results, we have found that the conductance of Glucose is highest in comparison to all and smallest for NaCl with L-Alanine (Figure-4).

The increase in density with a concentration of L-Alanine in salts suggest a solute-solvent interaction exist between the electrolyte and water. Density provides interesting information regarding the ion-ion, ion-solvent, and solvent-solvent interaction and also on the structural effect of solute and solvent in the solution. Adding salt (NaCl and KCl) to a solution does slightly increase the surface tension of solution showing in Figure-3 although not by any significant amount. As we know NaCl and KCl are strong electrolytes which mean they dissociate into their ions when placed in solution. It turns out that the interaction between the cations and a partial negative ion of solution and anions and the partial positive ion of solution although they disrupt part of the hydrogen bonding. Alanine behaves as weak structure maker in an aqueous glucose solution. The density of Sucrose is highest in comparison to all and smallest for NaCl (Figure-2).

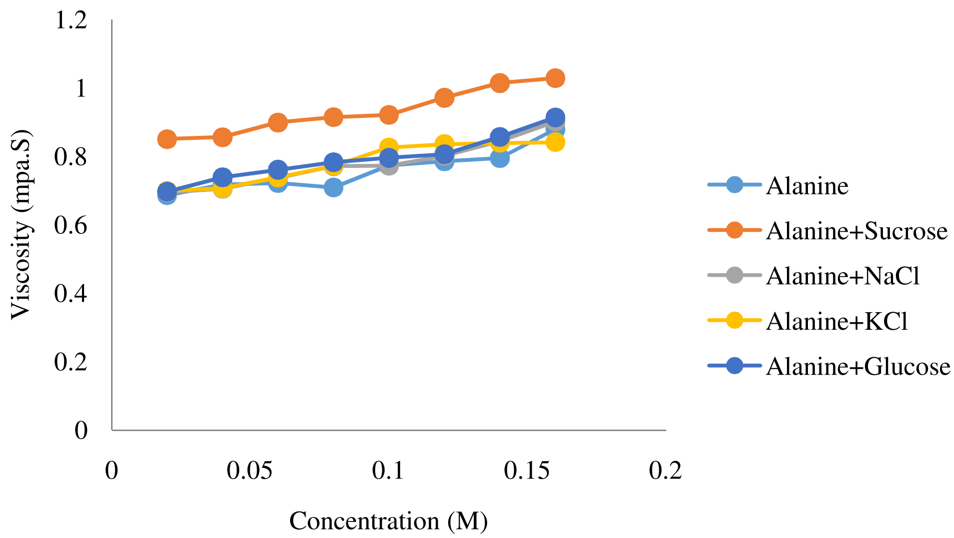

Figure-1: Specific viscosity versus concentration of L-Alanine in 0.02M NaCl, 0.02M KCl, 0.2M glucose and 0.2M sucrose at 293.15K.

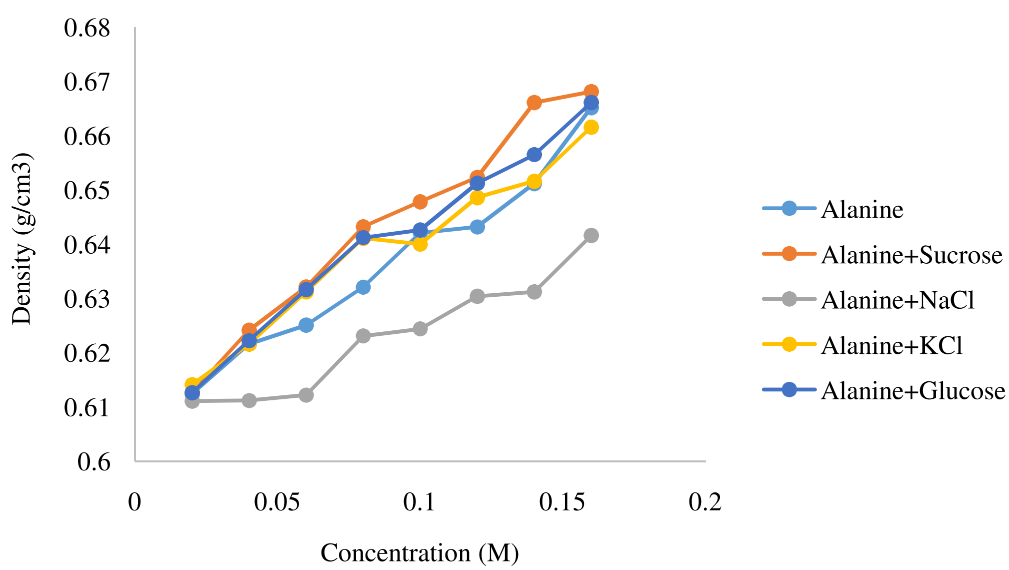

Figure-2: Density versus concentration of L-Alanine in 0.02M NaCl, 0.02M KCl, 0.2M glucose and 0.2M sucrose at 293.15K.

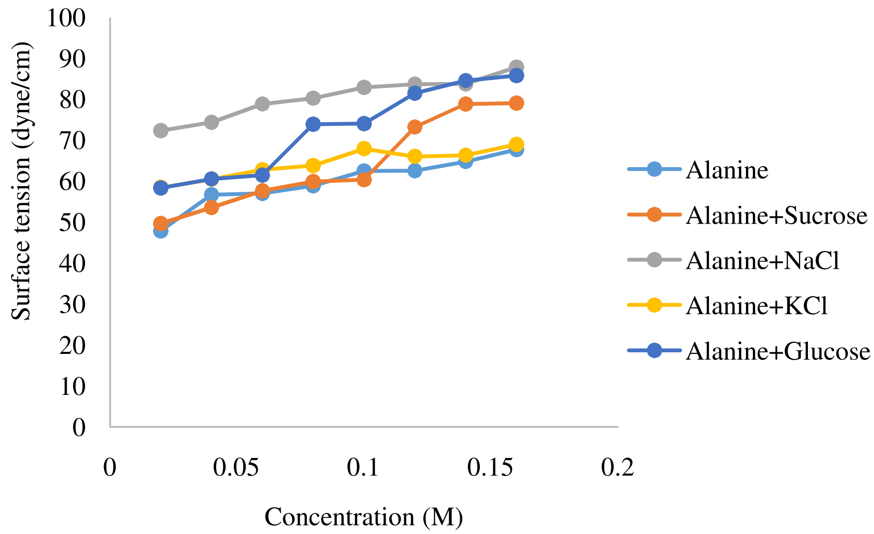

Figure-3: Surface tension versus concentration of L-Alanine in 0.02M NaCl, 0.02M KCl, 0.2M glucose and 0.2M sucrose at 293.15K.

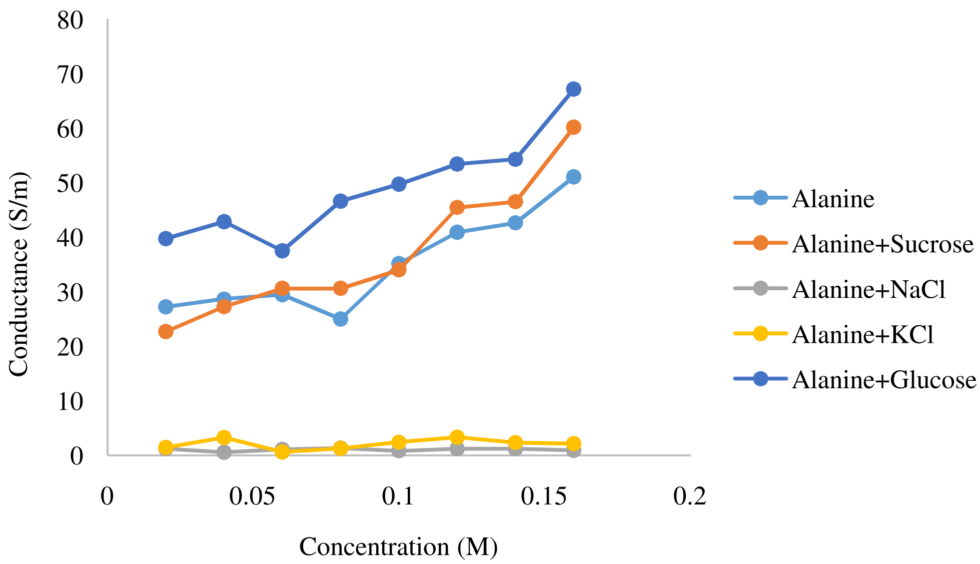

Figure-4: Specific conductance versus concentration of L-Alanine in 0.02M NaCl, 0.02M KCl, 0.2M glucose and 0.2M sucrose at 293.15K.

Conclusion

In this work, we studied the interaction of Glucose, Sucrose, NaCl and KCl with the L-Alanine at different concentrations. The viscosity (η), surface tension (γ), density (ρ) and the specific conductance (κ) measurements have been carried out for amino acid L-Alanine, and L-Alanine in aqueous glucose, sucrose, NaCl and KCl at 293.15K for several concentrations. The results show that there is an increase in the viscosity, surface tension, conductance and the density of the amino acid with an increase in the concentrations. But there is a decrease in the conductance of the KCl and NaCl with an increase in the concentrations. And, also there is an increase in the viscosity (η), conductance (κ), surface tension (γ) and density (ρ) with increase in the concentration of L-Alanine in Glucose, Sucrose, NaCl, and KCl. We have found that the viscosity of Sucrose is highest in comparison to all and smallest for Alanine. The surface tension is found to be highest when we interact NaCl solution with L-Alanine solution while smallest in the case of L-Alanine solution itself. We have also described that the conductance of Glucose is highest in comparison to all and smallest for NaCl. On the other hand, the density of Sucrose is highest in comparison to all and smallest for NaCl.

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