Available on line www.jocpr.com

Journal of Chemical and Pharmaceutical Research

ISSN No: 0975-7384
CODEN(USA): JCPRC5

J. Chem. Pharm. Res., 2011, 3(3):579-586

Interionic association in glycylglycine in aqueous solution of NaCl

O. P. Chimankar[1], Ranjeeta S. Shriwas[1], Prachi S. Chopade[1] and V. A. Tabhane[2]

[1] Department of Physics, RTM Nagpur University, Nagpur, India
[2] Department of Physics, Pune University, Ganeshkhind, Pune, India

ABSTRACT
Peptides are most important molecules due to their wide application in drug production and their role as signal transmitters in the cell communications. Therefore, the systematic study of peptides can prove valuable information about their behavior in solutions and insight into the conformational stability of proteins. Ultrasonic velocity and density values for ternary system (amino acid / di-peptide + salt + water) i.e. glycylglycine each in 1.5 M aqueous solution of NaCl used as a solvent for variable concentrations of glycylgycine in the range of 0.00 to 0.15 molality at a temperature 303.15K. Using ultrasonic velocity and density data, the thermodynamic parameters such as molar volume (V),volume expansivity (α), specific heat (C_p), molecular radius (r_0), Molwyn-Hughes parameter (C_1), cohesive energy density (ε), internal pressure (P_i), change in entropy(ΔΦ), disorder parameter (δ), interaction energy (ΔE) and solubility parameter (δ_S). The observed intermolecular interaction shows ion–solvent, ion-ion and dipole-dipole interactions. The interaction of di-peptide like glycylglycine with aqueous electrolyte solutions due to its vital role in various biological processes in our life. The present study gives us valuable information about various parameters to explore the application of Glycylglycine in medicinal purpose.

Keywords: Peptides, Inter-ionic association, Cohesive energy density, Solubility parameter.

INTRODUCTION

A biomolecule is any organic molecule that is produced by a living organism, including large polymeric molecules such as proteins, polysaccharides, and nucleic acids as well as small molecules such as primary metabolites, secondary metabolites, and natural products. Peptides are short polymers formed from the linking, in a defined order, of α-amino acids. The link between one amino acid residue and the next is known as an amide bond or a peptide bond.

Ultrasonic velocity studies of amino acids [1-2], peptides [3-7] and proteins[8-9] in aqueous media , aqueous urea solution , mixed aqueous solutions and organic solvents have been carried out by number of researchers for investigation of solute–solute, solute-solvent intermolecular/ interionic interactions. However few authors [1, 4, 10, 6 & 7] have studied the behavior of amino acids and peptides in aqueous electrolyte solutions. We have taken ternary system (glycylglycine + salt + water) into consideration which gives us the interesting information about various interactions operative in solution.

Thermodynamic studies of (amino acid/peptide + water) [3, 4, 11] and (amino acid/peptide + salt + water) systems [2, 6, 10] are useful to understand several biochemical processes such as protein hydration, denaturation, aggregation etc. Badarayani and Kumar [7] have reported that the 1:2 and 2:1 electrolytes such as Na_2SO_4 and $MgCl_2$ respectively influence the apparent molar and transfer properties of the volumes and compressibility's of an aqueous amino acid solution more strongly than those of 1:1 electrolytes such as KCl, KBr and NaBr.

The present work is continuation of research work [7] for extension of thermodynamic studies on amino acid/di-peptide + salt + water. From these studies we are trying to discuss the importance of interionic interaction of glycylglycine + salt + water in drug production.

EXPERIMENTAL SECTION

In this paper, ultrasonic velocity and density values for ternary system (di-peptide + salt + water) i.e. glycylglycine each in 1.5M aqueous solution of NaCl used as a solvent for variable concentrations of glycylglycine each in the range of 0.00 to 0.15 molality at temperature range 298K- 323K have been measured by using PEO technique and hydrostatic plunger method. Using ultrasonic velocity and density data, the thermodynamic parameters such as molar volume (V),volume expansivity (α), specific heat (C_p), molecular radius (r_0), Molwyn-Hughes parameter (C_1), cohesive energy density (ε), internal pressure (P_i), change in entropy($\Delta\Phi$), disorder parameter (δ), interaction energy (ΔE) and solubility parameter (δ_S) have been calculated using standard formulae.

RESULTS AND DISCUSSION

In present study of system (di- peptide + salt + water) there is nonlinear variation of ultrasonic velocity and adiabatic compressibility. One of the components generally indicates complex formation in mixture.

When an ion is added to a solvent , it attracts certain solvent molecules towards itself by wrenching the molecule from bulk of the solvent due to the force of electrostriction .Because of this , available solvent molecules for the next incoming ion gets decreased .This process is called as compression. Every solvent has a limit for the compression called the limiting compressibility value. The compressibility of a solvent is higher than that of a solution and decreases with increase in concentration of the solution. With increase in ionic solute concentration , their electrostrictive forces causes the water structure to break and the solute surrounded water molecules are more compactly packed. This hydration effect in turn, results in reducing the compressibility with increasing ionic solute concentration. From the graph we observe that adiabatic compressibility decrease with the increase in concentration of di-peptide .This confirms the presence of the solute-solvent interactions through dipole-dipole interactions of –OH groups of peptides with the surrounding water molecules [12].

In the present system Moelwyn–Hughes parameter C_1 found to be nonlinearly decreasing, which signifies the nonlinear variation of volume expansivity α with molar concentration. In a ternary system, the variation of C_1 and α shows the opposite behaviour with the increase molar concentration i.e. when C_1 increases, volume expansivity (α) decreases and vice-versa .This result indicates the associating nature of the ternary liquid mixture.

The decreasing value of βa with increase in concentration in aqueous NaCl dipeptide solution shows an increase in the internal pressure Pi in ternary liquid systems. This shows the orientation of the solvent molecules around the ions, which may be due to the influence of electrostatic field of ions. This means the solution becomes harder to compress. It also indicates associating tendency of the molecules in aqueous NaCl di-peptide solution.

The cohesive energy density ϵ and solubility parameter δs increase with increase in molar concentration. The increase in values of ϵ and δs shows the increase in degree of association in the molecules. Total internal molecular binding energy (ΔE) and solubility parameter (δs) exhibit a similar behavior as cohesive energy density (ϵ).

The variation of disorder parameter ΔΦ exhibits a nonlinear increase with rise in concentration. Disorder parameter is related to the entropy of the system and from figure it seems to be nonlinearly decreasing. The values of molecular radius (r_o) increases which shows the decrease in molecular order. The values of molecular radius are nearly equal to nanorange, which clearly indicates molecules are smaller.

Specific heat Cp increase with increasing concentration of di-peptide. This indicates structure making ability of di-peptide i.e. hydrophobic hydration or structure enhancing property of di-peptide with rise in concentration of di-peptide.

The ultrasonic velocity (u) value increase with increase in concentration of di-peptide in aqueous electrolyte under investigation. This increase in ultrasonic velocity value in aqueous di-peptide electrolyte solutions may be attributed to the overall increase of cohesion brought about by solute – solute, solute- solvent and solvent – solvent interactions in solutions. Di-Peptide in aqueous solution generally behaves as Zwitterions having NH_4^+ and COO^- groups at two ends of the molecule. The Na^+ ions furnished by electrolytes interact electrostatically with NH_4^+ and COO^- groups of di-Peptide zwitterions .In addition, the water dipoles are strongly aligned to the cations /anions as well as to the di-peptide zwitterions by the electrostatic forces. These interactions comprehensively introduce the cohesion into the solution under investigation .The cohesive forces are further enhanced on successive increase in solute concentration The added di-peptide zwitterions may also occupy the cavities of water clusters, which may lead to the formation of denser structures of the aqueous electrolyte solutions [13].This process may have continued until a concentration of a solute is reached at which all cavities are filled. Raman studies substantiate the view that more number of compact Zwitterions –water structures is formed in solutions with the addition of solute.

Riyazzudden et al. calculated the isentropic compressibility (β_s) of di-peptide in aqueous electrolyte solution from the ultrasonic velocity and density data using Newton-Laplace equation [14].

$$\beta_s=1/\rho u^2$$

This trend of variation of β_s is in consonance with variation of u with concentration and temperature .The smaller values of K_s for aqueous electrolyte solution than that of water may be attributed to cations –water dipole and anions –water dipole interactions in solution, which ultimately may lead to an overall increase in cohesion forces in solutions.

Peptides are involved in many life processes in living organisms. Peptide hormones acts as chemical messengers and controls various processes in our body. Also Neuropeptides in neural tissues involved in regulatory and signaling processes. There are different types of peptides which are present in the form of alkaloids, antibiotics.

Dipeptides are produced from polypeptides by the action of hydrolase enzyme dipeptydyl peptidase. Dietary proteins are digested to dipeptides and amino acids, and the dipeptides are absorbed more rapidly than the amino acids because their uptake involves a separate mechanism. Dipeptides activate G-cells found in the stomach to secrete gastrin which a digestive hormone.

First clinical acute study demonstrated that the glycylglycine –bicarbonate solution was well tolerated by the patients and significantly increased ultra filtration as compared to standard lactate solution.

Glycylglycine also functions as gamma-glutamyl acceptor. The gamma glutamyl transpeptidase enzymes is present in various biological tissues, such as human and animal kidneys as well as in urine and liver diseases and extremely high levels have been associated with cancer of liver, bile duct obstruction and heart disorders of postmyocardial infarction. Thus clinical determination of gamma glutamyl transpeptidase activity in serum has a routine test in a large volume of pathological diagnosis

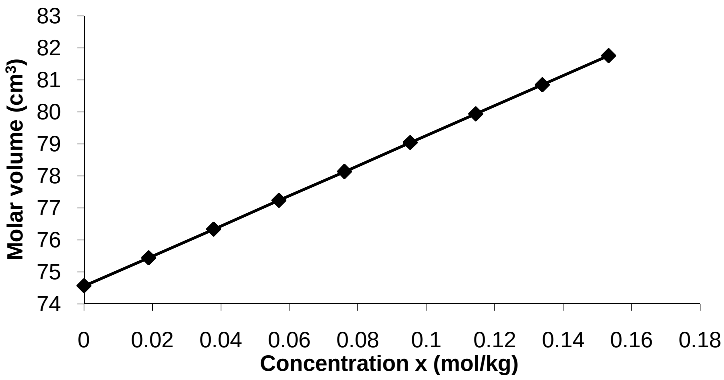

Figure 1: Variation of molar volume with concentration of peptide

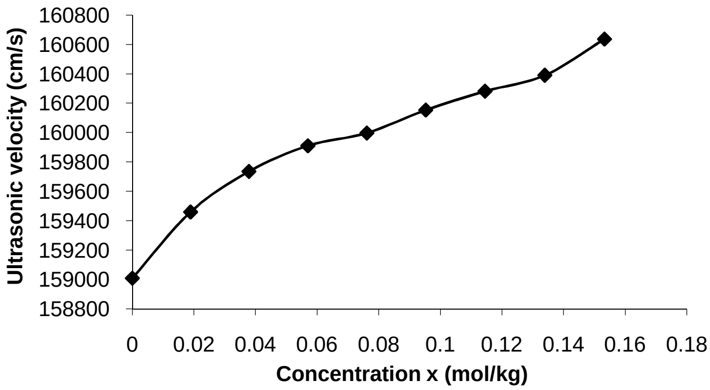

Figure 2: Variation of ultrasonic velocity with concentration of peptide

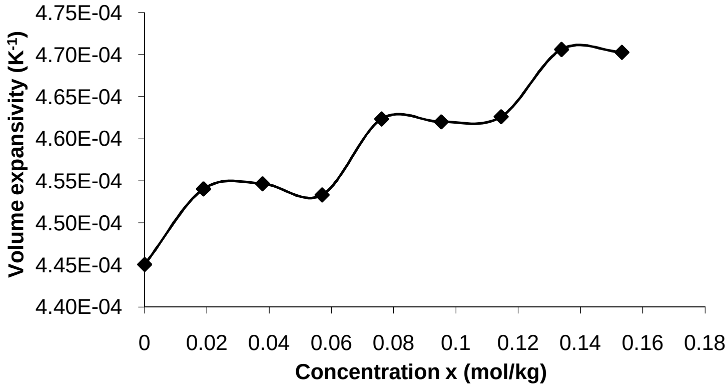

Figure 3: Variation of volume expansivity with concentration of peptide

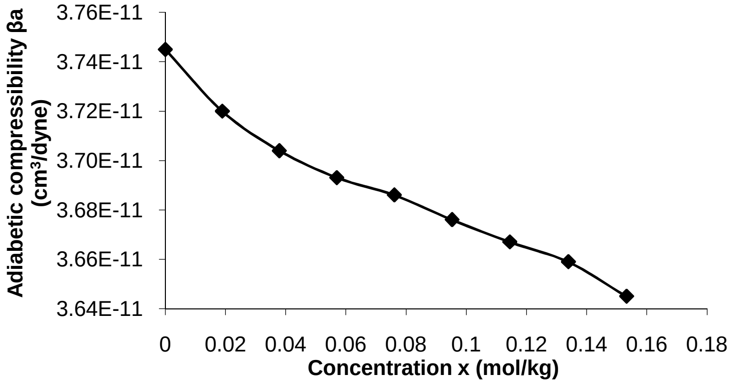

Figure 4: Variation of adiabatic compressibility with concentration of peptide

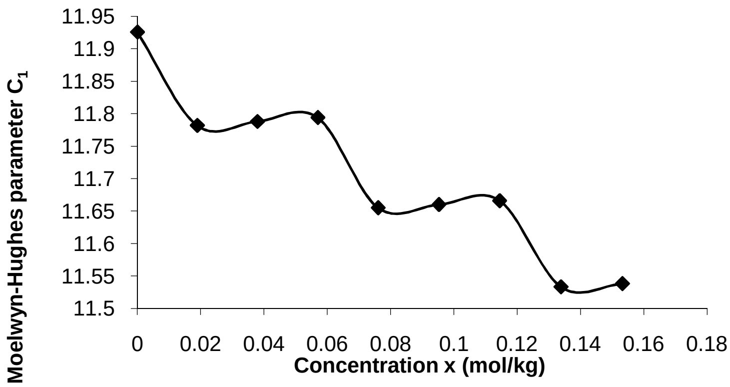

Figure 5: Variation of Moelwyn-Hughes parameter with concentration of peptide

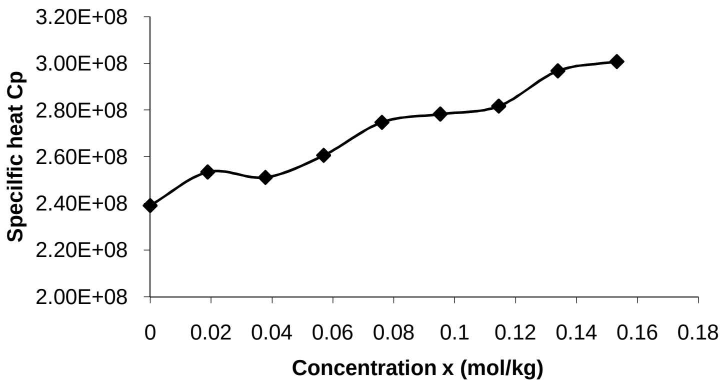

Figure 6: Variation of Specific heat with concentration of peptide

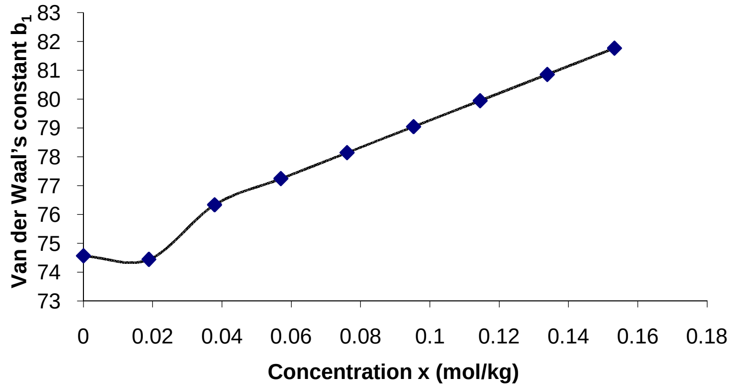

Figure 7: Variation of Van der Waal's constant with concentration of peptide

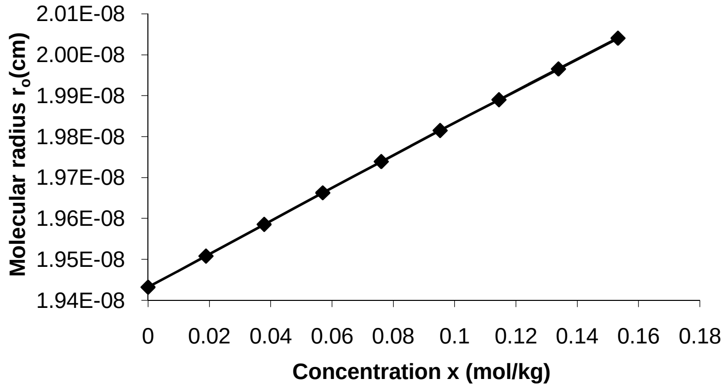

Figure 8: Variation of Molecular radius with concentration of peptide

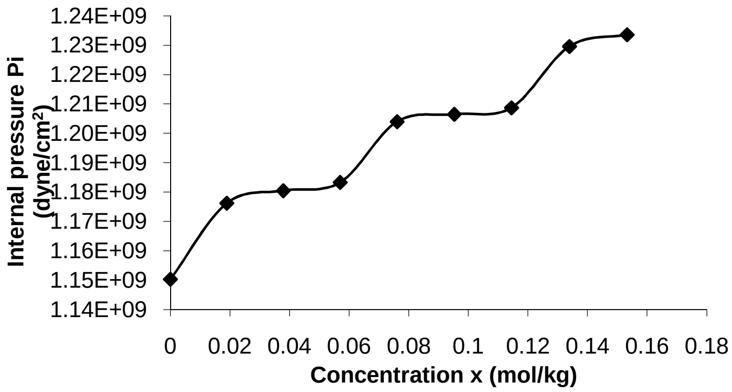

Figure 9: Variation of internal pressure with concentration of peptide

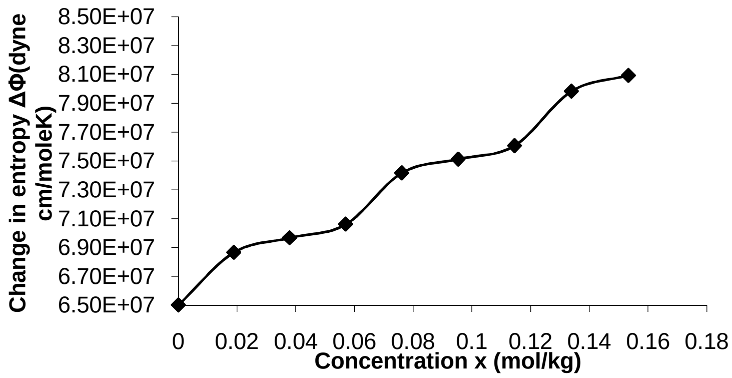

Figure 10: Variation of change in entropy with concentration of peptide

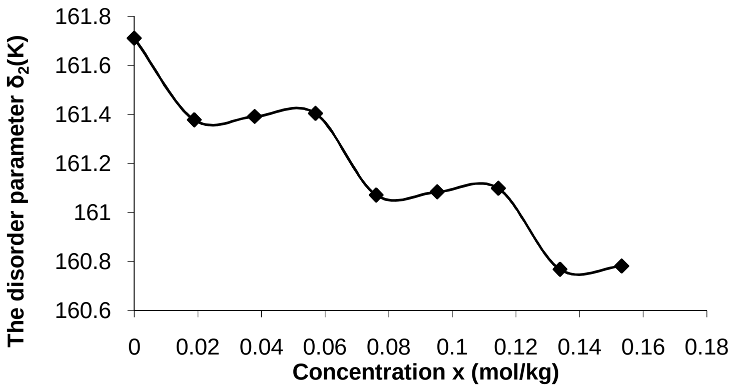

Figure 11: Variation of the disorder parameter with concentration of peptide

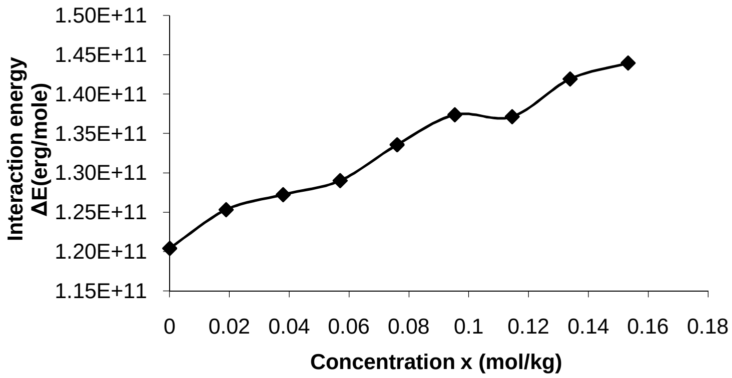

Figure 12: Variation of interaction energy with concentration of peptide

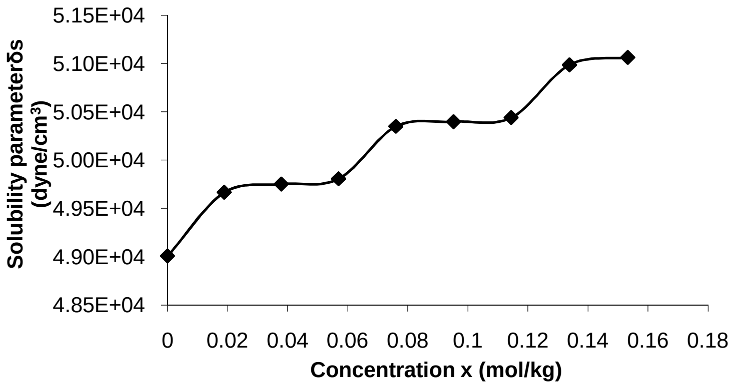

Figure 13: Variation of solubility parameter with concentration of peptide

These applications of peptides shows that they play a vital role in our life being involved in various biological processes & also have medicinal uses. So it becomes necessary to study the interionic association of dipeptides like glycylglycine with aqueous electrolyte solutions because our body consists of such type of electrolytic solutions.

Acknowledgement

The one of the author (OPC) is greatful to University grant commission, New Delhi for providing financial support to this work through Major research project letter F.No.39-456/2010 (SR).

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