Studies on Volumetric and Sound Velocity of Ciprofloxacin in Aqueous Solution of L-Alanine & Glycine at Different Temperatures

by

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Declaration

This is to certify that the thesis work entitled **"Studies on Volumetric and Sound Velocity of Ciprofloxacin in Aqueous Solution of L-Alanine & Glycine at Different Temperatures"** has been carried out by Kanij Fatima in the Department of Chemistry, Khulna University of Engineering & Technology, Khulna, Bangladesh. The above thesis work or any part of this work has not been submitted anywhere for the award of any degree or diploma.

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This is to certify that the thesis work submitted by Kanij Fatima entitled **"Studies on Volumetric and Sound Velocity of Ciprofloxacin in Aqueous Solution of L-Alanine & Glycine at Different Temperatures"** has been approved by the board of examiners for the partial fulfillment of the requirements for the degree of Masters of Science in the Department of Chemistry, Khulna University of Engineering & Technology, Khulna, Bangladesh in 23 January, 2018.

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ABSTRACT

Volumetric and sound velocity method was applied to analyze the effect of ciprofloxacin on the structure of non-essential amino acids (L-alanine & Glycine). Densities and sound velocities of L-alanine and glycine in water and in aqueous (0.03, 0.045 and 0.06) $mol.kg^{-1}$ ciprofloxacin solutions have been studied at 293.15 K to 318.15 K with an interval of 5 K temperature. The density data have been used to calculate apparent molar volume (φ_v), limiting apparent molar volume (φ_v^0), limiting apparent molar volume transfer ($\Delta_{tr}\varphi_v^0$), apparent molar expansibilities $(\delta\varphi_v^0/\delta T)_p$ and Hepler's constant $(\delta^2\varphi_v^0/\delta T^2)_p$. The acoustic properties such as adiabatic compressibility (β_s), apparent molar adiabatic compressibility (φ_k), limiting apparent molar adiabatic compressibility (φ_k^0), apparent molar adiabatic compressibility of transfer ($\Delta_{tr}\varphi_k^0$), acoustic impedance (Z), relative association (R_A) and hydration number (n_H) have been calculated by densities and sound velocities data.

The densities increase with the increase of concentration of amino acids. Densities of amino acids in aqueous ciprofloxacin solutions are higher than that of amino acids in aqueous solution. The increase of density with concentration of amino acids can be attributed to solute-solvent interaction. The limiting apparent molar volumes (φ_v^0) are positive at the studied temperatures for the all mixtures indicate the presence of solute-solvent interactions. The positive values of S_v indicate strong solute-solute interaction and φ_v^0 values suggest the dominance of solute-solvent interaction.

The limiting apparent molar volume transfer ($\Delta_{tr}\varphi_v^0$) values of L-alanine are negative which suggest the existence of ion-hydrophobic and hydrophobic-hydrophobic group interaction. But $\Delta_{tr}\varphi_v^0$ values of Glycine are positive which suggest the existence of ion-hydrophilic and hydrophilic-hydrophilic interactions. The values of limiting apparent molar expansibility $(\delta\varphi_v^0/\delta T)_p$ are positive which suggest the presence of solute-solvent interactions in solutions of amino acids in ciprofloxacin. Hepler's constant $(\delta^2\varphi_v^0/\delta T^2)_p$ values are small negative for all studied amino acids suggest the studied systems act as structure makers. The values of partial molar volumes ($\bar{V}_2$) increase with increasing of concentration of L-alanine and Glycine for the studied systems. This trend of $\bar{V}_2$ indicates solute-solvent interactions increase with increasing concentration of amino acids.

The sound velocity increases with the increase of concentration of L-alanine and glycine. This may be attributed to the increase of compactness of the medium with the increase in amino acids concentration. Sound velocities of amino acids in aqueous ciprofloxacin solutions are higher than that of amino acids in aqueous solution. The adiabatic compressibility (β_s) decreases with the increasing concentration of L-alanine and glycine. This indicates the water molecules around the amino acids are less compressible than the water molecules in the bulk solution. The negative apparent molar adiabatic compressibility (φ_k) values indicate the greater loss of structural compressibility of water. The values of limiting apparent molar adiabatic compressibility (φ_k^0) are negative. The values of apparent molar adiabatic compressibility transfer ($\Delta_{tr}\varphi_k^0$) are positive which suggest the existence of strong ion-solvent interaction. At lower concentration, negative values of $\Delta_{tr}\varphi_k^0$ indicate that increase in hydrophobic-hydrophobic group interactions. The positive S_k values also indicates the solute–solute interaction. The acoustic impedance, Z increases with the increase of concentration of amino acids. The relative association, R_A decreases linearly with increasing the concentration of solute indicates the increase of solute-solvent interaction. The positive hydration number (n_H) values indicate an appreciable solvation of solutes.

Therefore, the water molecules around amino acids are less compressible than water molecules in the bulk solution. The compressibility of ternary solution is less than binary solution. This result suggests that the proteins or peptides generated from the studied amino acids that will be denatured in ternary ciprofloxacin solution.

Contents

LIST OF TABLES

LIST OF FIGURES

Nomenclature

φ_v	The apparent molar volume
ρ_0	Density of solvent
ρ	Density of solution
u_0	Sound velocity of solvent
u	Sound velocity of solution
$\bar{V}_2$	Partial molar volume
m	Molality
M	Molecular mass
n_1	Number of moles of solvent
n_2	Number of moles of solute
n_H	Hydration number
R_A	Relative association
Z	Acoustic impedance
β_s	Adiabatic compressibility of solution
$\beta_{s,o}$	Adiabatic compressibility of solvent
h	Plank's constant
N	Avogadro's number
R	Universal gas constant
A,B,C	Constants related with temperature effects

CHAPTER I

Introduction

1.1 General

The volumetric and transport properties of binary and ternary mixtures have been extensively used to understand the molecular interactions between the components of the mixture, to develop new theoretical models and also for engineering applications in the process industry concerning heat transfer, mass transfer and fluid flow. Knowledge of the macroscopic properties (densities, sound velocities, viscosities, surface tensions etc.) of the mixtures is of vital importance for accurate design of the equipment for various unit operations and unit processes [1, 2]. Solid liquid or liquid-liquid mixtures is of considerable importance in understanding the molecular interaction occurring among component molecules and finds their applications in several industrial and technological processes such as petrochemical, pharmaceutical and cosmetics etc. [3]. The interaction of important biomolecules such as amino acids with aqueous ciprofloxacin solutions and temperature dependence play an important role in the understanding of biomolecule action. It is also clear that if the solute and the solvent are interacting, as indeed they do, then the chemistry of the solute in a solvent must be different and the presence of a solvent can modify the properties of a solute. So the interactions of amino acids with their surrounding environment play an important role in their characteristic properties.

1.2 Properties of solute in solvent

In chemistry, a solution is a homogeneous mixture composed of two or more substances. In such a mixture, a solute is a substance dissolved in another substance, known as a solvent. The solution more or less takes on the characteristics of the solvent including its phase and the solvent

is commonly the major fraction of the mixture. The concentration of a solute in a solution is a measure of how much of that solute is dissolved in the solvent, with regard to how much solvent is present.

The physicochemical properties involving solute–solvent interactions in mixed solvents have increased over the past decade in view of their greater complexity in comparison with pure solvents [4–6]. This puzzling behavior results from the combined effects of preferential solvation of the solute by one of the components in the mixture [7, 8] and of solvent–solvent interactions [9]. Preferential solvation occurs when the polar solute has in its microenvironment more of one solvent than the other, in comparison with the bulk composition. The understanding of these phenomena may help in the elucidation of kinetic, spectroscopic and thermodynamic events that occur in solution.

Theoretically, solute-solvent interactions that mean the properties of solutions can be calculated from the properties of the individual components. But, the liquid state creates inherent difficulties and the properties of solution cannot understand properly. The theoretical treatments, therefore, have to assume some model (e.g., lattice model, cell model etc.) for the structure of the components and their solution. Alternatively, it is considered convenient and useful to determine experimentally the values of certain macroscopic properties of solutions for proper understanding of the structure of the solution. Some of the usually experimentally determined macroscopic properties are: density, sound velocity, thermodynamic properties, surface tension, etc., which are readily measurable.

Physical properties like density, sound velocity, surface tension, conductivity, dielectric constant, refractive index etc. provide an indication about the molecular structure as well as the molecular interactions that occur when solute and solvent are mixed together. The density and sound velocity are two fundamental physico-chemical properties of which are easy, simple, inexpensive and precise tools, by which one can get the valuable information about the molecular interactions in solid and liquid mixture correlated with equilibrium and transport properties. From the above mentioned properties, quantitative conclusion can be drawn about the molecular interactions even in simple liquids or their mixtures. Our present investigation is based on the methods of physico-chemical analysis, which is a useful tool in getting sound information about

the structure of some aqueous ciprofloxacin with amino acids in studying the solute-solvent and solvent-solvent interactions in ternary systems.

1.3 Amino Acids

Amino acids are defined as organic substances containing both amino and acid groups. Among more than 300 amino acids in nature, only 20 of them (α-amino acid) serve as building blocks of protein. Glycine and L-alanine are most important of them. Contrary to plants and some microorganisms, animals and humans are only capable of synthesizing 10 of the 20 naturally occurring amino acids. The rest must be included in the diet; these amino acids are classified as essential. Because of variations in their side chains, amino acids have remarkably different biochemical properties and functions [10].

From a chemical viewpoint an amino acid is a base as well as an acid; i.e. it consists both of an amino group and a carboxylic group. The amino acid is therefore an ampholyte since it can react both as a base and as an acid. The most common amino acids are the α-amino acids, which are amino acids where the amino group is located at the α-carbon atom of the carboxylic group as shown in Figure 1.1. The α-carbon atom (usually) has hydrogen and a side chain at the last two sites.

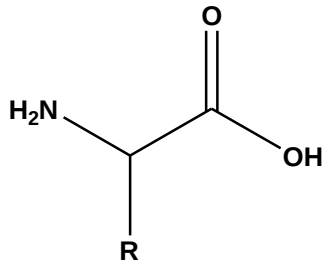


Figure 1.1. Basic structure of α-amino acids.

When two amino acids are linked together by a peptide bond is called a dipeptide. Continuing this process will eventually lead to the formation of protein [11]. Amino acids have a higher solubility in polar solvents (e.g. water, ammonia) than in less polar solvents (e.g. ethanol, methanol, and acetone). They are crystalline solids with relatively high melting points. In

aqueous solutions, the amino acids are generally stable, at physiological pH, and they exist as neutral dipolar ions, i.e., due to physiological conditions, the two terminals of amino acids are both charged; positive charge (amino group) and negative charge (carboxyl group,), therefore the molecules have the properties of zwitterion [12].

1.4 Properties of glycine

Glycine is the amino acid that has a single hydrogen atom as its side chain. It is the simplest possible amino acid. The chemical formula of glycine is NH_2-CH_2-COOH. Glycine is a colorless, sweet-tasting crystalline solid. It is the only achiral proteinogenic amino acid. It can fit into hydrophilic or hydrophobic environments, due to its minimal side chain of only one hydrogen atom [13].

Glycine is the second most widespread amino acid found in human enzymes and proteins, which is why it has roles in nearly every part of the body. The usage of glycine in organ transplantation is most widely investigated in liver transplantation [14, 15]. Glycine improves function of liver, cures liver injury, and prevents mortality in experimental sepsis caused by cercal puncture and ligation [16]. One of the researchers demonstrated that platelets express glycine gated chloride channels in rats. They also reported that human platelets are glycine responsive and express glycine gated chloride channels [17].

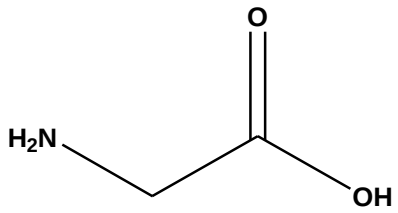


Figure 1.2: Structure of glycine

1.5 Properties of L-alanine

L-alanine is a non-essential amino acid and plays a crucial role as a building block of important proteins. It contains an α-amino group (which is in the protonated form, $-NH3^{+}$, under biological conditions), an α-carboxylic acid group (which is in the deprotonated form, $-COO^{-}$, under biological conditions), and a side chain methyl group, making it a nonpolar, aliphatic amino acid. It has the chemical formula $HO_2CCH(NH_2)CH_3$.

L-alanine supplements are therefore often used in cases of hypoglycaemia to prevent the organism from suffering low blood sugar or insulin shocks. They enable rapid energy delivery by stimulating the immediate release of glucose into the blood stream. L-alanine can be an effective nutrient supporting an intensive training regime and achieve effective muscle growth. L-alanine is easily washed away and lost in foods due to its strong hydrophilic (water soluble) properties. Other important tasks of this non-essential amino acid are the support of the immune system and prevention of kidney stones. L-alanine is also an important reactant for glucagon because it will stimulate its production when the blood sugar is too low. Additionally, it will support the generation of glucose from other amino acids [18].

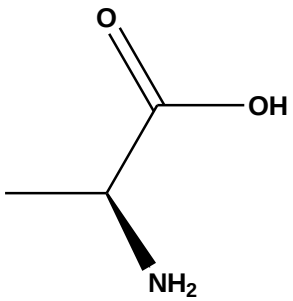


Figure 1.3: Structure of L-alanine

1.6 Properties of ciprofloxacin

Ciprofloxacin is an antibiotic used to treat a number of bacterial infections [19]. Ciprofloxacin is 1-cyclopropyl-6-fluoro-1, 4-dihydro-4-oxo-7-(1-piperazinyl)-3-quinolinecarboxylic acid. Its empirical formula is $C_{17}H_{18}FN_3O_3$ and its molecular weight is 331.4 g/mol. It is a faintly yellowish to light yellow crystalline substance [20]. This includes bone and joint infections, intra-abdominal infections, certain type of infectious diarrhea, respiratory tract infections, skin infections, typhoid fever, and urinary tract infections, among others. For some infections it is used in addition to other antibiotics. It can be taken by mouth or used intravenously [21].

Ciprofloxacin is a broad-spectrum antibiotic of the fluoroquinolone class. It is active against both Gram-positive and Gram-negative bacteria. It functions by inhibiting DNA gyrase, and a type II topoisomerase, topoisomerase IV [22, 23], necessary to separate bacterial DNA, thereby inhibiting cell division. Ciprofloxacin is the most widely used of the second-generation quinolones [24, 25]. In 2010, over 20 million prescriptions were written, making it the 35th-most commonly prescribed generic drug and the 5th-most commonly prescribed antibacterial in the U.S [26].

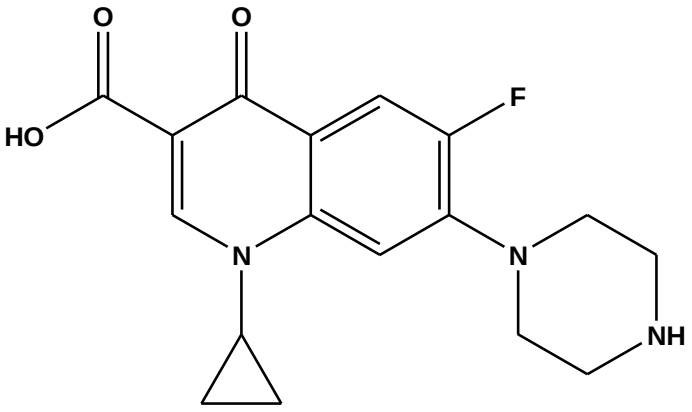


Figure 1.4: Structure of ciprofloxacin

1.6 Properties of water

Water has a very simple molecular structure. The nature of the molecular structure of water causes its molecules to have unique electrochemical properties. The hydrogen side of the water molecule has a slight positive charge. On the other side of the molecule a negative charge exists. This molecular polarity causes water to be a powerful solvent and is responsible for its strong surface tension.

When the water molecule makes a physical phase change its molecules arrange themselves in distinctly different patterns. The molecular arrangement taken by ice (the solid form of the water molecule) leads to an increase in volume and a decrease in density. Expansion of the water molecule at freezing allows ice to float on top of liquid water.

1.7 Structure of water

It has been recognized that water is an 'anomalous' liquid many of its properties is differ essentially from normal liquids of simple structures [27]. The deviations from regularity indicate some kind of association of water molecules. The notable unique physical properties exhibited by liquid water are [28] : i) negative volume of melting ii) density maximum in normal liquid range (at 4^0C) iii) isothermal compressibility minimum in the normal liquid range at (46^0C) iv) numerous crystalline polymorphs v) high dielectric constant vi) abnormally high melting, boiling and critical temperatures for such a low molecular weight substance that is neither ionic nor metallic vii) increasing liquid fluidity with increasing pressure and viii) high mobility transport for H^+ and OH^- ions pure water has a unique molecular structure. The O-H bond length is 0.096 nm and the H-O-H angle 104.5^0. For a very long time the physical and the chemist have pondered over the possible structural arrangements that may be responsible for imparting very unusual properties to water. To understand the solute water interaction the most fundamental problem in solution chemistry the knowledge of water structure is a prerequisite. The physicochemical properties of aqueous solution in most of the cares are interpreted in terms of the structural

change produced by solute molecules. It is recognized that an understating of the structural changes in the solvent may be crucial to study of the role of water in biological systems.

Various structural models that have been developed to describe the properties of water may generally be grouped into two categories, namely the continuum model and the mixture models. The continuum models [29, 30] treat liquid water as a uniform dielectric medium, and when averaged over a large number of molecules the environment about a particular molecules is considered to be the same as about any other molecules that is the behavior of all the molecules is equivalent.

The mixture model theories [30-32] depict the water as being a mixture of short lived liquid clusters of varying extents consisting of highly hydrogen bonded molecules which are mixed with and which alternates role with non bonded monomers.

Among the mixture models, the flickering cluster of Frank and Wen [33], later developed by Nemethy and Scherage [34], is commonly adopted in solution chemistry. Properties of dilute aqueous solutions in terms of structural changes brought about by the solutes can be explained more satisfactorily using this model than any other model. According to this model the tetrahedral hydrogen bonded clusters, referred to as bulky water $(H_2O)_b$, are in dynamic equilibrium with the monomers, referred to as dense water, $(H_2O)d$ as represented by [35].

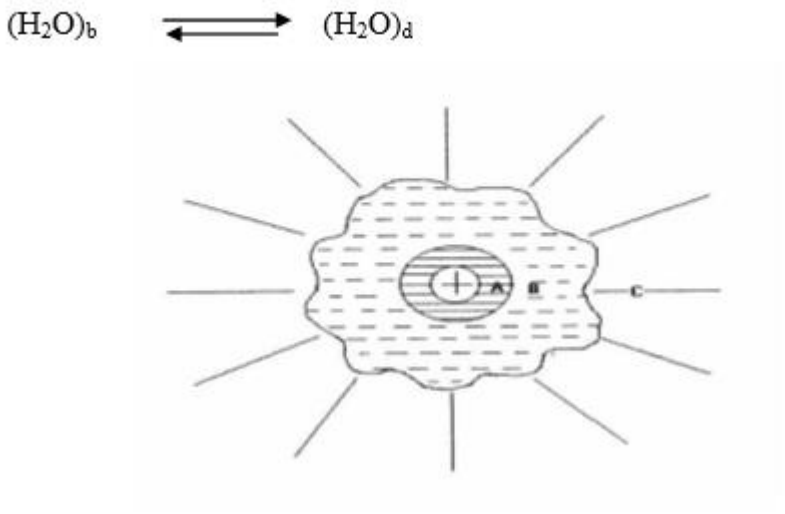


Fig 1.5: Frank and Wen model for the structure modification produce by an ion

The hydrogen bonding in the clusters is postulated [36] to be cooperative phenomenon. So that when one bond forms several others also come into existence. The properties of solution can be accounted for in terms of solvent-solvent, solvent-solute and solute-solute interaction. In terms of thermodynamics, the concentration dependence of a given property extrapolated to the limit of infinite dilution provides a measure of solute-solvent interactions. Solute-water interaction or hydration phenomenon can be conveniently classified into three basic types:

i. Hydrophilic Hydration
ii. Ionic hydration
iii. Hydrophobic hydration

The introduction of a solute into liquid water produces changes in the properties of the solvent which are analogous to these brought about by temperature or pressure. The solute that shifts the equilibrium to the left and increase the average half-life of the clusters is termed as structure maker whereas that which has an effect in the opposite direction is called 'Structure breaker'.

The experimental result on various macroscopic properties provides useful information for proper understanding of specific interactions between the components and the structure of the solution. The thermodynamic and transport properties are sensitive to the solute-solvent, solute-solute, and solvent-solvent interaction. In solution systems these three types of interaction are possible but solute-solute interaction are negligible at dilute solutions. The concentration dependencies of the thermodynamic properties are a measure of solute-solute interaction and in the limit of infinite dilutions these parameters serve as a measure of solute-solvent interactions. The solute induced changes in water structure also result in a change in solution viscosity.

1.8 Hydrophilic hydration

Solvation occurs as the consequences of solute-solvent interactions different from those between solvent molecules themselves. The solubilization of a solute molecule in water is characterized by changes in the water structure that depend on the nature of the solute.

Dissolution of any solute will disrupt the arrangement of water molecules in the liquid state and create a hydration shell around the solute molecule. If the solute is an ionic species, then this hydration shell is characterized to extend from an inner layer where water molecules near the charge species are strongly polarized and oriented by the electrostatic field, through an intermediate region where water molecules are significantly polarized but not strongly oriented, to an outer solvent region of bulk water where the water molecules are only slightly polarized by the electric field of the ion [37].

1.9 Hydrophobic hydration and hydrophobic interaction

The hydrophobic effect refers to the combined phenomena of low solubility and the entropy dominated character of the solvation energy of non-polar substances in aqueous media (38). It is also reflected by anomalous behavior in other thermodynamic properties, such as the partial molar enthalpies, heat capacities and volumes of the nonpolar solutes in water. This effect originated from a much stronger attractive interaction energy between the nonpolar solutes merged in water than their vander waals interaction in free space [39]. The tendency of relativity nonpolar molecules to "stick together" in aqueous solution is denoted as the hydrophobic interaction [40]. It results from hydrophobic hydration of a nonpolar molecule. Because hydrophobic hydration plays an important role in facilitating amphiphiles to aggregates in the aqueous bulk phase and to absorb, excessively, at the aqueous solution/air interface, it has been an ongoing objective of chemists working in these areas to seek a clearer understanding of the molecular nature behind the subtle hydration phenomenon occurring between nonpolar solutes and water. A brief but detailed account of the general aspects of hydrophobic hydration, which is essential to the rationalization of the results obtained in this work, is given at this point.

1.10Amino acids-solvent systems

The experimental data on volumetric and ultrasonic properties provide valuable information for proper understanding the nature of interaction between the components of the solution. The study of volumetric and sound velocity of solution containing amino acids and drug (ciprofloxacin) are interesting. The correlation between solute-solvent interactions is complex. The environment of the solute affects the volumetric and sound velocity properties; it is of interesting to study the effect of the media changing from water-drug (ciprofloxacin) with amino acids on the thermodynamic properties. Research on density and optical Properties of ciprofloxacin hydrochloride + aqueous-ethanol mixtures at 30°C has been reported [41]. Acoustic and volumetric properties of ciprofloxacin hydrochloride in dioxane-water mixture at 303.3 K has been measured previously [42].

1.11 The object of the present work

The developments in solution theory are still far from being adequate to account for the properties of the constituent molecules. Accordingly, it is the experimental data on various volumetric and ultrasonic properties, which provide useful information for proper understanding of specific interaction between the components and structure of the solution. The experimental approach of measurements of various macroscopic properties is also useful in providing guidance to theoretical approaches, since the experimentally determined values of solution properties may bring to light certain inadequacies in the proposed model on which theoretical treatments may be based. Volumetric and ultrasonic studies on ternary solutions have attracted a great deal of attention and experimental data on a good number of systems are available in a number of review articles [43-44]. Since there has to be the same origin, namely, the characteristic intermolecular interactions, it is natural to seek functional relationships among the volumetric properties, ultrasonic properties and thermodynamic properties. However, such attempts have not met with much success.

Besides the theoretical importance, the knowledge of physicochemical properties of multicomponent mixtures is indispensable for many chemical process industries. For instance, in petroleum, petrochemical and related industries the above mentioned processes are commonly used to handle the mixture of hydrocarbons, alcohols, aldehydes, ketones etc., which exhibit ideal to non-ideal behavior. For accurate design of equipment required for these processes, it is necessary to have information regarding the interactions between the components. Similarly, knowledge of the sound velocity of liquids/mixtures is indispensable. Sound velocity and density data yield a lot of information on the nature of intermolecular interaction and mass transport.

The experimental data on volumetric and ultrasonic properties such as apparent molar volumes, partial molar volumes, apparent molar adiabatic compressibility and hydration number often provide valuable information for the understanding of the nature of homo and hetero-molecular interactions. The knowledge of the main factors involved in the solute-solvent and solvent-solvent interactions of liquid mixtures is fundamental for a better understanding of apparent molar volumes and ultrasonic properties.

The thermo-physical properties of liquid systems like density and sound velocity are strictly related to the molecular interactions taking place in the system [45]. The studies of amino acids express the interaction of dipolar ions with other functions and components in the biological system [46]. The interactions are of different types such as ionic or covalent, charge transfer, hydrogen bonding, ion-dipole and hydrophobic interactions. There are various papers appeared recently which use volumetric and ultrasonic method to access physiochemical parameters of biological molecule and interpreted the solute-solvent interactions [47-48]. Therefore we decided to study the density and sound velocities properties of amino acids in mixed solvent system.

In the present investigations, (i) densities, apparent molar volumes, partial molar volumes, apparent molar expansibilities (ii) sound velocities, apparent molar adiabatic compressibility, hydration number, acoustic impedance, relative association parameters of aqueous ciprofloxacin with amino acids at six different temperatures (293.15-318.15K) have been determined. Research on density and sound velocity study of ciprofloxacin in aqueous L-alanine and glycine solution has been reported by a researcher [49]. To the best of our knowledge, no data on density, sound velocity, apparent molar volume, partial molar volume, adiabatic

compression and isobaric expansion of ciprofloxacin in aqueous L-alanine and glycine solutions at different temperatures under atmospheric pressure has previously been reported. With these points of view, we have undertaken this research and the measurement of density and sound velocity are thought to be powerful tools to investigate the intermolecular interactions of biological component L-alanine and glycine with aqueous ciprofloxacin which are focused in this study. In order to understand the issue of solute-solvent interactions in aqueous solution of ciprofloxacin-amino acids systems a theoretical and experimental aspect of interactions in terms of apparent molar volume, partial molar volume, adiabatic compression and sound velocity properties analysis is necessary.

The specific aims of this study are-

i) to measure the density and sound velocity of ciprofloxacin in aqueous L-alanine and glycine solution at different temperature,

ii) to understand the effect of ciprofloxacin on the structure of L-alanine and glycine in solution,

iii) to predict about the structure making or breaking mechanism of ciprofloxacin in aqueous and aqueous L-alanine and glycine systems,

iv) to examine the apparent molar volume, limiting apparent molar volume, apparent molar volume transfer, partial molar volume, apparent molar volume expansibilities, isentropic compression, acoustic impedance and relative association of the studied systems at different temperature,

CHAPTER II

Theoretical Background

2.1 Physical Properties and chemical constitutions

In interpreting the composition, the structure of molecules and the molecular interaction in the binary and ternary systems, it is inevitable to find out the size and the shape of the molecules and the geometry of the arrangement of their constituent atoms. For this Purpose, the important parameters are bond lengths or interatomic distance and bond angles. The type of atomic and other motions as well as the distribution of electrons around the nuclei must also be ascertained; even for a diatomic molecule a theoretical approach for such information would be complicated. However the chemical analysis and molecular weight determination would reveal the composition of the molecules, and the study of its chemical properties would unable one to ascertain the group or sequence of atoms in a molecule. But this cannot help us to find out the structures of molecules, as bond length, bond angles, internal atomic and molecular motions, polarity etc. cannot be ascertained precisely.

For such information it is indispensable to study the typical physical properties, such as absorption or emission of radiations, refractivity, light scattering, electrical polarization, magnetic susceptibility, optical rotations etc. The measurement of bulk properties like density, surface tension, viscosity etc. are also have gained increased importance during the recent years, because not only of their great usefulness in elucidating the composition and structure of molecules, but also the molecular interaction in binary and ternary systems.

The various physical properties based upon the measurement of density, viscosity, surface tension, refractive index, dielectric constant etc., have been found to fall into the following four categories [50].

i. Purely additive properties: An additive property is one, which for a given system is the sum of the corresponding properties of the constituents. The only strictly additive property is mass, for the mass of a molecule is exactly equal to the sum of the masses of its constituent atoms, and similarly the mass of a mixture is the sum of the separate masses of the constituent parts. There are other molecular properties like molar volume, radioactivity etc. are large additive in nature.

ii. Purely constitutive properties: The property, which depends entirely upon the arrangement of the atoms in the molecule and not on their number is said to be a purely constitutive property. For example, the optical activity is the property of the asymmetry of the molecule and occurs in all compounds having an overall asymmetry.

iii. Constitutive and additive properties: These are additive properties, but the additive character is modified by the way in which the atom or constituent parts of a system are linked together. Thus, atomic volume of oxygen in hydroxyl group (-OH) is 7.8 while in kenotic group (=CO) it is 12.2. The parachor, molar refraction, molecular viscosity etc. are the other example of this type.

iv. Colligative properties: A colligative property is one which depends primarily on the number of molecules concerned and not on their nature and magnitude. These properties are chiefly encountered in the study of dilute solutions. Lowering of vapor pressure, elevation of boiling point, depression of freezing point and osmotic pressure of dilute solutions on the addition of non-volatile solute molecules are such properties.

2.2 Density

The density of a liquid may be defined as the mass per unit volume of the liquid unit of volume being the cubic centimeter (cm^3) or milliliter (mL). Since the milliliter is defined to be the volume occupied by one gram of water at temperature of maximum density (i.e., at 4^0C), the density of water at this temperature in gmL^{-1} is unity and the density of water at any other temperature is expressed relative to that of water at 4^0C and expressed by (d^{10}_4).

The relative density of a substance is the ratio of the weight of a given volume of the substance to the weight of an equal volume of water at the same temperature (d^{10}_4). The absolute density of a certain substance temperature t^0C is equal to the relative density multiplied by the density of water at the temperature. The density of a liquid may be determined either by weighing a known volume of the liquid in a density bottle or picnometer or by buoyancy method based on "Archimedes principle".

In our present investigation, the densities of the pure components and the mixture were determined by weighing a definite volume of the respective liquid in a density bottle.

2.3 Density and temperature

An increase in temperature of a liquid slightly increases the volume of the liquid, thus decreasing its density to some extent. The temperature increase brings about an increase in molecular velocity. These energetic molecules then fly apart causing more holes in the bulk of the liquid. This causes the expansion of the liquid, thereby decreasing the number of molecules per unit volume and hence the density.

2.4 Molarity

Molarity (C), is defined as the number of moles of solute per litre of solution. If n_2 is number of moles of solute and V liters is the volume of the solution then,

$$Molarity(C) = \frac{Number\ of\ moles\ of\ solute}{Volume\ of\ solution}$$

Or, $C = \frac{n_2}{V}$……..…..(2.1)

For one mole of solute dissolved in one liter of solution, C=l i.e. molarity is one. Such a solution is called 1 molar. A solution containing two moles of solute in one liter is 2 molar and so on. As evident from expression (2.1), unit of molarity is $molL^{-1}$ [51].

2.5 Molar volume of mixtures

The volume in mL occupied by one gram of any substance is called its specific volume and the volume occupied by 1 mole is called the molar volume of the substance. Therefore, if ρ is the density and M be the molar mass, we have the molality (m) of a solution is defined as the number of moles of the solute per 1000 g of solvent [51]. Mathematically,

$$\text{Molality(m)} = \frac{\text{Number of moles of solute}}{\text{Weight of solvent in gram}} \times 1000$$

$$\text{Or, m} = \frac{\frac{a}{M_2} \times 1000}{\text{Volume of solvent in mL} \times \text{Density of solvent in g cm}^{-3}}$$

$$\text{Or, m} = \frac{\frac{a}{M_2} \times 1000}{V_1 \times \rho_0}$$

$$\text{Or, m} = \frac{a}{M_2} \times \frac{1000}{V_1 \times \rho_0} \quad \text{……..……..(2.2)}$$

Where,

a = Weight of solute in gram

M_2 = Molecular weight of solute in gram

V_1 = Volume of solvent in mL

ρ_0 = Density of solvent in g cm^{-3}

Specific volume, $(V) = \frac{1}{\rho} mLg^{-1}$……..…..(2.3)

and Molar volume, $(V_m) = \frac{M}{\rho} mLmol^{-1}$…….…….....…….(2.4)

When two components are mixed together, there may be either a positive or a negative deviation in volume. The positive deviation in volume i.e. volume expansion has been explained by the breakdown of the mode of association through H-bonding of the associated liquids. The negative deviation in molar volume i.e. volume contraction has been thought of by many observers, as arising from the i) compound formation through association, ii) decrease in the intermolecular distance between the interacting molecules, iii) interstitial accommodation of smaller species in the structural network of the larger species and (iv) change in the bulk structure of either of the substance forming the mixture.

2.6 Apparent/ partial molar volume

The apparent molar volume of a solute in solution, generally denoted by is defined by φ_v the relation [52]

$$\varphi_v = \frac{V - n\bar{V}_1^0}{n_2} \quad \text{……..(2.5)}$$

Where, V is the volume of solution containing n1 moles of solvent and n_2 moles of solute and $\bar{V}_1^0$ is the molal volume of the pure solvent at specified temperature and pressure. For binary solution, the apparent molar volume (φ_v) of an electrolyte in an aqueous solution is given by [51],

$$\varphi_v = \frac{1}{n_2}\left[\frac{n_1M_1 + n_2M_2}{\rho} - n_1\bar{V}_1^0\right]$$

Where,

$V = \frac{n_1M_1 + n_2M_2}{\rho}$ and

n_1 and n_2 are the number of moles, M_1 and M_2 are molar masses of the solvent and solute respectively and ρ is the density of the solution. For molal concentration, n_2 = m, the molality and n_1 = 55.51, the number of moles of solvent in 1000g of solvent (water), the equation for apparent molal volume takes the form [57, 58]

$$\varphi_v = \frac{1}{m}\left[\frac{1000 + mM_2}{\rho} - \frac{1000}{\rho_0}\right]$$

Or, $$\varphi_v = \left[\frac{M_2}{\rho} - \frac{1000(\rho - \rho_0)}{m\rho\rho_0}\right] \quad \text{.....(2.7)}$$

Or, $$\varphi_v = \frac{1}{\rho}\left[M_2 - \frac{1000}{m}\left(\frac{W - W_0}{W_0 - W_e}\right)\right] \quad \text{.....(2.8)}$$

where, ρ_o and ρ are the densities of the solvent and solution and W_e, W_0 and W are the weight of empty bottle, weight of bottle with solvent and weight of bottle with solution respectively.

If the concentration is expressed in molarity (C), the equation 2.8 takes the form [57]:

$$\varphi_v = \left[\frac{M_2}{\rho_0} - \frac{1000(\rho - \rho_0)}{C\rho_0}\right] \quad \text{.....(2.9)}$$

Where, the relation, $$C = \frac{m.\varphi_v.1000}{1000 + \varphi_v.m.\rho_0} \quad \text{.....(2.10)}$$

is used for inter conversion of the concentration in the two scales [59].

The partial molal property of a solute is defined as the change in property when one mole of the solute is added to an infinite amount of solvent, at constant temperature and pressure, so that the concentration of the solution remains virtually unaltered. If „Y“ represents partial molal property of a binary solution at constant temperature and pressure, Y will then be a function of two independent variables n_1 and n_2, which represent the number of moles of the two components present. The partial molar property of component one is then defined by the relation:

$$\overline{Y_1} = \left(\frac{\delta Y}{\delta n_1}\right)_{n_2,P,T} \quad \text{.....(2.11)}$$

Similarly for component 2

$$\overline{Y_2} = \left(\frac{\delta Y}{\delta n_2}\right)_{n_{12},P,T} \quad \text{.....(2.12)}$$

The partial molar property is designated by a bar above the letter representing the property and by a subscript, which indicates the components to which the value refers. The usefulness of the concept of partial molar property lies in the fact that it may be shown mathematically as,

$$Y_{(n_1,n_2)} = n_1\overline{Y_1} + n_2\overline{Y_2} \qquad \text{at constant T and P} \quad \text{.....(2.13)}$$

In respect of the volume of solution, equation 2.5 gives directly

$$V = n_1\overline{V_1} + n_2\overline{V_2} \qquad \text{at constant T and P} \quad \text{.....(2.14)}$$

The partial molar volumes of solute and solvent can be derived using the equation 2.5 as follows [56]

$$\overline{V_2} = \left(\frac{\delta V}{\delta n_2}\right)_{P,T,n_1} = \varphi_v + n_2\left(\frac{\delta \varphi_v}{\delta n_2}\right)_{P,T,n_1} = \varphi_v + m\left(\frac{\delta \varphi_v}{\delta m}\right)_{P,T,n_1} \quad \text{.....(2.15)}$$

and

$$\overline{V_1} = \frac{\left(V - n_2\overline{V_2}\right)}{n_1} = \frac{1}{n_1}\left[n_1\overline{V_1^0} - n_2^2\left(\frac{\delta \varphi_v}{\delta n_2}\right)\right]_{P,T,n_1} = \overline{V_1^0} - \frac{m^2}{55.51}\left(\frac{\delta \varphi_v}{\delta m}\right)_{P,T,n_1} \quad \text{.....(2.16)}$$

For solutions of simple electrolytes, the apparent molar volume (φ_v) vary linearly with $\sqrt{m}$, even upto moderate concentrations. This behavior is in agreement with the prediction of the Debye-Huckel theory of dilute solutions as [53]:

$$\frac{\delta \varphi_v}{\delta m} = \frac{\delta \varphi_v}{\delta \sqrt{m}} \cdot \frac{\delta \sqrt{m}}{\delta m} = \frac{1}{2\sqrt{m}} \cdot \frac{\delta \varphi_v}{\delta \sqrt{m}} \quad \text{.....(2.17)}$$

If φ_v is available as a function of molal concentration, the partial molar volumes of solute and solvent can be obtained from equation 2.15 and 2.16 as:

$$\overline{V_2} = \varphi_v + \frac{\sqrt{m}}{2}\left(\frac{\delta\varphi_v}{\delta\sqrt{m}}\right) = \varphi^0{}_v + \frac{3\sqrt{m}}{2}\left(\frac{\delta\varphi_v}{\delta\sqrt{m}}\right) \quad \text{.....(2.18)}$$

and,

$$\overline{V_1} = \overline{V_1^0} - \frac{m}{55.51}\left(\frac{\sqrt{m}}{2}.\frac{\delta\varphi_v}{\delta\sqrt{m}}\right) = V_1^0 - \frac{M_1 m^{3/2}}{2000}\left(\frac{\delta\varphi_v}{\delta\sqrt{m}}\right) \quad \text{.....(2.19)}$$

Where, $\varphi^0{}_v$ is the apparent molal volumes at zero concentration. When molar concentration scale is used to express φ_v as a function of concentration, then

$$\overline{V_2} = \varphi_v + \left[\frac{1000 - C\varphi_v}{2000 + C^{3/2}\left(\frac{\delta\varphi_v}{\delta\sqrt{C}}\right)}\right]\sqrt{C} \quad \text{.....(2.20)}$$

and,

$$\overline{V_1} = \frac{2000\overline{V_1}^0(18.016/\rho_0)}{2000 + C^{3/2}\left(\frac{\delta\varphi_v}{\delta\sqrt{C}}\right)} \quad \text{.....(2.21)}$$

From equation 2.18 and 2.20, it follows that at infinite dilution, (m or c → 0), the partial molar volume and the apparent molar volume are identical. To obtain reliable φ_v values, it is necessary to measure the density ρ, with great precision because errors in ρ contribute, considerably to the uncertainties in φ_v.

The concentration dependence of the apparent molar volume of electrolytes has been described by the Masson equation [56], the Redlich-Mayer equation [58] and OwenBrinkley equation [57]. Masson [56] found that the apparent molar volume of the electrolytes vary with the square root of the molar concentration as,

$$\varphi_v = \varphi_v^0 + S_v\sqrt{c} \quad \text{.....(2.22)}$$

Where, S_v is the experimental slope depending on the nature of the electrolyte.

Redlich and Rosenfeld predicated that a constant limiting slope S_v, should be obtained for a given electrolyte charge type if the Debye-Huckel limiting law is obeyed. By differentiating the Debye-Huckel limiting law for activity coefficients with respect to pressure, the theoretical limiting law slope S_v, could be calculated using the equation,

$$S_v = KW^{3/2} \quad \text{……(2.23)}$$

where, the terms K and W are given by

$$K = N^2 e^3 \left(\frac{8\pi}{100 D^3 RT}\right)^{1/2} \left\{\left(\frac{\delta \ln D}{\delta \rho}\right) - \left(\frac{\beta}{3}\right)\right\} \quad \text{……(2.24)}$$

and, $W = 0.5 \sum \gamma_i Z_i^2$ ……(2.25)

Where, β is the compressibility of the solvent, γ_i is the number of ions of the species i of valency Zi formed by one molecule of the electrolyte and the other symbols have their usual significance [58]. For dilute solutions the limiting law for the concentration dependence of the apparent molar volume of electrolytes is given by the equation,

$$\varphi_v = \varphi_v^0 + KW^{3/2}\sqrt{C} \quad \text{……(2.26)}$$

And for not too low concentrations, the concentration dependence can be represented as,

$$\varphi_v = \varphi_v^0 + S_v\sqrt{C} + b_v C \quad \text{……(2.27)}$$

Where, Sv, is the theoretical limiting law slope and bv an empirical constant for 1:1 electrolyte, the limiting law slope at 298.15K is 1.868 $cm^3 mol^{-3/2}$. $L^{1/2}$.

2.7 Theory of ultrasonic velocity

Sound is propagated through a medium by longitudinal waves. A longitudinal wave is a type of periodic motion in which the displacement of the particles in the medium occurs in the same direction as the wave itself. A schematic diagram of a longitudinal sound wave is shown in

Figure 2.1. For simplicity a one-dimensional wave is depicted, one can imagine that sound generated by an oscillating boundary at the left, is traveling to the right through a medium. The motion of the sound wave is a function of both time and space. The figure can be viewed as a density contour map of the medium. The darker areas have higher density; these are periodic compressions (C). The lighter areas have lower density; these are periodic expansions, or refractions (R). The density of the fluid ahead of the wave front is the undisturbed bulk density (ρ), which is intermediate between the local densities of the medium C and R.

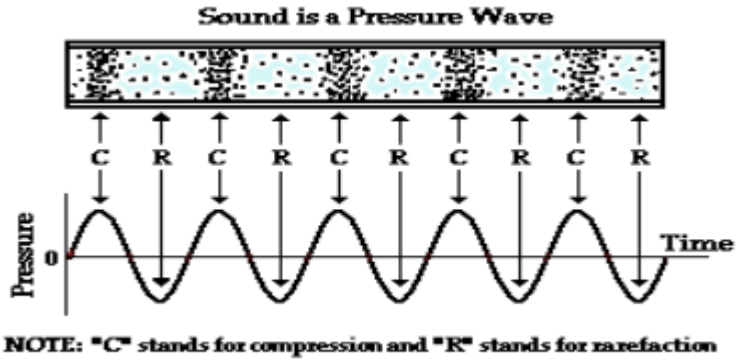


Figure 2.1. Schematic diagram of a longitudinal standing wave; C and R show positions of medium compressions and refractions (high and low densities), respectively.

When a layer of fluid medium is compressed or rarefied during the passage of a sound wave, the pressure in the layer changes from the equilibrium pressure. The amount of pressure changed is defined as the excess pressure or sound pressure or acoustic pressure. Considering the acoustic pressure an equation for sound wave [59] or sound velocity can be derived, which is expressed as,

$$u = (\frac{1}{\rho\beta})^{1/2} \quad \text{.....(2.28)}$$

Where, ρ is the equilibrium density and β is the compressibility, which is the reciprocal of bulk modulus, k, of medium, given by

$$\beta = k^{-1} = -\frac{1}{v}\left(\frac{\partial v}{\partial P}\right) \quad \text{.....(2.29)}$$

Where, ∂V = volume changed during the passage of sound

∂P = acoustic pressure

V = volume of medium at equilibrium

An important aspect of sound propagation as the fact that if the frequency of the sound being generated by high enough i.e., audio frequencies which are between 10^3 and 10^4 Hz

(oscillations per second), the compressions and refractions are established very rapidly as the sound way moves through the medium. This condition means that heat transport between the compressed and rarefied regions of the medium and the surroundings is slow relative to the creations of the compressions and refractions. Thus, on a local basis, the compressions and refractions are carried out adiabatically. At much lower sound frequencies, on the other hand, it is possible to imagine that heat transport between the medium and the surroundings is fast enough to allow the medium to be compressed and expanded isothermally (if the thermal mass of the surroundings is large enough). Accordingly, the compressibility β can be described under constant-temperature or constant-energy conditions, and one can thus distinguish between isothermal and adiabatic compressibilities of a substance, β_T, and β_S respectively. Since audio frequencies are used in this experiment, we must use the adiabatic (or isentropic) , which can be explicitly written as,

$$\beta_s = -\frac{1}{v}\left(\frac{\partial v}{\partial P}\right)_s \quad \text{.....(2.30)}$$

Writing βs instead of β in equation (3.36) gives the Newton-La place equation of the form

$$u = \left(\frac{1}{\rho\beta_s}\right)^{1/2} \text{.....(2.31)}$$

Various attempts [60-65] have been made to calculate theoretically ultrasonic sound velocity through binary mixtures.

2 .8 Adiabatic Compressibility

A more convenient path is to use the Newton-La Place equation to get the adiabatic Compressibility from speed of sound and density data. Rearranging equation (2.31) yields

$$\beta_s = \frac{1}{\rho u^2} \text{ .....(2.32)}$$

Differentiating equation (2.31) with respect to pressure, P at constant entropy and Combining the above equations with its yields the expression of apparent molar adiabatic compressibility $\varphi_{\beta,s}$

$$\varphi_{\beta,S} = \left(\frac{M\beta_s}{\rho}\right) - \left(\frac{\beta_{s,op} - \beta_s \rho_0}{m\rho\rho_0}\right) \text{.....(2.33)}$$

Where, zero (0) in subscript and superscript refers to pure solvent (water) and symbols have their usual meaning.

2.9 Acoustic Impedance

Sound travels through materials under the influence of sound pressure. Because molecules or atoms of a solid are bound elastically to one another, the excess pressure results in a wave propagating through the solid. The acoustic impedance is important in i) the determination of acoustic transmission and reflection at the boundary of two materials having different acoustic impedance, ii) the design of ultrasonic transducers and iii) assessing absorption of sound in a medium. Mathematically, it is defined as,

$$Z = u\rho \text{.....(2.34)}$$

Where, ρ and u are the densities and ultrasonic speeds of the mixture respectively.

2.10 Relative association

The relative association is defined as a measure of the extent of interaction between the component molecules in a real mixture relative to that in an ideal one

$$R_A = \left(\frac{\rho}{\rho_0}\right)\left(\frac{u_0}{u}\right) \text{ ……..(2.35)}$$

Where ρ, ρ_o and u, u_o are the densities and ultrasonic speeds of the solution and solvent respectively.

2.11 Hydration number

Hydration number is the number of molecules of water with which an ion can combine in an aqueous solution of given concentration. Hydration number has been computed using the relation

$$n_H = \frac{n_1}{n_2}\left(1 - \frac{\beta_s}{\beta_{s,o}}\right) \text{ ……(2.36)}$$

Where, n_H denotes the hydration number. β_s, $\beta_{s,o}$ are adiabatic compressibilities of solution and solvent respectively and n_1 and n_2 are number of moles of solvent and solute respectively.

CHAPTER III

Experimental

During the course of the present work constant efforts for attaining the ideal conditions for the experiments were always attempted. The glass pieces were thoroughly cleaned and dried in oven before used.

The following systems have been carried for the investigation of molecular interactions of L-alanine and glycine with water and in aqueous solution of ciprofloxacin.

1. Water+ L-alanine
2. Water + glycine
3. Water + L-alanine + 0.03 $mol.kg^{-1}$ ciprofloxacin
4. Water + L- alanine + 0.045 $mol.kg^{-1}$ ciprofloxacin
5. Water + L- alanine + 0.06 $mol.kg^{-1}$ ciprofloxacin
6. Water + glycine + 0.03 $mol.kg^{-1}$ ciprofloxacin
7. Water + glycine + 0.045 $mol.kg^{-1}$ ciprofloxacin
8. Water + glycine + 0.06 $mol.kg^{-1}$ ciprofloxacin

All experiments have been carried out at six equidistant temperature viz. 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K over the aqueous 0.03, 0.045 and 0.06 $mol.kg^{-1}$ composition, where m represents the molality of solution. The details of various information have been described in the following sections.

3.1 Materials

The chemicals used for study were –L-alanine, glycine and ciprofloxacin. All chemicals were of analytical reagent (A.R) grade. Specifications and structural formula for all of them are given below:

Chemicals	**Molecular formula**	**Molar mass**	**Reported purity**	**Producer**
Ciprofloxacin	$C_{17}H1_8FN_3O_3$	331.346	99.42%	SIGMA-ALDRICH, Germany
L-Alanine	$C_3H_7NO_2$	89.09	99.0%	LOBA Chemical, India
Glycine	H_2NCH_2COOH	75.06	99.0%	MERCK Chemical, India

3.2 Apparatus

A HR-200 electronic balance with an accuracy of ±0.0001g was used for the mass determination. Densities and speeds of sound was measured by an Anton Paar DSA 5000 model high precision vibrating tube digital density meter and speed of sound measuring device, with automatic velocity corrections.

3.3 Preparation of solution

The solutions were prepared immediately before the measurement. The binary solutions were prepared by mixing appropriate mass of the components. The amount of each component was later converted into the molality. The molality of the samples are controlled to ±0.00005 $mol.kg^{-1}$. Precautions were taken to prevent the introduction of moisture into the experimental example. Each time, the solution was prepared immediately before the density measurement.

3.4 Density and sound velocity measurements

The density of liquid may be define as the mass per unit volume of the liquid, the unit of volume being the cubic centimeter (cm^3) or millimeter . Since the millimeter is defined to be the volume occupied by one gram of water at temperature in g mL^{-1} is unity and the density of water at any other temperature is expressed relative to that of water at 4^0C. The absolute density of a certain substance at temperature t^0 C is equal to the relative density multiplied by the density of water at the temperature. Density and sound velocity of pure liquid and liquid-liquid mixtures was measured using high precession vibrating tube digital densitometer (Anton Paar, DSA -5000, Austria). The density and sound velocity values have been found with an error of ±0.000006 g cm^{-3} and ±0.05 ms^{-1} respectively. The method is based on the principle of time lapse measurement for certain member of oscillations of a vibrating U-shaped sample tube fill with the sample liquid. At constant temperature, the natural vibrational period of the U- tube is related to density of liquid filling the tube. In the latest version of Anton Paar digital density meter (DSA -5000), the natural vibration period is automatically converted into the density value and display directly on the LC display monitor of the decimeter. The DSA -5000 density measuring cell consists of a cell consists of a U-shaped oscillator glass cylinder. The temperature of the sample tube is controlled by two integrated in-built Pt 100 platinum thermometers to a level of highest accuracy and traceable to national standard. The temperature of the sample tube is controlled to ± 0.001K. The design of the cell ensures identical volumes to be used for the measurement on

different samples. Using a polyethylene syringe the sample was continuously and slowly injected from the upper part of U tube until the excess fluid flowed out of the lower part. This ensured that the inner surface of the cell was completely wet and there are no micro bubbles inside the U-tube. The syringe was kept as such in plugged. After the measurement the sample was removed and air was passed, by built in pump, through the tube to remove excess liquid. The tube was then rinsed several times with the solution of higher concentration and finally the solution was injected for the measurement. Measuring the density of water supplied with the densitometer checked the working of the densitometer. All measurements were made starting from the lowest to the highest solute concentration.

3.5 Apparent/ Partial molar volume measurements

The apparent molar volumes of the solution for binary and ternary systems were determined from density measurement using the following equation [52, 53]:

$$\varphi_v = \frac{1}{\rho}\left\{M_2 - \frac{1000}{m}\left(\frac{\rho-\rho_0}{\rho_0}\right)\right\}$$

Or, $$\varphi_v = \frac{1000}{m\rho\rho_0}(\rho_0-\rho)+\frac{M_2}{\rho} \quad \text{.....(3.1)}$$

Where, ρ is the density of the experimental solution, M_2 and m are the molar mass and molality of the electrolyte respectively and ρ_0 is the density of the solvent. The molality 'm' of a solution was calculated from mole fraction of solute and solvent

$$m = \frac{X_2 \times 1000}{X_1 M_1}$$

Where, M_1 and M_2 = the molecular weight of solvent and solute

And also from molarity C,

$$m = \frac{1}{\left(\frac{\rho}{C} - \left(\frac{M_2}{1000}\right)\right)} \quad \text{……..(3.2)}$$

Where, C is the molarity, M_2 is the solute molecular weight and ρ is the density of the solution respectively.

The molarity 'C' of a solution was calculated from the following equation

$$C = \frac{1}{M_2} \times \frac{a}{\text{vol. of solution in liter}} \quad \text{…….(3.3)}$$

Where, a = weight of the solute (electrolyte) in gm, M_2 = solute molecular weight.

Molar volume of solvent (pure water) at experimental temperature was calculated using the following equation [52].

$$\bar{V}_1^0 = \frac{\text{Molecular masses of solvent}}{\text{Density of solvent (at expt. temp.)}} \quad \text{……..……..(3.4)}$$

The partial molar volumes of the solute and solvent can be obtained from density measurement using the following equation.

$$\bar{V}_2 = \varphi_v + \frac{\sqrt{m}}{2}\left(\frac{\delta\varphi_v}{\delta\sqrt{m}}\right) = \varphi^0{}_v + \frac{3\sqrt{m}}{2}\left(\frac{\delta\varphi_v}{\delta\sqrt{m}}\right) \quad \text{……(3.5)}$$

Where, $\varphi^0{}_v$ = apparent molar volumes at zero concentration.

$$\text{and, } \bar{V}_1 = V_1^0 - \frac{M_1 m^{3/2}}{2000}\left(\frac{\delta\varphi_v}{\delta\sqrt{m}}\right) \quad \text{…….(3.6)}$$

The values of $\frac{\delta\varphi_v}{\delta\sqrt{m}}$ were obtained from the slope of the plot of φ_v against $\sqrt{C}$ by the use of Masson (50) equation and the apparent molar volume of solutes at infinite dilution ($\varphi_v^0 \approx \bar{V}_2^{\,0}$) were determined from the intercept of the plot, at C equal to zero.

3.6 Limiting apparent molar volume of transfer

Limiting apparent molar volume of transfer can be obtained from using the following equation,

$\Delta\ \varphi_v^0 = \varphi_v^0$ (in aq. ciprofloxacin solution) - φ_v^0 (in water) ……. (3.7)

Where, φ_v^0 is limiting apparent molar volume.

3.7 Temperature dependent limiting apparent molar volume

At infinite dilution, the variation of limiting apparent molar volumes i.e. (Φ_v^0) with the temperature can be expressed by the general polynomial equation as follows:

$\varphi_v^0 = A + B\ (T\text{-}Tm) + C\ (T\text{-}Tm)^2$ …….. (3.8)

Where, T is the temperature in Kelvin, T_m is the average temperature A, B, and C are the empirical constants.

The limiting apparent molar expansibilities are calculated as follows:

$E_\varphi^0 = B + 2C\ (T\text{-}T_m)$ ……. (3.9)

Hepler developed the general thermo-dynamic expression to determine the capacity of solute as a structure maker or structure breaker in mixed solvent system using general thermodynamic expression [66]:

$(\delta E^0\varphi/\delta T)p = 2C$ ……..(3.10)

3.8 Adiabatic Compressibility measurements

The adiabatic compressibility, β_s of the solution for binary and ternary systems were determined from density and sound velocity data using the following equation,

$$\beta_s = \frac{1}{\rho u^2} \quad \text{.....(3.11)}$$

Where, ρ is the density of the experimental solution and u is the ultrasonic speed of the solution.

3.9 Apparent molar Adiabatic Compressibility measurements

The apparent molar adiabatic compressibility, β_s of the solution for binary and ternary systems were determined from density and sound velocity data using the following equation,

$$\varphi_{\beta,s} = \left(\frac{M\beta_s}{\rho}\right) - \left(\frac{\beta_{s,op} - \beta_s \rho_0}{m\rho\rho_0}\right) \quad \text{.....(3.12)}$$

Where, ρ and ρ_o are the density of the experimental solution and solvent, m is the molarity of the solution and β_s and $\beta_{s,o}$ are the adiabatic compressibility of the experimental solution and solvent.

3.10 Acoustic Impedance measurements

The acoustic impedance, Z is of the solution for binary and ternary systems were determined from density and sound velocity data using the following equation,

$$Z = u\rho \quad \text{..... (3.13)}$$

Where, ρ is the density of the experimental solution and u is the ultrasonic speed of the solution.

3.11 Relative association measurements

The relative associations, R_A of the solution for binary and ternary systems were determined from density and sound velocity data using the following equation,

$$R_A = \left(\frac{\rho}{\rho_0}\right)\left(\frac{u_0}{u}\right) \quad \text{.....(3.14)}$$

Where, ρ, ρ_o and u, u_o are the densities and ultrasonic speeds of the experimental solution and solvent.

3.12 Hydration number

The hydration number, n_H of the solution for binary and ternary systems were determined from density and sound velocity data using the following equation,

$$n_H = \frac{n_1}{n_2}\left(1 - \frac{\beta_s}{\beta_{s,o}}\right) \quad \text{.....(3.15)}$$

Where n_H denotes the hydration number. β_s, $\beta_{s,o}$ are adiabatic compressibility of solution and solvent respectively and n_1 and n_2 are number of moles of solvent and solute respectively.

CHAPTERE IV

Results and Discussion

Amino acids are very important for living organisms. Ciprofloxacin is a fluoroquinolone antibiotic that fights bacteria in the body. It is used to treat different types of bacterial infections. It is also used to treat people who have been exposed to anthrax or certain types of plague. Our studies included the interaction of amino acids (L-alanine and glycine) with ciprofloxacin in terms of volumetric and sound velocity measurement. The experimental results and the properties derived from experimental data are presented in this chapter. The results have been discussed in the light of recent developments of the subject. The studied systems are:

a) Water + L-alanine
b) Water + Glycine
c) Water + L-alanine + 0.03 $mol.kg^{-1}$ ciprofloxacin
d) Water + L-alanine + 0.045 $mol.kg^{-1}$ ciprofloxacin
e) Water + L-alanine + 0.06 $mol.kg^{-1}$ ciprofloxacin
f) Water + Glycine + 0.03 $mol.kg^{-1}$ ciprofloxacin
g) Water + Glycine + 0.045 $mol.kg^{-1}$ ciprofloxacin
h) Water + Glycine + 0.06 $mol.kg^{-1}$ ciprofloxacin

The above-mentioned systems have been studied precisely at six equidistant temperatures ranging from 293.15K to 318.15K at interval of 5K by density and sound velocity methods. The volumetric properties such as apparent molar volume (ϕ_v), partial molar volume ($\bar{V}_2$), limiting apparent molar volume (ϕ_v^0), limiting apparent molar volume transfer ($\Delta_{tr}\phi_v^0$), limiting apparent molar expansibilities ($E\phi^0 = \delta\phi_v^0/\delta T)_p$) and Hepler's constant [$(\delta E\phi^0/\delta T)_p = (\delta^2\phi_v^0/\delta T^2)p$] have been determined from density data. The ultrasonic properties like adiabatic compressibility (β_s), apparent molar adiabatic compressibility (ϕ_k), limiting apparent molar adiabatic compressibility

(ϕ_k^0), experimental slope (S_k), apparent molar adiabatic compressibility of transfer ($\Delta_{tr}\phi_k^0$), acoustic impedance (Z), relative association (R_A) and hydration number (n_H) have been determined from sound velocity data. The obtained information of these systems have presented in various sections and discussed in the light of theories mentioned in the earlier chapter.

4.1 Volumetric Properties

The densities, ρ of amino acids in water systems have been determined at temperatures ranging from (293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K) with an interval of 5K over the concentration ranging from 0.10 mol.kg^{-1} to 0.50 mol.kg^{-1}. The densities of aqueous L-alanine and glycine have been shown in tables 4.1-4.2 and figures are graphically shown in 4.1-4.2 at different temperatures as a function of molality of aqueous amino acids. Figures 4.1-4.2 show that the densities of aqueous L-alanine and glycine increase with the increase of L-alanine and glycine concentration. These are due to the increase in number of particles in given region which leads to shrinkage in volume of solution [67, 68]. The densities of the aqueous glycine and L-alanine decrease in the order of L-alanine > glycine for the same molality of amino acids and at the same temperature, which provides that the density is higher for glycine. The densities decrease with the increase of temperature in aqueous L-alanine and glycine systems. Because the solution is heated, the thermal energy of molecules increases and accordingly the intermolecular distance increases, which leads to the decrease of the density.

The densities, ρ of ternary systems such as L-alanine and glycine in 0.03 mol.kg^{-1}, 0.045 mol.kg^{-1}and 0.06 mol.kg^{-1} aqueous ciprofloxacin solutions are listed in tables 4.3-4.8 and figures are graphically shown in 4.3-4.8. The values of densities of amino acids (L-alanine and glycine) in aqueous ciprofloxacin systems has been found to be in the order of,

Amino acids + water + 0.06 mol.kg^{-1}ciprofloxacin > Amino acids + water + 0.045 mol.kg^{-1} ciprofloxacin > Amino acids + water + 0.03 mol.kg^{-1} ciprofloxacin

It is seen that the density increase with the increasing of amino acid concentration at a fixed ciprofloxacin concentration. The increase of density with concentration of ciprofloxacin can be

attributed to solute- solvent interaction and weight of ciprofloxacin in solution. The densities of the L-alanine and glycine solutions increase in the order of L-alanine > glycine for the same molality of amino acids and ciprofloxacin at the same temperature, which provides that the density is higher for glycine. For ternary systems the densities also decrease with the increase of temperature. Because the solution is heated, the thermal energy of molecules increases and accordingly the intermolecular distance increases, which leads to the decrease of the density [69].

Densities of amino acids + ciprofloxacin + water are higher than that of amino acids + water systems. Increase in density with concentration is also due to the shrinkage in the volume which in turn is due to the presence of solute molecules. In other words, an increase in density may be interpreted to the structure-maker of the solvent due to the added solute [67, 68].

The apparent molar volumes (φ_v) of L-alanine and glycine in water are calculated from density data. The value of apparent molar volume of aqueous L-alanine and glycine at different temperatures (293.15, 298.15, 303.15, 308.15, 313.15, 318.15) K are given in tables 4.9-4.10 and the variation of φ_v with molality of L-alanine and glycine are graphically represented in figures 4.9-4.10. It appears from the figure that apparent molar volume is dependent upon the amino acids concentration as well as on the temperature. Plots of φ_v vs. molality (m) of amino acids show linear relationship in water system. The values of apparent molar volume (φ_v) of aqueous amino acids are positive and linearly increase with the increase of concentration of amino acids. The positive values of φ_v are indicative of greater solute–solvent interactions. The values of apparent molar volume (φ_v) of aqueous L-alanine is higher than glycine which due to the number of carbon in alkyl group present in amino acids i.e. from L-alanine to glycine at all temperatures and concentrations, due to the increase in surface of solute to interact with solvent. This indicates that the aqueous solution of L-alanine is more organized than glycine [39]. The value of φ_v increases with increase in temperature because of thermal agitation, which leads to the bond braking.

The value of apparent molar volume of L-alanine and glycine in aqueous ciprofloxacin solutions (0.03 $mol.kg^{-1}$, 0.045 $mol.kg^{-1}$ and 0.06 $mol.kg^{-1}$) at different temperatures (293.15, 298.15, 303.15, 308.15, 313.15, 318.15) K are given in tables 4.11-4.16 and figures 4.11-4.16 show the plots of apparent molar volume as a function of molality of L-alanine and glycine at different

temperatures. Plots of φ_v vs. molality of amino acids show linear relationship in aqueous ciprofloxacin system. For L-alanine and glycine in aqueous ciprofloxacin solutions systems, the values of apparent molar volume (φ_v) are also positive and linearly increase with the increase of concentration of L-alanine and glycine. It has been also found that apparent molar volumes for L-alanine and glycine increase with the increase of ciprofloxacin concentration (0.03 $mol.kg^{-1}$, 0.045 $mol.kg^{-1}$ and 0.06 $mol.kg^{-1}$). The positive values of φ_v are indicative of greater solute–solvent interactions. At a fixed ciprofloxacin concentration and temperature, the increase of φ_v with the concentration of added amino acids in the studied molality range may be due to the cluster formation or aggregation. Also, the apparent molar volumes increase with an increase in the number of carbon in alkyl group present in amino acids i.e. from glycine to L-alanine at all temperatures and concentrations of ciprofloxacin, due to the increase in surface of solute to interact with solvent [39].

Comparatively lower apparent molar volume, φ_v of glycine in aqueous ciprofloxacin solutions than aqueous L-alanine was found. This indicates that the glycine are more compressed in aqueous ciprofloxacin solution than aqueous solution. Whereas higher apparent molar volume, φ_v of L-alanine in aqueous ciprofloxacin solution than aqueous glycine solution was found. This indicates that the L-alanine is less compressed in aqueous ciprofloxacin solution than aqueous solution.

The value of φ_v increases with increase in temperature. This cause may be: (i) due to the increase in thermal energy at higher temperature, the relaxation to the bulk of the electrostricted water molecules from the interaction regions of ion -dipole or dipole- dipole interaction results in a positive volume change; (ii) that an increase in temperature renders the ion–ion interactions relatively stronger giving rise to positive volume change and (iii) the ciprofloxacin–ciprofloxacin or ciprofloxacin-water or water–water interactions decrease with the increase in temperature leading to a positive change in volume [56].

The limiting apparent molar volume (φ_v^0) which is also called the standard partial molar volume of aqueous L-alanine and glycine at 293.15, 298.15, 303.15, 308.15, 313.15 and 318.15 K are reported in tables 4.17-4.18. The limiting apparent molar volumes (φ_v^0) of amino acids reflect the true volume of the solute. However, limiting apparent molar volumes at infinite dilution (φ_v^0) of the solute can provide further information regarding solute + solvent interactions. The

apparent molar volumes (φ_v) were observed to correlate linearly with solution molality (m) at all experimental temperatures, hence standard partial molar volumes (φ_v^0) were obtained from Masson equation [60]. Tables 4.17-4.18 show that values of limiting apparent molar volume (φ_v^0) are positive at each temperature, the (φ_v^0) values increase with size of carbon chain i.e. increase in the number of carbon of alkyl part from glycine to L-alanine. Furthermore, the values of φ_v^0 also increase with an increase in the molar mass and size of the amino acid, that is, higher values of φ_v^0 are obtained for L-alanine as compared to glycine. These trends in limiting apparent molar volumes (φ_v^0) indicate the presence of strong solute-solvent interactions. The increase in φ_v^0 values with the increase in temperature for all amino acids may be explained as release of some solvent molecules from the loose solvation layers of the solutes in solution.

The values of limiting apparent molar volume (φ_v^0) for L-alanine and glycine in ternary (water + ciprofloxacin) solution at the studied temperatures are presented in tables 4.19-4.24. These tables show that values of limiting apparent molar volume (φ_v^0) are positive and increase with an increase in the ciprofloxacin concentration. Further, at each temperature, the φ_v^0 values increase with the size of carbon chain i.e. increase in chain length of alkyl part from glycine to L-alanine. As per cosphere overlap model [71,72], an overlap of hydration co-spheres of two ionic species causes an increase in volume, whereas overlap of hydrophobic-hydrophobic groups and ion-hydrophobic groups results in the volume decrease. In the present ternary systems the overlap of cosphere of two ionic species take place. Furthermore, the values of φ_v^0 also increase with an increase in the molar mass and size of the amino acid, that is, higher values of φ_v^0 are obtained for L-alanine as compared to glycine in aqueous ciprofloxacin solutions. The increase in φ_v^0 values with the increase in temperature for the studied systems may be explained as release of some solvent molecules from the loose solvation layers of the solutes in solution. This can also be explained by considering the size of primary and secondary solvation layers around zwitterions. At higher temperatures, the solvent from the secondary solvation layers of amino acid zwitterions is released into the bulk of the solvent, resulting into the expansion of solution, as inferred from larger values of φ_v^0 at higher temperatures [39]. In simple terms, an increase in temperature reduces the electrostriction and hence φ_v^0 increases.

The values of experimental slope (S_V) for aqueous amino acids and amino acids in ternary (water + ciprofloxacin) solution at the experimental temperatures are reported in tables 4.19-4.24. The

values of experimental slope (S_V) are positive for all the concentration of amino acids. The non-zero values of S_V indicate the presence of solute–solute interactions in solutions of amino acids. Since there is no regular trend in the values of S_V, this clearly indicates that solute-solute interaction is also influenced by other factors [73]. The positive values of S_V indicate solute-solute interaction and φ_v^0 suggest the dominance of solute-solvent interaction.

S_V values are positive and decrease with an increase of temperature (with some exception) of amino acids in the aqueous and aqueous ciprofloxacin solution suggesting that less solute is accommodated in the void space left in the packing of the large associated solvent molecules. The results also indicate the presence of strong solute-solute interactions, and these interactions decrease with the increase in temperature. The values of Sv increase with the increase in composition of aqueous ciprofloxacin solution showing strong solute-solute interactions.

The values of limiting apparent molar volume transfer of amino acids from water to aqueous ciprofloxacin solutions at infinite dilution was calculated by using the equation,

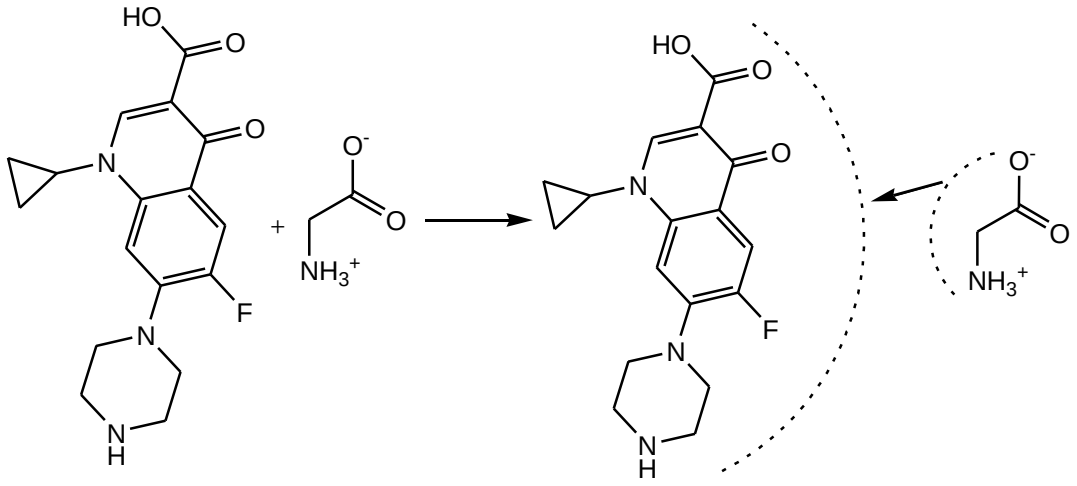
$\Delta_{tr}\varphi_v^0 = \varphi_v^0$ (in aq. ciprofloxacin) - φ_v^0 (in water).

The values of limiting apparent molar volume transfer ($\Delta_{tr}\varphi_v^0$) of L-alanine and glycine in aqueous ciprofloxacin solutions have been reported in tables 4.19-4.24. The $\Delta_{tr}\varphi_v^0$ values of L-alanine in aqueous ciprofloxacin solutions are negative where glycine in aqueous ciprofloxacin systems shows positive value. The observed positive values of $\Delta_{tr}\varphi_v^0$ suggest strong ion-ion interactions of amino acids with ciprofloxacin. Since the structural moiety of amino acids and aqueous ciprofloxacin contain polar groups, so interactions between them promote the structure maker ability of solute in the solvent. Hence, the mentioned positive values of transfer volume indicate structure promoter nature of the solute which is due to their solvophobic solvation as well as the structural interaction according to co-sphere overlap model [71,72]. Depending upon the co-sphere overlap model regarding the values of $\Delta_{tr}\varphi_v^0$, there is negligible contribution from solute-solute interactions and hence they provide information regarding solute-solvent interactions. The various interactions that occur between amino acids and aqueous ciprofloxacin molecules can be categorized as: (i) ion-ion interactions (between zwitterionic centers of amino acids and ciprofloxacin) (ii) hydrophilic-hydrophilic interactions (between polar groups of amino acids and polar groups of ciprofloxacin) (iii) ion-hydrophobic interactions (between

zwitterionic centers of amino acids and non-polar groups of ciprofloxacin) and (iv) hydrophobic-hydrophobic interactions (between non-polar groups of amino acids and nonpolar groups of ciprofloxacin). According to co-sphere overlap model, ion-hydrophobic interactions and hydrophobic-hydrophobic interactions contribute negatively whereas ion-hydrophilic and hydrophilic-hydrophilic interactions contribute positively to the $\Delta_{tr}\varphi_v^0$ values. Therefore, in our study of L-alanine + ciprofloxacin + water shows that ion-hydrophobic and hydrophobic-hydrophobic interactions are dominating whereas glycine + ciprofloxacin + water shows ion-hydrophilic and hydrophilic- hydrophilic are dominating (scheme 1).

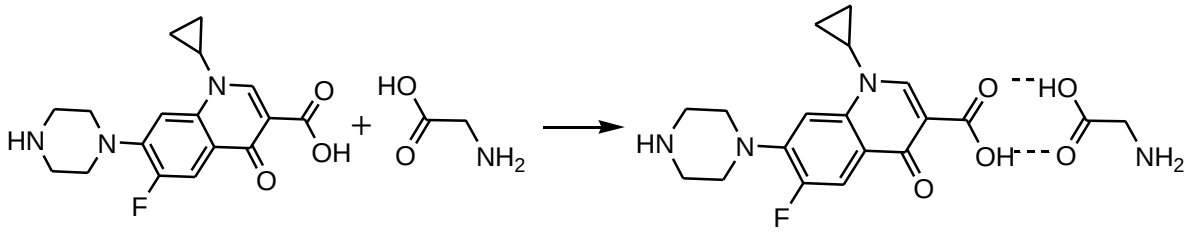
From the structural view point of L-alanine and glycine, it is seen that the structure of L-alanine is in open chain. In addition to that glycine also contains open chain. Therefore, in glycine hydrophilic-hydrophilic or ion-hydrophilic interactions are dominating whereas in L-alanine hydrophobic-hydrophobic interactions are dominating.

1. Ion-hydrophilic interaction



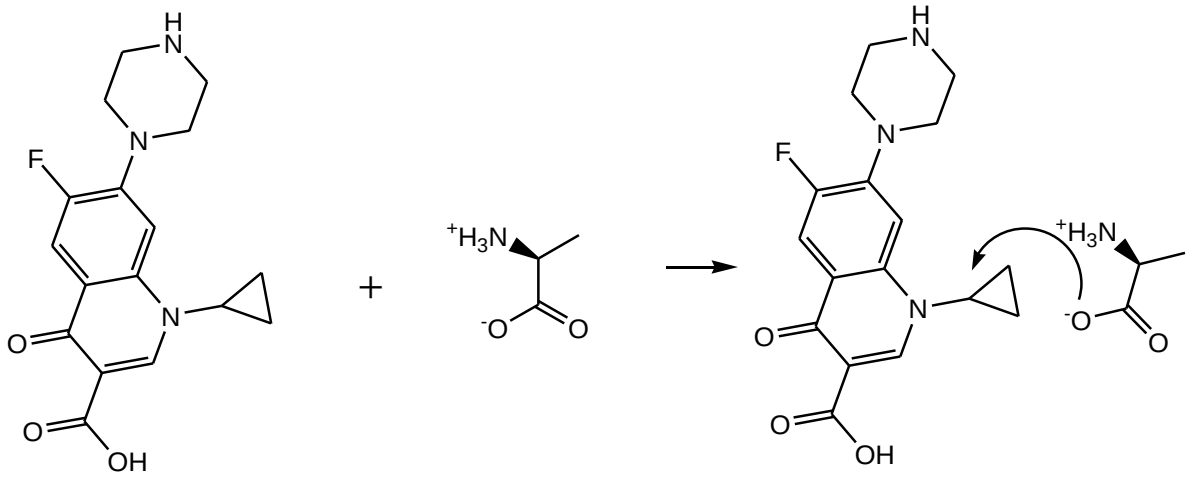
Ciprofloxacin Glycine Ciprofloxacin Glycine

2.Hydrophilic-hydrophilic interaction



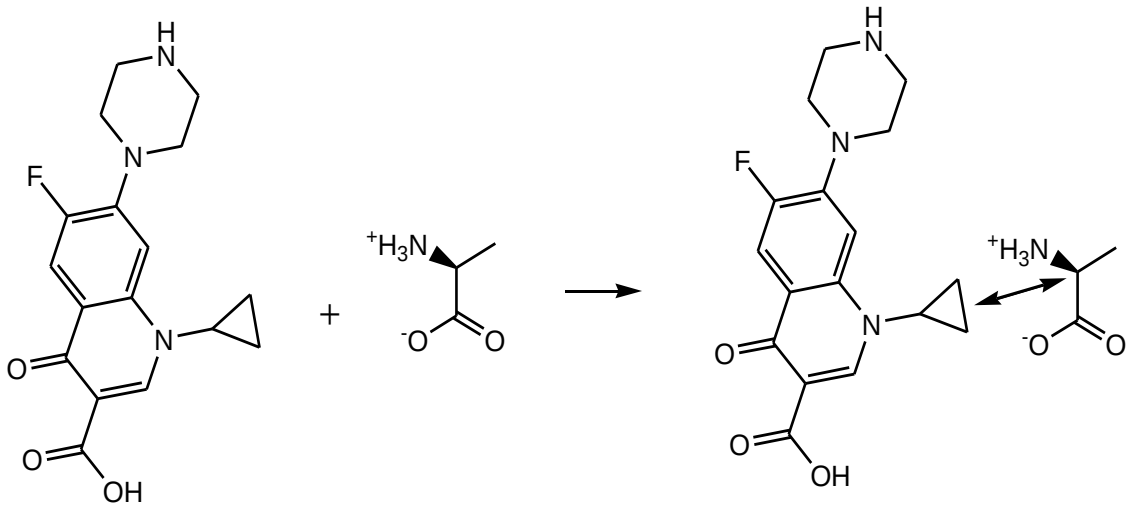
ciprofloxacin Glycine ciprofloxacin Glycine

3. Ion-hydrophobic interaction



Ciprofloxacin L-alanine Ciprofloxacin L-alanine

4. Hydrophobic-hydrophobic interaction



Ciprofloxacin L-alanine Ciprofloxacin L-alanine

Scheme 1: A schematic representation of the possible interaction of amino acids with ciprofloxacin in aqueous solutions.

The values of limiting apparent molar volume expansibilities E_φ^0 and $(\delta E_\varphi^0/\delta T)p$ of aqueous L-alanine and glycine are reported in tables 4.17-4.18. The E_φ^0 values are found to be positive at all temperatures and concentrations of amino acids. The positive values of E_φ^0 suggest that the presence of solute-solvent interactions in these systems, as already indicated by apparent molar volume data. The E_φ^0 values show an irregular trend with an increase of temperature. The sign of $(\delta E\varphi^0/\delta T)p$ determines the tendency of a dissolved solute as a structure maker or structure breaker in a solvent which suggests that positive $(\delta E\varphi^0/\delta T)p$ values are observed for solutes having structure making capacity. The small negative values of $(\delta E\varphi^0/\delta T)p$ for studied systems may act as the structure making ability.

The values of limiting apparent molar volume expansibilities $E\varphi^0$ and $(\delta E\varphi^0/\delta T)p$ of L-alanine and glycine in ternary (water + ciprofloxacin) solutions are reported in tables 4.19-4.24. The $E\varphi^0$ values are found to be positive at all temperatures and concentrations of amino acids in

ciprofloxacin solution which is similar with the binary systems. The positive values of $E\varphi^0$ suggest that the presence of solute-solvent interactions in these systems. The positive values of $E\varphi^0$ may occur due to phenomenon of packing effect or caging which further suggests interaction between amino acids and aqueous ciprofloxacin molecules. The positive values of $(\delta E\varphi^0/\delta T)p$ for studied systems show the structure making ability of amino acids in all aqueous ciprofloxacin solutions [66,74-78].

The values of Partial molar volume ($\bar{V}_2$) of aqueous amino acids and amino acids in ternary (water + ciprofloxacin) solutions are shown in tables 4.27-4.32 and Figures 4.19-4.25 show the plots of partial molar volume as a function of concentration of aqueous amino acids and amino acids in aqueous solution of ciprofloxacin. The value of partial molar volume ($\bar{V}_2$) increases with the increase of concentration of amino acid. This suggests that solute-solvent interactions increase with the increase of concentration of amino acids.

4.2 Ultrasonic properties

The ultrasonic velocity is highly sensitive to molecular interactions and provides qualitative information about the physical nature and strength of molecular interaction in the liquid mixtures [79]. The ultrasonic velocity is a measure of arrangement, continuity, continuousness and availability of void space of the medium.

The sound velocities u of aqueous amino acids and amino acids in ternary (water + ciprofloxacin) systems have been determined at temperatures ranging from (293.15K, 298.15K, 303.15K, 308.15K, 313.15K, and 318.15K) with an interval of 5K over the concentration ranging from 0.10 $mol.kg^{-1}$ to 0.50 $mol.kg^{-1}$. The sound velocities of aqueous amino acids and amino acids in aqueous ciprofloxacin solution have been shown in tables 4.33-4.40 at different temperatures. Figures 4.26-4.33 show the plots of sound velocities as a function of molality of aqueous amino acids and amino acids in aqueous ciprofloxacin solution. These figures show that the sound velocity increases with the increase of concentration of amino acids. This may be attributed to the increase of compactness of the medium with the increase in amino acids concentration [80].

The sound velocity of aqueous L-alanine is higher than aqueous glycine .This is due to the molecular weight of L-alanine is higher than glycine. The existence of molecular interactions between solute and solvent molecules is responsible for the observed increase in the sound velocity of these mixtures.

The compressibility is a very sensitive indicator of molecule interactions [81]. The structural change of molecules takes place due to existence of electrostatic field between interacting molecules. The change in adiabatic compressibility value in liquid and liquid mixtures may be ascribed to the strength of intermolecular attraction. The relative value change upon application of pressure is defined as adiabatic compressibility, which depends on intermolecular states. The liquids/solution having compact structure, rigid bonding and strong intermolecular interaction are less compressible. Evidently, hydrogen bonding, strong dipole-dipole interactions and geometrical fitting of one component into other structural network lead to decrease adiabatic compressibility.

The adiabatic compressibility (β_s) of aqueous L-alanine and glycine has been shown in tables 4.41-4.42 at different temperatures. Figures 4.34-4.35 show the plots of adiabatic compressibility as a function of molality of aqueous L-alanine and glycine. From the figures it is apparent that the values of β_s decrease with the increase of molar concentration of L-alanine and glycine. The value of β_s also decreases with the increases of temperature.

The decrease in the β_s values with increasing concentration of L-alanine and glycine indicates that the water molecules around the amino acids are less compressible than the water molecule in the bulk solution [86,87]. The decrease in β_s may be due to the introduction of amino acids molecule into water which reduces the void space in solution.

The values of adiabatic compressibility, β_s of L-alanine and glycine in ternary (water + ciprofloxacin) solution are shown in tables 4.43-4.48 and figures 4.36-4.41 show the plots of adiabatic compressibility as a function of molality of L-alanine and glycine in aqueous solution of ciprofloxacin. From these figures it is apparent that the values of β_s decrease with the increase of concentration of L-alanine and glycine in ciprofloxacin solution which is similar with binary systems. The values of β_s also decrease with the increase of temperature. The decrease in the β_s values of L-alanine and glycine in aqueous ciprofloxacin solutions by increasing concentration

of amino acids indicates that the water molecules around the amino acids are less compressible than the water molecule in the bulk solution [82,83]. The decrease in β_s may be due to the introduction of amino acids molecule into water and aqueous ciprofloxacin solutions which reduce the void space in solution.

The apparent molar adiabatic compressibility (φ_k) of aqueous L-alanine and glycine are calculated from density and sound velocity data. The values of apparent molar adiabatic compressibility (φ_k) of aqueous L-alanine and glycine at different temperatures (293.15, 298.15, 303.15, 308.15, 313.15, 318.15) K are given in tables 4.49-4.50 and the variation of φ_k with molality of L-alanine and glycine are graphically represented in figures 4.42-4.43. From the data it is observed that values of φ_k are negative at all temperatures and concentrations of L-alanine and glycine. The values of φ_k increase with an increase in the concentration of amino acids. The values of φ_k also increase with the increase of temperature. The negative φ_k values show that water molecules around ionic charged groups of amino acids are less compressible than water molecules in the bulk solution. This indicates the ordering of water molecules around solute or the negative φ_k values indicate greater loss of structural compressibility of water implying a greater ordering effect by the solute on the solvent [39].

The value of apparent molar adiabatic compressibility (φ_k) of L-alanine and glycine in ternary (water + ciprofloxacin) solution at different temperatures (293.15, 298.15, 303.15, 308.15, 313.15, 318.15) K are given in tables 4.51-4.56 and the variation of φ_k with molality of L-alanine and glycine are graphically represented in figures 4.42-4.50. From the data it is observed that values of φ_k are negative at all temperatures and concentrations of ciprofloxacin which is similar with binary systems. The values of φ_k increase with an increase in the concentration of amino acids. The values of φ_k also increase with the increase of temperature. The negative φ_k values show that water molecules around ionic charged groups of amino acids are less compressible than water molecules in the bulk solution. This indicates the ordering of water molecules around solute or the negative φ_k values indicate greater loss of structural compressibility of water implying a greater ordering effect by the solute on the solvent [39].

The values of apparent molar adiabatic compressibility (φ_k) of amino acids + ciprofloxacin + water are higher than the values of amino acids + water systems. This higher values of ternary systems than the binary systems show a greater ordering effect by the solute on the solvent.

The values of limiting apparent molar adiabatic compressibility (φ_k^0) and experimental slope (S_k) of aqueous amino acids and amino acids in ternary (water + ciprofloxacin) solution at different temperatures (293.15, 298.15, 303.15, 308.15, 313.15, 318.15) K are tabulated in tables 4.57-4.64. The value of S_k is the indicative of solute–solute interactions. As solute–solute interactions are negligible at infinite dilution due to small size of S_k values, this indicates that solute–solvent interactions [84] are prevailing in the mixtures. The more negative values of φ_k^0 for amino acids at low temperature are attributed to the strong attractive interactions between amino acids and water [85]. With an increase in temperature, the φ_k^0 values become less negative, which means that electrostriction reduces and some water molecules are released to bulk. Furthermore, the attractive interactions between ciprofloxacin and water molecules induce the dehydration of amino acids and therefore at high ciprofloxacin concentrations the water molecules around the amino acids are more compressible than those at lower ciprofloxacin concentrations.

The values of apparent molar adiabatic compressibility of transfer ($\Delta_{tr}\varphi_k^0$) for molal concentrations of aqueous L-alanine and glycine at different temperatures are reported in tables 4.59-4.64. These values of apparent molar adiabatic compressibility of transfer ($\Delta_{tr}\varphi_k^0$) of amino acids are negative but glycine in aqueous 0.045 $mol.kg^{-1}$ & 0.06 $mol.kg^{-1}$ ciprofloxacin systems show the positive value.

The positive values of $\Delta_{tr}\varphi_k^0$ indicated that the consequence of increase in the number of monomeric water molecules on breakdown of hydrogen bonding among the water molecules in overlapping of several hydration spheres such as zwitterionic group of amino acids and alkyl chains of both amino acids and ciprofloxacin result the increase in the number of monomeric water molecules. The $\Delta_{tr}\varphi_k^0$ values of amino acids in aqueous ciprofloxacin solutions increase with increasing the mass of chain is due to the strengthening the hydrophobic-hydrophobic interaction [86]. Negative values of $\Delta_{tr}\varphi_k^0$ indicate that increase in hydrophilic-hydrophobic and hydrophobic- hydrophobic group interactions results in disruption of hydration sphere of charged centers of amino acid thereby reducing the positive contribution to $\Delta_{tr}\varphi_k^0$ [39]. The values of acoustic impedance, Z of aqueous L-alanine and glycine have been shown in tables 4.65-4.72 at different temperatures. Figures 4.51-4.58 show the plots of acoustic impedance as a function of molality of aqueous L-alanine and glycine. It is evident from the figures 4.51-4.58 that acoustic

impedance increases with the increase in molality of amino acids. The increase in Z with the molality of amino acids indicates that as concentration increases the sound wave has to face resistance to flow. The positive acoustic impedance is, therefore, an evidential parameter for solute-solvent interaction [84]. The present data support that there exist a strong solute-solvent interaction in L-alanine and glycine in aqueous ciprofloxacin solution. The values of acoustic impedance, Z of amino acids + ciprofloxacin + water are higher than the values of amino acids + water systems. These higher values of ternary systems than the binary systems show strong solute-solvent interaction in ternary systems than binary systems.

The values of relative association, R_A of aqueous L-alanine and glycine have been shown in tables 4.73-4.80 at different temperatures. Figures 4.59-4.66 show the plots of relative association as a function of molality of aqueous L-alanine and glycine. The relative association decrease with the increase of molality of L-alanine and glycine. The linear decrease in R_A indicates that solute-solvent interaction is maxima at infinite dilution. As the concentration of amino acids increases, the deviation from ideality increases thereby decreasing the solute-solvent interaction. This may be due to the increase in solute-solute interaction [80]. The values of R_A decrease with concentration but more decrease at higher temperature.

The hydration number (n_H) of L-alanine and glycine in water are listed in tables 4.81-4.82 and figures are graphically shown in 4.67-4.78. The hydration numbers decrease with the increase of concentration for aqueous L-alanine and glycine system. The hydration numbers also decrease with the increase of temperature. The hydration number of aqueous L-alanine is more than the aqueous glycine. The values of hydration number decreases as appreciable increases of solutes. This is an added support for the structure promoting nature of the amino acids as well as the presence of dipolar interaction between amino acids and water molecules. This also suggests that compressibility of the solution is less than that of the solvent. This may enhance the interaction between solute and solvent molecules [85]. From the tables, it is observed that the values of hydration number decrease with the increase of concentration of amino acids.

The values of hydration number (n_H) for molal concentrations of L-alanine and glycine in (0.03, 0.045 and 0.06) $mol.kg^{-1}$ aqueous ciprofloxacin solutions at different temperatures are reported in tables 4.83-4.88. The variation of n_H with molality is graphically shown in figures 4.69-4.74. The hydration numbers decrease with the increase of concentration for L-alanine and glycine in

aqueous ciprofloxacin systems which is similar with binary systems. The hydration numbers decrease with the increase of temperature. The hydration number of L-alanine in aqueous ciprofloxacin is more than glycine in aqueous ciprofloxacin. The hydration number of high ciprofloxacin concentrations the water molecules around the amino acids is lower than those at lower ciprofloxacin concentrations. The positive values of hydration number decreases as appreciable increases of solutes. This is an added support for the structure promoting nature of the amino acids as well as the presence of dipolar interaction between amino acids and water molecules. This also suggests that compressibility of the solution is less than that of the solvent. As a result amino acids will gain mobility and have more probability of contacting aqueous ciprofloxacin molecules. This may enhance the interaction between solute and solvent molecules [87]. From the tables, it is observed that the values of hydration number decrease with the increase of concentration of amino acids in aqueous ciprofloxacin solution.

The values of hydration number (n_H) of glycine + ciprofloxacin + water are lower than the values of L-alanine + ciprofloxacin + water systems. The lower values of hydration number in ternary system compared to binary system suggest strong solute-solvent interaction in ternary system than binary system.

Table 4.1: Density (ρ) of aqueous L-alanine as a function of molality at different temperature

L-Alanine + Water						
Density, ρ/kg.m^{-3}						
m/mol.kg^{-1}	293.15K	298.15K	303.15K	308.15K	313.15K	318.15K
0.0	998.453	997.289	995.9	994.283	992.465	990.008
0.1	1002.309	1001.132	1000.713	998.079	996.225	994.651
0.2	1005.135	1004.936	1002.499	999.845	997.981	995.571
0.3	1008.836	1007.604	1005.143	1004.484	1002.607	1000.320
0.4	1011.649	1010.396	1009.918	1007.238	1005.335	1003.849
0.5	1014.285	1013.010	1012.514	1010.82	1008.94	1006.856

Table 4.2: Density (ρ) of aqueous glycine as a function of molality at different temperature

Glycine + Water						
Density, ρ/kg.m^{-3}						
m/mol.kg^{-1}	293.15K	298.15K	303.15K	308.15K	313.15K	318.15K
0.0	998.453	997.289	995.9	994.283	992.465	990.008
0.1	1001.665	1000.479	999.052	997.379	995.52	993.821
0.2	1004.861	1003.638	1002.182	1000.506	998.578	996.852
0.3	1007.928	1006.675	1005.199	1003.521	1001.638	999.942
0.4	1010.971	1009.684	1008.175	1006.479	1004.442	1002.737
0.5	1013.960	1012.645	1011.112	1009.387	1007.317	1005.566

Table 4.3: Density (ρ) of L-alanine in aqueous solution of ciprofloxacin (0.03 mol.kg^{-1}) as a function of molality at different temperature

0.03 mol.kg^{-1} Ciprofloxacin + Water + L-Alanine						
Density, ρ/kg.m^{-3}						
m/mol.kg^{-1}	293.15K	298.15K	303.15K	308.15K	313.15K	318.15K
0.0	1001.794	1000.608	999.182	997.536	995.697	993.67
0.1	1005.592	1004.381	1002.931	1001.264	1000.056	997.104
0.2	1008.529	1007.108	1005.546	1003.797	1001.760	1000.478
0.3	1011.133	1009.876	1008.388	1006.688	1004.624	1002.262
0.4	1013.803	1012.520	1011.013	1009.298	1007.369	1004.960
0.5	1016.478	1015.172	1013.647	1012.091	1010.014	1007.362

Table 4.4: Density (ρ) of L-alanine in aqueous solution of ciprofloxacin (0.045 $mol.kg^{-1}$) as a function of molality at different temperature

0.045 $mol.kg^{-1}$ Ciprofloxacin + Water + L-Alanine						
Density, $\rho/kg.m^{-3}$						
$m/mol.kg^{-1}$	293.15K	298.15K	303.15K	308.15K	313.15K	318.15K
0.0	1003.437	1002.235	1000.788	999.134	997.275	995.226
0.1	1007.274	1006.046	1004.582	1002.911	1001.046	1000.618
0.2	1009.992	1008.74	1007.259	1005.562	1003.657	1001.321
0.3	1012.764	1011.496	1009.99	1008.282	1006.339	1003.999
0.4	1015.454	1014.149	1012.627	1010.908	1009.006	1006.94
0.5	1018.437	1017.235	1015.788	1014.134	1012.075	1011.009

Table 4.5: Density (ρ) of L-alanine in aqueous solution of ciprofloxacin (0.06 $mol.kg^{-1}$) as a function of molality at different temperature

0.06 $mol.kg^{-1}$ Ciprofloxacin + Water + L-Alanine						
Density, $\rho/kg.m^{-3}$						
$m/mol.kg^{-1}$	293.15K	298.15K	303.15K	308.15K	313.15K	318.15K
0.0	1005.103	1003.886	1002.432	1000.756	998.891	996.83
0.1	1009.940	1008.697	1007.208	1005.435	1003.464	1001.519
0.2	1012.732	1010.458	1009.962	1008.259	1006.370	1003.342
0.3	1015.381	1014.083	1012.567	1010.852	1008.939	1006.933
0.4	1018.018	1016.706	1015.164	1013.431	1011.418	1009.463
0.5	1018.537	1017.205	1015.652	1013.906	1011.975	1009.988

Table 4.6: Density (ρ) of glycine in aqueous solution of ciprofloxacin (0.03 $mol.kg^{-1}$) as a function of molality at different temperature

0.03 $mol.kg^{-1}$ Ciprofloxacin + Water + glycine						
Density, $\rho/kg.m^{-3}$						
$m/mol.kg^{-1}$	293.15K	298.15K	303.15K	308.15K	313.15K	318.15K
0.0	1001.794	1000.608	999.182	997.536	995.697	993.67
0.1	1004.991	1003.769	1002.31	1000.645	998.785	996.737
0.2	1008.926	1007.494	1005.978	1004.385	1002.412	1000.297
0.3	1012.726	1011.416	1009.891	1008.171	1006.265	1004.144
0.4	1016.259	1014.913	1013.359	1011.608	1009.438	1007.415
0.5	1021.655	1020.277	1018.696	1016.926	1014.982	1012.888

Table 4.7: Density (ρ) of glycine in aqueous solution of ciprofloxacin (0.045 $mol.kg^{-1}$) as a function of molality at different temperature

0.045 $mol.kg^{-1}$ Ciprofloxacin + Water + glycine						
Density, $\rho/kg.m^{-3}$						
$m/mol.kg^{-1}$	293.15K	298.15K	303.15K	308.15K	313.15K	318.15K
0.0	1003.437	1002.235	1000.788	999.134	997.275	995.226
0.1	1006.559	1005.326	1003.856	1002.176	1000.079	997.928
0.2	1009.547	1008.279	1006.788	1005.088	1003.195	1001.121
0.3	1012.608	1011.313	1009.785	1008.07	1006.126	1003.926
0.4	1015.734	1014.408	1012.854	1011.012	1009.129	1006.99
0.5	1018.662	1017.306	1015.736	1013.975	1012.026	1009.96

Table 4.8: Density (ρ) of glycine in aqueous solution of Ciprofloxacin (0.06 $mol.kg^{-1}$) as a function of molality at different temperature

0.06 $mol.kg^{-1}$ Ciprofloxacin + Water + glycine						
Density, $\rho/kg.m^{-3}$						
$m/mol.kg^{-1}$	293.15K	298.15K	303.15K	308.15K	313.15K	318.15K
0.0	1005.103	1003.886	1002.432	1000.756	998.891	996.83
0.1	1008.247	1006.998	1005.516	1003.825	1001.939	999.83
0.2	1011.317	1010.035	1008.526	1006.815	1004.884	1003.001
0.3	1014.150	1012.838	1011.307	1009.575	1007.61	1005.484
0.4	1017.233	1015.889	1014.329	1012.554	1010.355	1008.384
0.5	1020.215	1018.842	1017.259	1015.484	1013.425	1011.296

Table 4.9: Apparent molar volume (φ_v) of aqueous L-alanine as a function of molality ($m/mol.kg^{-1}$) at different temperature

Only L-Alanine +Water						
$\varphi_v \times 10^6/m^3.mol^{-1}$						
$m/mol.kg^{-1}$	293.15K	298.15K	303.15K	308.15K	313.15K	318.15K
0.1	60.26	60.55	60.83	61.19	61.54	61.96
0.2	60.38	60.70	61.00	61.36	61.73	62.17
0.3	60.53	60.87	61.16	61.55	61.92	62.38
0.4	60.68	61.05	61.35	61.73	62.11	62.56
0.5	60.82	61.21	61.53	61.92	62.33	62.75

Table 4.10: Apparent molar volume (φ_v) of aqueous glycine as a function of molality (m/mol.kg^{-1}) at different temperature

Only Glycine +Water						
$\varphi_v \times 10^6/m^3.mol^{-1}$						
m/mol.kg^{-1}	293.15 K	298.15K	303.15K	308.15K	313.15K	318.15K
0.1	42.76	42.99	43.39	43.78	44.42	44.71
0.2	42.85	43.19	43.54	43.88	44.47	44.86
0.3	43.03	43.34	43.65	44.00	44.52	45.00
0.4	43.18	43.51	43.83	44.15	44.63	45.09
0.5	43.33	43.65	43.96	44.30	44.74	45.19

Table 4.11: Apparent molar volume (φ_v) of L-alanine in aqueous solution of ciprofloxacin (0.03 mol.kg^{-1}) as a function of molality (m/mol.kg^{-1}) at different temperature

0.03 mol.kg^{-1}Ciprofloxacin + Water + L-Alanine						
$\varphi_v \times 10^6/m^3.mol^{-1}$						
m/mol.kg^{-1}	293.15K	298.15K	303.15K	308.15K	313.15K	318.15K
0.1	57.99	58.48	58.97	59.44	59.84	60.63
0.2	58.63	59.14	59.68	60.16	60.57	61.21
0.3	59.34	59.82	60.37	60.81	61.24	61.75
0.4	60.05	60.43	60.89	61.32	61.81	62.36
0.5	60.74	61.12	61.57	61.94	62.39	62.85

Table 4.12: Apparent molar volume (φ_v) of L-alanine in aqueous solution of ciprofloxacin (0.045 mol.kg^{-1}) as a function of molality (m/mol.kg^{-1}) at different temperature

0.045 mol.kg^{-1}Ciprofloxacin + Water + L-Alanine						
$\varphi_v \times 10^6/m^3.mol^{-1}$						
m/mol.kg^{-1}	293.15K	298.15K	303.15K	308.15K	313.15K	318.15K
0.1	59.99	60.50	60.86	61.09	61.41	61.72
0.2	60.37	60.93	61.28	61.56	61.87	62.22
0.3	60.80	61.37	61.83	62.11	62.42	62.78
0.4	61.27	61.87	62.31	62.60	62.91	63.26
0.5	61.78	62.39	62.83	63.11	63.45	63.76

Table 4.13: Apparent molar volume (φ_v) of L-alanine in aqueous solution of ciprofloxacin (0.06 $mol.kg^{-1}$) as a function of molality ($m/mol.kg^{-1}$) at different temperature

0.06 $mol.kg^{-1}$Ciprofloxacin + Water + L-Alanine						
$\varphi_v \times 10^6/m^3.mol^{-1}$						
$m/mol.kg^{-1}$	293.15K	298.15K	303.15K	308.15K	313.15K	318.15K
0.1	60.30	60.59	60.89	61.15	61.40	61.62
0.2	60.45	60.72	61.13	61.41	61.61	61.92
0.3	60.68	60.94	61.28	61.62	61.90	62.19
0.4	60.88	61.16	61.46	61.87	62.17	62.48
0.5	61.14	61.41	61.66	62.06	62.48	62.80

Table 4.14: Apparent molar volume (φ_v) of glycine in aqueous solution of ciprofloxacin (0.03 $mol.kg^{-1}$) as a function of molality ($m/mol.kg^{-1}$) at different temperature

0.03 $mol.kg^{-1}$Ciprofloxacin + Water + Glycine						
$\varphi_v \times 10^6/m^3.mol^{-1}$						
$m/mol.kg^{-1}$	293.15K	298.15K	303.15K	308.15K	313.15K	318.15K
0.1	41.07	41.55	42.09	42.50	43.04	43.58
0.2	41.26	41.79	42.35	42.73	43.28	43.74
0.3	41.54	42.06	42.59	42.94	43.47	43.91
0.4	41.78	42.28	42.81	43.28	43.69	44.12
0.5	42.08	42.67	43.09	43.44	43.86	44.28

Table 4.15: Apparent molar volume (φ_v) of glycine in aqueous solution of ciprofloxacin (0.045 $mol.kg^{-1}$) as a function of molality ($m/mol.kg^{-1}$) at different temperature

0.045 $mol.kg^{-1}$Ciprofloxacin + Water + Glycine						
$\varphi_v \times 10^6/m^3.mol^{-1}$						
$m/mol.kg^{-1}$	293.15K	298.15K	303.15K	308.15K	313.15K	318.15K
0.1	43.26	43.59	43.89	44.13	44.40	44.61
0.2	43.49	43.83	44.13	44.33	44.63	44.86
0.3	43.67	43.99	44.28	44.59	44.86	45.11
0.4	43.87	44.19	44.49	44.76	45.03	45.34
0.5	44.04	44.37	44.65	44.97	45.29	45.56

Table 4.16: Apparent molar volume (φ_v) of glycine in aqueous solution of ciprofloxacin (0.06 $mol.kg^{-1}$) as a function of molality ($m/mol.kg^{-1}$) at different temperature

0.06 $mol.kg^{-1}$Ciprofloxacin + Water + Glycine						
$\varphi_v \times 10^6/m^3.mol^{-1}$						
$m/mol.kg^{-1}$	293.15K	298.15K	303.15K	308.15K	313.15K	318.15K
0.1	49.99	50.50	50.86	51.09	51.41	51.72
0.2	50.37	50.93	51.28	51.56	51.87	52.22
0.3	50.80	51.37	51.83	52.11	52.42	52.78
0.4	51.27	51.87	52.31	52.60	52.91	53.26
0.5	51.78	52.39	52.83	53.11	53.45	53.76

Table 4.17: Limiting apparent molar volume (φ_v^0), experimental slope (S_V), limiting apparent molar volume expansibilities ($E\varphi^0$) and $(\delta E^0\varphi/\delta T)_p$ of L-alanine + water system at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively

Temp (K)	$\varphi_v^0\times10^6$ ($m^3.mol^{-1}$)	$S_V \times10^6$ ($m^3.mol^{-2}.kg$)	$E\varphi^0\times10^8$ ($m^3.mol^{-1}.K^{-1}$)	$(\delta E^0\varphi/\delta T)p\times10^8$ ($m^3.mol^{-2}.K^{-2}$)
293.15K	60.11	1.42	4	
298.15K	60.37	1.67	5.7	
303.15K	60.64	1.42	6.5	1.6
308.15K	61.00	1.83	7.3	
313.15K	61.34	1.95	8.1	
318.15K	61.77	1.96	8.9	

Table 4.18: Limiting apparent molar volume (φ_v^0), experimental slope (S_V), limiting apparent molar volume expansibilities ($E\varphi^0$) and $(\delta E^0\varphi/\delta T)p$ of Glycine + water system at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively

Temp (K)	$\varphi_v^0\times10^6$ ($m^3.mol^{-1}$)	$S_V \times10^6$ ($m^3.mol^{-2}.kg$)	$E\varphi^0\times10^8$ ($m^3.mol^{-1}.K^{-1}$)	$(\delta E^0\varphi/\delta T)p\times10^8$ ($m^3.mol^{-2}.K^{-2}$)
293.15K	42.58	1.47	6.50	
298.15K	42.84	1.63	7.50	
303.15K	43.24	1.47	8.50	2.00
308.15K	43.62	1.31	9.50	
313.15K	44.61	1.19	1.15	
318.15K	44.30	0.81	1.05	

Table 4.19: Limiting apparent molar volume (φ_v^0), experimental slope (S_V), limiting apparent molar volume transfer ($\Delta\varphi_v^0$), limiting apparent molar volume expansibilities ($E\varphi^0$) and $(\delta E^0\varphi/\delta T)p$ of water + L-alanine + 0.03 mol.kg^{-1} ciprofloxacin system at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively

Temp (K)	$\varphi_v^0\times10^6$ ($m^3.mol^{-1}$)	$S_V\times10^6$ ($m^3.mol^{-2}.kg$)	$\Delta_{tr}\varphi_v^0\times10^6$ ($m^3.mol^{-1}$)	$E\varphi^0\times10^8$ ($m^3.mol^{-1}.K^{-1}$)	$(\delta E^0\varphi/\delta T)p\times10^8$ ($m^3.mol^{-2}.K^{-2}$)
293.15K	57.27	6.92	-2.83	9.82	
298.15K	57.82	6.57	-2.54	9.89	
303.15K	58.37	6.41	-2.27	9.96	1.4
308.15K	58.87	6.17	-2.12	10.00	
313.15K	59.26	6.36	-2.08	10.10	
318.15K	60.07	5.60	-1.69	10.17	

Table 4.20: Limiting apparent molar volume (φ_v^0), experimental slope (S_V), limiting apparent molar volume transfer ($\Delta\varphi_v^0$), limiting apparent molar volume expansibilities ($E\varphi^0$) and $(\delta E^0\varphi/\delta T)p$ of water + L-alanine + 0.045 mol.kg^{-1} ciprofloxacin system at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively

Temp (K)	$\varphi_v^0\times10^6$ ($m^3.mol^{-1}$)	$S_V\times10^6$ ($m^3.mol^{-2}.kg$)	$\Delta_{tr}\varphi_v^0\times10^6$ ($m^3.mol^{-1}$)	$E\varphi^0\times10^8$ ($m^3.mol^{-1}.K^{-1}$)	$(\delta E^0\varphi/\delta T)p\times10^8$ ($m^3.mol^{-2}.K^{-2}$)
293.15K	59.49	4.47	-0.6	5.24	
298.15K	59.99	4.72	-0.37	5.94	
303.15K	60.33	4.96	-0.31	6.64	1.4
308.15K	60.56	5.07	-0.43	7.34	
313.15K	60.87	5.11	-0.46	8.04	
318.15K	61.21	5.12	-0.56	8.74	

Table 4.21: Limiting apparent molar volume (φ_v^0), experimental slope (S_V), limiting apparent molar volume transfer ($\Delta\varphi_v^0$), limiting apparent molar volume expansibilities ($E\varphi^0$) and $(\delta E^0\varphi/\delta T)p$ of water + L-alanine + 0.06 mol.kg^{-1} ciprofloxacin system at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively

Temp (K)	$\varphi_v^0\times10^6$ ($m^3.mol^{-1}$)	$S_V\times10^6$ ($m^3.mol^{-2}.kg$)	$\Delta_{tr}\varphi_v^0\times10^6$ ($m^3.mol^{-1}$)	$E\varphi^0\times10^8$ ($m^3.mol^{-1}.K^{-1}$)	$(\delta E^0\varphi/\delta T)p\times10^8$ ($m^3.mol^{-2}.K^{-2}$)
293.15K	60.05	2.10	-0.05	9.83	
298.15K	60.34	2.06	-0.03	9.89	
303.15K	60.72	1.86	0.07	9.97	1.4
308.15K	60.93	2.28	-0.06	10.03	
313.15K	61.09	2.71	-0.24	10.10	
318.15K	61.32	2.92	-0.44	10.17	

Table 4.22: Limiting apparent molar volume (φ_v^0), experimental slope (S_V), limiting apparent molar volume transfer ($\Delta\varphi_v^0$), limiting apparent molar volume expansibilities ($E\varphi^0$) and $(\delta E^0\varphi/\delta T)p$ of water + Glycine + 0.03 mol.kg^{-1} ciprofloxacin system at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively

Temp (K)	$\varphi_v^0\times10^6$ ($m^3.mol^{-1}$)	$S_V\times10^6$ ($m^3.mol^{-2}.kg$)	$\Delta_{tr}\varphi_v^0\times10^6$ ($m^3.mol^{-1}$)	$E\varphi^0\times10^8$ ($m^3.mol^{-1}.K^{-1}$)	$(\delta E^0\varphi/\delta T)p\times10^8$ ($m^3.mol^{-2}.K^{-2}$)
293.15K	40.78	2.54	1.80	9.25	
298.15K	41.24	2.74	1.60	9.55	
303.15K	41.85	2.44	1.39	9.85	6
308.15K	42.25	2.42	1.19	10.05	
313.15K	42.85	2.40	0.99	10.25	
318.15K	43.39	2.38	0.79	10.45	

Table 4.23: Limiting apparent molar volume (φ_v^0), experimental slope (S_V), limiting apparent molar volume transfer ($\Delta\varphi_v^0$), limiting apparent molar volume expansibilities ($E\varphi^0$) and $(\delta E^0\varphi/\delta T)p$ of water + Glycine + 0.045 mol.kg^{-1} ciprofloxacin system at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively

Temp (K)	$\varphi_v^0\times10^6$ ($m^3.mol^{-1}$)	$S_V\times10^6$ ($m^3.mol^{-2}.kg$)	$\Delta_{tr}\varphi_v^0\times10^6$ ($m^3.mol^{-1}$)	$E\varphi^0\times10^8$ ($m^3.mol^{-1}.K^{-1}$)	$(\delta E^0\varphi/\delta T)p\times10^8$ ($m^3.mol^{-2}.K^{-2}$)
293.15K	43.08	1.92	0.50	3.49	
298.15K	43.42	1.90	0.57	4.09	1.2
303.15K	43.72	1.87	0.64	4.69	
308.15K	43.92	2.11	0.71	5.29	
313.15K	44.18	2.18	0.85	5.89	
318.15K	44.38	2.38	0.92	6.49	

Table 4.24: Limiting apparent molar volume (φ_v^0), experimental slope (S_V), limiting apparent molar volume transfer ($\Delta\varphi_v^0$), limiting apparent molar volume expansibilities ($E\varphi^0$) and $(\delta E^0\varphi/\delta T)p$ of Water + Glycine + 0.06 mol.kg^{-1} ciprofloxacin system at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively

Temp (K)	$\varphi_v^0\times10^6$ ($m^3.mol^{-1}$)	$S_V\times10^6$ ($m^3.mol^{-2}.kg$)	$\Delta_{tr}\varphi_v^0\times10^6$ ($m^3.mol^{-1}$)	$E\varphi^0\times10^8$ ($m^3.mol^{-1}.K^{-1}$)	$(\delta E^0\varphi/\delta T)p\times10^8$ ($m^3.mol^{-2}.K^{-2}$)
293.15K	49.49	4.47	6.91	5.24	
298.15K	49.99	4.72	7.14	5.94	
303.15K	50.33	4.96	7.09	6.64	1.4
308.15K	50.56	5.07	6.94	7.34	
313.15K	50.87	5.11	6.56	8.04	
318.15K	51.21	5.12	6.60	8.74	

Table 4.25: Partial molar volume ($\bar{V}_2$) of aqueous L-alanine as a function of molality (m/mol.kg^{-1}) at different temperature

L-Alanine+ Water						
$\bar{V}_2 \times 10^6/m^3.mol^{-1}$						
m/mol.kg^{-1}	293.15 K	298.15K	303.15K	308.15K	313.15K	318.15K
0.1	60.49	60.82	61.11	61.49	61.86	62.28
0.2	60.71	61.08	61.40	61.78	62.18	62.62
0.3	60.93	61.33	61.64	62.07	62.46	62.93
0.4	61.14	61.58	61.91	62.33	62.74	63.20
0.5	61.33	61.81	62.16	62.58	63.03	63.46

Table 4.26: Partial molar volume ($\bar{V}_2$) of aqueous glycine as a function of molality (m/mol.kg^{-1}) at different temperature

Glycine+ Water						
$\bar{V}_2 \times 10^6/m^3.mol^{-1}$						
m/mol.kg^{-1}	293.15 K	298.15K	303.15K	308.15K	313.15K	318.15K
0.1	43.00	43.26	43.62	43.99	44.55	44.90
0.2	43.18	43.57	43.93	44.30	44.81	45.21
0.3	43.42	43.80	44.14	44.51	45.06	45.45
0.4	43.64	44.04	44.39	44.74	45.26	45.73
0.5	43.85	44.25	44.59	44.96	45.45	45.90

Table 4.27: Partial molar volume ($\bar{V}_2$) of aqueous solution of ciprofloxacin (0.03 mol.kg^{-1}) with L-alanine as a function of molality (m/mol.kg^{-1}) at different temperature

0.03 mol.kg^{-1} Ciprofloxacin + Water + L-Alanine						
$\bar{V}_2 \times 10^6/m^3.mol^{-1}$						
m/mol.kg^{-1}	293.15K	298.15K	303.15K	308.15K	313.15K	318.15K
0.1	59.11	59.54	60.01	60.44	60.87	61.53
0.2	60.20	60.64	61.15	61.57	61.95	62.58
0.3	61.27	61.65	62.17	62.55	62.93	63.43
0.4	62.28	62.56	62.97	63.32	63.77	64.30
0.5	63.24	63.50	63.90	64.19	64.58	65.02

Table 4.28: Partial molar volume ($\bar{V}_2$) of aqueous solution of ciprofloxacin (0.045 mol.kg^{-1}) with L-alanine as a function of molality (m/mol.kg^{-1}) at different temperature

0.045 mol.kg^{-1} Ciprofloxacin + Water + L-Alanine						
$\bar{V}_2 \times 10^6/m^3.mol^{-1}$						
m/mol.kg^{-1}	293.15K	298.15K	303.15K	308.15K	313.15K	318.15K
0.1	60.71	61.26	61.66	61.91	62.24	62.55
0.2	61.39	62.01	62.41	62.71	63.04	63.40
0.3	62.04	62.68	63.22	63.53	63.84	64.21
0.4	62.71	63.39	63.91	64.24	64.55	64.92
0.5	63.38	64.08	64.62	64.94	65.30	65.62

Table 4.29: Partial molar volume ($\bar{V}_2$) of aqueous solution of ciprofloxacin (0.06 mol.kg^{-1}) with L-alanine as a function of molality (m/mol.kg^{-1}) at different temperature

0.06 mol.kg^{-1} Ciprofloxacin + Water + L-Alanine						
$\bar{V}_2 \times 10^6/m^3.mol^{-1}$						
m/mol.kg^{-1}	293.15K	298.15K	303.15K	308.15K	313.15K	318.15K
0.1	60.93	61.22	61.59	62.02	62.34	62.59
0.2	61.63	61.92	62.40	62.63	62.99	63.30
0.3	62.32	62.58	62.95	63.25	63.59	63.87
0.4	63.01	63.28	63.54	63.87	64.13	64.42
0.5	63.63	63.88	64.18	64.40	64.67	64.97

Table 4.30: Partial molar volume ($\bar{V}_2$) of aqueous solution of ciprofloxacin (0.03 mol.kg^{-1}) with Glycine as a function of molality (m/mol.kg^{-1}) at different temperature

0.03 mol.kg^{-1} Ciprofloxacin + Water + Glycine						
$\bar{V}_2 \times 10^6/m^3.mol^{-1}$						
m/mol.kg^{-1}	293.15K	298.15K	303.15K	308.15K	313.15K	318.15K
0.1	41.48	41.99	42.49	42.90	43.37	43.87
0.2	41.83	42.41	42.91	43.28	43.75	44.15
0.3	42.25	42.82	43.27	43.62	44.05	44.41
0.4	42.60	43.16	43.60	44.06	44.36	44.69
0.5	42.99	43.65	43.97	44.32	44.61	44.92

Table 4.31: Partial molar volume ($\bar{V}_2$) of aqueous solution of ciprofloxacin (0.045 mol.kg^{-1}) with Glycine as a function of molality (m/mol.kg^{-1}) at different temperature

0.045 mol.kg^{-1} Ciprofloxacin + Water + Glycine						
$\bar{V}_2 \times 10^6/m^3.mol^{-1}$						
m/mol.kg^{-1}	293.15K	298.15K	303.15K	308.15K	313.15K	318.15K
0.1	41.88	42.29	42.89	43.20	43.59	44.07
0.2	42.53	42.99	43.52	43.95	44.26	44.81
0.3	43.20	43.69	44.19	44.58	44.97	45.49
0.4	43.91	44.41	44.89	45.28	45.65	46.16
0.5	44.58	45.05	45.61	45.90	46.25	46.79

Table 4.32: Partial molar volume ($\bar{V}_2$) of aqueous solution of ciprofloxacin (0.06 mol.kg^{-1}) with Glycine as a function of molality (m/mol.kg^{-1}) at different temperature

0.06 mol.kg^{-1} Ciprofloxacin + Water + Glycine						
$\bar{V}_2 \times 10^6/m^3.mol^{-1}$						
m/mol.kg^{-1}	293.15K	298.15K	303.15K	308.15K	313.15K	318.15K
0.1	43.58	43.90	44.20	44.48	44.75	45.00
0.2	43.94	44.27	44.56	44.81	45.13	45.40
0.3	44.21	44.53	44.81	45.18	45.47	45.78
0.4	44.50	44.81	45.10	45.45	45.74	46.11
0.5	44.74	45.06	45.33	45.74	46.08	46.43

Table 4.33: Sound velocity (u) and of aqueous L-alanine as a function of molality at different temperature

L-Alanine + Water						
Sound velocity, u/m.s^{-1}						
m/mol.kg^{-1}	293.15K	298.15K	303.15K	308.15K	313.15K	318.15K
0.0	1482.68	1496.55	1508.83	1519.45	1528.51	1536.29
0.1	1489.32	1502.96	1515.05	1525.51	1534.38	1541.81
0.2	1496.08	1509.39	1521.26	1531.51	1540.22	1547.48
0.3	1502.33	1515.53	1527.21	1537.25	1545.8	1552.91
0.4	1508.97	1521.95	1533.39	1543.26	1551.62	1558.56
0.5	1515.36	1528.08	1539.3	1548.97	1557.14	1563.92

Table 4.34: Sound velocity (u) of aqueous Glycine as a function of molality at different temperature

Glycine + Water						
Sound velocity, u/m.s^{-1}						
m/mol.kg^{-1}	293.15K	298.15K	303.15K	308.15K	313.15K	318.15K
0.0	1482.68	1496.55	1508.83	1519.45	1528.51	1536.29
0.1	1488.06	1501.75	1513.91	1524.43	1533.39	1541.99
0.2	1493.44	1506.99	1519.01	1529.4	1538.25	1546.64
0.3	1498.66	1512.03	1523.92	1534.17	1542.91	1551.21
0.4	1503.95	1517.18	1528.09	1539.09	1547.62	1556.04
0.5	1508.99	1522.04	1533.62	1543.61	1552.38	1560.48

Table 4.35: Sound velocity (u) of L-alanine in aqueous solution of ciprofloxacin (0.03 mol.kg^{-1}) as a function of molality at different temperature

0.03 mol.kg^{-1} Ciprofloxacin + Water + L-Alanine						
Sound velocity, u/m.s^{-1}						
m/mol.kg^{-1}	293.15K	298.15K	303.15K	308.15K	313.15K	318.15K
0.0	1486.21	1499.92	1512.02	1522.48	1531.37	1538.78
0.1	1492.94	1506.36	1518.24	1528.5	1537.44	1544.69
0.2	1500.01	1513.04	1524.71	1534.96	1543.47	1550.53
0.3	1506.22	1519.08	1530.51	1540.62	1548.98	1555.91
0.4	1512.52	1525.24	1536.46	1546.37	1554.54	1561.3
0.5	1518.78	1531.32	1542.35	1551.84	1559.85	1566.47

Table 4.36: Sound velocity (u) of L-alanine in aqueous solution of ciprofloxacin (0.045 mol.kg^{-1}) as a function of molality at different temperature

0.045 mol.kg^{-1} Ciprofloxacin + Water + L-Alanine						
Sound velocity, u/m.s^{-1}						
m/mol.kg^{-1}	293.15K	298.15K	303.15K	308.15K	313.15K	318.15K
0.0	1488.01	1501.55	1513.56	1523.92	1532.97	1540.31
0.1	1494.94	1508.29	1520.10	1530.27	1538.88	1546.22
0.2	1501.20	1514.27	1525.85	1536.07	1544.5	1551.51
0.3	1507.81	1520.59	1531.95	1542	1550.27	1557.13
0.4	1514.15	1527.02	1538.19	1547.76	1555.83	1562.5
0.5	1521.12	1533.46	1544.49	1554.45	1562.63	1569.37

Table 4.37: Sound velocity (u) of L-alanine in aqueous solution of ciprofloxacin (0.06 $mol.kg^{-1}$) as a function of molality at different temperature

0.06 $mol.kg^{-1}$ Ciprofloxacin + Water + L-Alanine						
Sound velocity, $u/m.s^{-1}$						
$m/mol.kg^{-1}$	293.15K	298.15K	303.15K	308.15K	313.15K	318.15K
0.0	1489.68	1503.16	1515.08	1525.65	1534.37	1541.62
0.1	1496.26	1509.49	1521.47	1531.56	1540.07	1547.13
0.2	1502.90	1516.15	1527.67	1537.54	1545.88	1552.78
0.3	1509.47	1522.51	1533.84	1543.53	1551.7	1558.45
0.4	1515.67	1528.22	1539.54	1549.05	1557.05	1563.63
0.5	1521.82	1534.14	1545	1554.35	1562.22	1568.71

Table 4.38: Sound velocity (u)) of Glycine in aqueous solution of ciprofloxacin (0.03 $mol.kg^{-1}$) as a function of molality at different temperature

0.03 $mol.kg^{-1}$ Ciprofloxacin + Water + Glycine						
Sound velocity, $u/m.s^{-1}$						
$m/mol.kg^{-1}$	293.15K	298.15K	303.15K	308.15K	313.15K	318.15K
0.0	1486.21	1499.92	1512.02	1522.48	1531.37	1538.78
0.1	1491.69	1505.2	1517.15	1527.49	1536.28	1543.83
0.2	1498.17	1511.67	1523.49	1533.66	1542.32	1549.5
0.3	1505.11	1518.38	1529.99	1539.96	1548.43	1555.5
0.4	1511.05	1524.17	1535.62	1545.45	1553.79	1560.75
0.5	1516.83	1529.76	1541.05	1550.75	1558.96	1565.8

Table 4.39: Sound velocity (u) of Glycine in aqueous solution of ciprofloxacin (0.045 $mol.kg^{-1}$) as a function of molality at different temperature

0.045 $mol.kg^{-1}$ Ciprofloxacin + Water + Glycine						
Sound velocity, $u/m.s^{-1}$						
$m/mol.kg^{-1}$	293.15K	298.15K	303.15K	308.15K	313.15K	318.15K
0.0	1488.01	1501.55	1513.56	1523.92	1532.97	1540.31
0.1	1493.10	1506.61	1518.50	1528.76	1537.45	1544.72
0.2	1498.32	1511.6	1523.35	1533.47	1542.06	1549.21
0.3	1503.56	1516.68	1528.27	1538.28	1546.72	1553.78
0.4	1508.81	1521.84	1533.29	1543.15	1551.52	1558.47
0.5	1513.94	1526.74	1538.05	1547.79	1556.05	1562.9

Table 4.40: Sound velocity (u) of Glycine in aqueous solution of ciprofloxacin (0.06 $mol.kg^{-1}$) as a function of molality at different temperature

0.06 $mol.kg^{-1}$ Ciprofloxacin + Water + Glycine						
Sound velocity, $u/m.s^{-1}$						
$m/mol.kg^{-1}$	293.15K	298.15K	303.15K	308.15K	313.15K	318.15K
0.0	1489.68	1503.16	1515.08	1525.65	1534.37	1541.62
0.1	1494.96	1508.27	1520.05	1530.21	1538.83	1545.99
0.2	1500.20	1513.37	1525.03	1535.05	1543.55	1550.63
0.3	1505.55	1518.53	1530.04	1539.93	1548.33	1555.29
0.4	1510.77	1523.73	1535.10	1544.89	1553.2	1560.07
0.5	1515.49	1528.22	1539.43	1549.11	1557.3	1564.1

Table 4.41: Adiabatic compressibility ($\beta s \times 10^{10}/Pa^{-1}$) of aqueous L-alanine as a function of molality ($m/mol.kg^{-1}$) at different temperature

Water + L-Alanine						
$m/mol.kg^{-1}$	293.15K	298.15K	303.15K	308.15K	313.15K	318.15K
0.0	4.56	4.48	4.41	4.36	4.31	4.28
0.1	4.50	4.43	4.36	4.31	4.27	4.24
0.2	4.45	4.38	4.31	4.26	4.22	4.19
0.3	4.40	4.33	4.27	4.22	4.18	4.15
0.4	4.35	4.28	4.22	4.18	4.14	4.11
0.5	4.30	4.24	4.18	4.14	4.10	4.07

Table 4.42: Adiabatic compressibility ($\beta s \times 10^{10}/Pa^{-1}$) of aqueous Glycine as a function of molality ($m/mol.kg^{-1}$) at different temperature

Water + Glycine						
$m/mol.kg^{-1}$	293.15K	298.15K	303.15K	308.15K	313.15K	318.15K
0.0	4.56	4.48	4.41	4.36	4.31	4.28
0.1	4.51	4.43	4.37	4.31	4.27	4.23
0.2	4.46	4.39	4.32	4.27	4.23	4.19
0.3	4.42	4.35	4.28	4.23	4.19	4.16
0.4	4.37	4.30	4.25	4.19	4.16	4.12
0.5	4.33	4.26	4.20	4.16	4.12	4.08

Table 4.43: Adiabatic compressibility ($\beta s \times 10^{10}/Pa^{-1}$) of L-alanine in aqueous solution of ciprofloxacin (0.03 $mol.kg^{-1}$) as a function of molality ($m/mol.kg^{-1}$) at different temperature

0.03 $mol.kg^{-1}$ Ciprofloxacin + Water + L-Alanine						
$m/mol.kg^{-1}$	293.15K	298.15K	303.15K	308.15K	313.15K	318.15K
0.0	4.52	4.44	4.38	4.32	4.28	4.25
0.1	4.47	4.39	4.33	4.28	4.24	4.21
0.2	4.41	4.34	4.28	4.23	4.19	4.17
0.3	4.36	4.30	4.24	4.19	4.15	4.13
0.4	4.32	4.25	4.19	4.15	4.11	4.09
0.5	4.27	4.20	4.15	4.11	4.07	4.05

Table 4.44: Adiabatic compressibility ($\beta s \times 10^{10}/Pa^{-1}$) of L-alanine in aqueous solution of ciprofloxacin (0.045$mol.kg^{-1}$) as a function of molality (m/mol.kg-1) at different temperature

0.045 $mol.kg^{-1}$ Ciprofloxacin + Water + L-Alanine						
$m/mol.kg^{-1}$	293.15K	298.15K	303.15K	308.15K	313.15K	318.15K
0.0	4.50	4.43	4.36	4.31	4.27	4.24
0.1	4.45	4.37	4.31	4.26	4.22	4.19
0.2	4.40	4.33	4.27	4.22	4.18	4.15
0.3	4.35	4.28	4.22	4.18	4.14	4.11
0.4	4.30	4.23	4.18	4.13	4.10	4.07
0.5	4.25	4.18	4.13	4.08	4.05	4.02

Table 4.45: Adiabatic compressibility ($\beta s \times 10^{10}/Pa^{-1}$) of L-alanine in aqueous solution of ciprofloxacin (0.06 $mol.kg^{-1}$) as a function of molality ($m/mol.kg^{-1}$) at different temperature

0.06 $mol.kg^{-1}$ Ciprofloxacin + Water + L-Alanine						
$m/mol.kg^{-1}$	293.15K	298.15K	303.15K	308.15K	313.15K	318.15K
0.0	4.48	4.41	4.35	4.29	4.25	4.22
0.1	4.43	4.36	4.30	4.25	4.21	4.18
0.2	4.38	4.31	4.25	4.20	4.17	4.14
0.3	4.33	4.26	4.21	4.16	4.12	4.10
0.4	4.28	4.22	4.16	4.12	4.09	4.06
0.5	4.24	4.18	4.12	4.08	4.05	4.02

Table 4.46: Adiabatic compressibility ($\beta s \times 10^{10}/Pa^{-1}$) of Glycine in aqueous solution of ciprofloxacin (0.03 $mol.kg^{-1}$) as a function of molality ($m/mol.kg^{-1}$) at different temperature

0.03 $mol.kg^{-1}$ Ciprofloxacin + Water + Glycine						
$m/mol.kg^{-1}$	293.15K	298.15K	303.15K	308.15K	313.15K	318.15K
0.0	4.52	4.44	4.38	4.32	4.28	4.25
0.1	4.47	4.40	4.33	4.28	4.24	4.21
0.2	4.42	4.34	4.28	4.23	4.19	4.16
0.3	4.36	4.29	4.23	4.18	4.14	4.12
0.4	4.31	4.24	4.18	4.14	4.10	4.07
0.5	4.26	4.20	4.14	4.10	4.06	4.03

Table 4.47: Adiabatic compressibility ($\beta s \times 10^{10}/Pa^{-1}$) of Glycine in aqueous solution of ciprofloxacin (0.045$mol.kg^{-1}$) as a function of molality ($m/mol.kg^{-1}$) at different temperature

0.045 $mol.kg^{-1}$ Ciprofloxacin + Water + Glycine						
$m/mol.kg^{-1}$	293.15K	298.15K	303.15K	308.15K	313.15K	318.15K
0.0	4.50	4.43	4.36	4.31	4.27	4.24
0.1	4.46	4.38	4.32	4.27	4.23	4.20
0.2	4.41	4.34	4.28	4.23	4.19	4.16
0.3	4.37	4.30	4.24	4.19	4.15	4.13
0.4	4.32	4.26	4.20	4.15	4.12	4.09
0.5	4.28	4.22	4.16	4.12	4.08	4.05

Table 4.48: Adiabatic compressibility ($\beta s \times 10^{10}/Pa^{-1}$) of Glycine in aqueous solution of ciprofloxacin (0.06 $mol.kg^{-1}$) as a function of molality ($m/mol.kg^{-1}$) at different temperature

0.06 $mol.kg^{-1}$ Ciprofloxacin + Water + Glycine						
$m/mol.kg^{-1}$	293.15K	298.15K	303.15K	308.15K	313.15K	318.15K
0.0	4.48	4.41	4.35	4.29	4.25	4.22
0.1	4.44	4.37	4.30	4.25	4.21	4.18
0.2	4.39	4.32	4.26	4.22	4.18	4.15
0.3	4.35	4.28	4.22	4.18	4.14	4.11
0.4	4.31	4.24	4.18	4.14	4.10	4.07
0.5	4.27	4.20	4.15	4.10	4.07	4.04

Table 4.49: Apparent molar adiabatic compressibility (φ_k) of aqueous L-alanine as a function of molality (m/mol.kg^{-1}) at different temperature

Only water + L-Alanine						
$\varphi_k \times 10^{14}/m^3.mol^{-1}.Pa^{-1}$						
m/mol.kg^{-1}	293.15K	298.15K	303.15K	308.15K	313.15K	318.15K
0.1	-2.6338	-2.4091	-2.2126	-2.0615	-1.8903	-1.7080
0.2	-2.5138	-2.3069	-2.1086	-1.9717	-1.7932	-1.5766
0.3	-2.4196	-2.2059	-2.0362	-1.8799	-1.6975	-1.5152
0.4	-2.3150	-2.1036	-1.9083	-1.7774	-1.5917	-1.4300
0.5	-2.2127	-2.0097	-1.8162	-1.6760	-1.4976	-1.3380

Table 4.50: Apparent molar adiabatic compressibility (φ_k) of aqueous Glycine as a function of molality (m/mol.kg^{-1}) at different temperature

Only water + Glycine						
$\varphi_k \times 10^{14}/m^3.mol^{-1}.Pa^{-1}$						
m/mol.kg^{-1}	293.15K	298.15K	303.15K	308.15K	313.15K	318.15K
0.1	-2.8183	-2.6596	-2.4801	-2.3517	-2.1889	-2.0581
0.2	-2.8044	-2.6125	-2.4523	-2.3194	-2.1526	-2.0039
0.3	-2.7252	-2.5321	-2.3781	-2.2503	-2.1227	-1.9704
0.4	-2.6882	-2.5000	-2.3060	-2.2237	-2.0447	-1.9017
0.5	-2.6252	-2.4376	-2.2817	-2.1541	-2.0013	-1.8418

Table 4.51: Apparent molar adiabatic compressibility (φ_k) of L-alanine in aqueous solution of ciprofloxacin (0.03 mol.kg^{-1}) as a function of molality (m/mol.kg^{-1}) at different temperature

0.03 mol.kg^{-1} Ciprofloxacin + Water + L-Alanine						
$\varphi_k \times 10^{14}/m^3.mol^{-1}.Pa^{-1}$						
m/mol.kg^{-1}	293.15K	298.15K	303.15K	308.15K	313.15K	318.15K
0.1	-2.7881	-2.5716	-2.3275	-2.1140	-1.8945	-1.7493
0.2	-2.6841	-2.4708	-2.2220	-2.0261	-1.8251	-1.6734
0.3	-2.5813	-2.3753	-2.1261	-1.9545	-1.7636	-1.6117
0.4	-2.4811	-2.2746	-2.0639	-1.8931	-1.7265	-1.5584
0.5	-2.3992	-2.1773	-1.9885	-1.8577	-1.6739	-1.4853

Table 4.52: Apparent molar adiabatic compressibility (φ_k) of L-alanine in aqueous solution of ciprofloxacin (0.045mol.kg^{-1}) as a function of molality (m/mol.kg^{-1}) at different temperature

0.045 mol.kg^{-1} Ciprofloxacin + Water + L-Alanine						
$\varphi_k \times 10^{14}$/m^3.mol^{-1}.Pa^{-1}						
m/mol.kg^{-1}	293.15K	298.15K	303.15K	308.15K	313.15K	318.15K
0.1	-2.7184	-2.4889	-2.3205	-2.1043	-1.8419	-1.5290
0.2	-2.5642	-2.3468	-2.1462	-1.9484	-1.7274	-1.4447
0.3	-2.4538	-2.2303	-2.0381	-1.8556	-1.6396	-1.3422
0.4	-2.3557	-2.1506	-1.9643	-1.7524	-1.5309	-1.2482
0.5	-2.2734	-2.0891	-1.8770	-1.6427	-1.4350	-1.1479

Table 4.53: Apparent molar adiabatic compressibility (φ_k) of L-alanine in aqueous solution of ciprofloxacin (0.06 mol.kg^{-1}) as a function of molality (m/mol.kg^{-1}) at different temperature

0.06 mol.kg^{-1} Ciprofloxacin + Water + L-Alanine						
$\varphi_k \times 10^{14}$/m^3.mol^{-1}.Pa^{-1}						
m/mol.kg^{-1}	293.15K	298.15K	303.15K	308.15K	313.15K	318.15K
0.1	-2.7881	-2.5716	-2.3275	-2.1140	-1.8945	-1.7493
0.2	-2.6841	-2.4708	-2.2220	-2.0261	-1.8251	-1.6734
0.3	-2.5813	-2.3753	-2.1261	-1.9545	-1.7636	-1.6117
0.4	-2.4811	-2.2746	-2.0639	-1.8931	-1.7265	-1.5584
0.5	-2.3992	-2.1773	-1.9885	-1.8577	-1.6739	-1.4853

Table 4.54: Apparent molar adiabatic compressibility (φ_k) of Glycine in aqueous solution of ciprofloxacin (0.03 mol.kg^{-1}) as a function of molality (m/mol.kg^{-1}) at different temperature

0.03 mol.kg^{-1} Ciprofloxacin + Water + Glycine						
$\varphi_k \times 10^{14}$/m^3.mol^{-1}.Pa^{-1}						
m/mol.kg^{-1}	293.15K	298.15K	303.15K	308.15K	313.15K	318.15K
0.1	-3.0257	-2.9058	-2.7664	-2.6413	-2.4480	-2.3373
0.2	-2.9513	-2.8311	-2.6986	-2.5717	-2.3961	-2.2835
0.3	-2.8830	-2.7661	-2.6278	-2.5051	-2.3426	-2.2299
0.4	-2.8106	-2.6979	-2.5540	-2.4276	-2.2963	-2.1825
0.5	-2.7484	-2.6159	-2.4862	-2.3645	-2.2391	-2.1154

Table 4.55: Apparent molar adiabatic compressibility (φ_k) of Glycine in aqueous solution of ciprofloxacin (0.045mol.kg^{-1}) as a function of molality (m/mol.kg^{-1}) at different temperature

0.045 mol.kg^{-1} Ciprofloxacin + Water + Glycine						
$\varphi_k \times 10^{14}$/m^3.mol^{-1}.Pa^{-1}						
m/mol.kg^{-1}	293.15K	298.15K	303.15K	308.15K	313.15K	318.15K
0.1	-2.6017	-2.4446	-2.2660	-2.1299	-2.0594	-1.9082
0.2	-2.5773	-2.3932	-2.2308	-2.0968	-2.0186	-1.8795
0.3	-2.5417	-2.3623	-2.1918	-2.0736	-1.9816	-1.8520
0.4	-2.5021	-2.3406	-2.1509	-2.0462	-1.9618	-1.8235
0.5	-2.4644	-2.2932	-2.1270	-2.0256	-1.9188	-1.7867

Table 4.56: Apparent molar adiabatic compressibility (φ_k) of Glycine in aqueous solution of ciprofloxacin (0.06 mol.kg^{-1}) as a function of molality (m/mol.kg^{-1}) at different temperature

0.06 mol.kg^{-1} Ciprofloxacin + Water + Glycine						
$\varphi_k \times 10^{14}$/m^3.mol^{-1}.Pa^{-1}						
m/mol.kg^{-1}	293.15K	298.15K	303.15K	308.15K	313.15K	318.15K
0.1	-2.6821	-2.5113	-2.3778	-2.2277	-2.1402	-1.9845
0.2	-2.6129	-2.4424	-2.3065	-2.1513	-2.0681	-1.9199
0.3	-2.5466	-2.3721	-2.2357	-2.0880	-1.9771	-1.8404
0.4	-2.4865	-2.3041	-2.1672	-2.0127	-1.9028	-1.7739
0.5	-2.4102	-2.2397	-2.0934	-1.9445	-1.8313	-1.7062

Table 4.57: Limiting apparent molar adiabatic compressibility (φ_k^0), experimental slope (S_k) of L-alanine + water system at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively

Only water + L-Alanine		
Temp (K)	$\varphi_k^0 \times 10^{14}$ (m^3.mol^{-1}.Pa^{-1})	$S_k \times 10^{14}$ (m^3.mol^{-1}.kg)
293.15K	-2.7313	1.041
298.15K	-2.5077	1.002
303.15K	-2.3143	0.9931
308.15K	-2.1629	0.9654
313.15K	-1.9901	0.9869
318.15K	-1.7796	0.8868

Table 4.58: Limiting apparent molar adiabatic compressibility (φ_k^0), experimental slope (S_k) of Glycine + water system at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively

Only water + Glycine		
Temp (K)	$\varphi_k^0 \times 10^{14}$ ($m^3.mol^{-1}.Pa^{-1}$)	$S_k \times 10^{14}$ ($m^3.mol^{-1}.kg$)
293.15K	-2.883	0.5024
298.15K	-2.7153	0.5565
303.15K	-2.5426	0.5432
308.15K	-2.4071	0.4909
313.15K	-2.247	0.4833
318.15K	-2.1157	0.5348

Table 4.59: Limiting apparent molar adiabatic compressibility (φ_k^0), experimental slope (S_k) and transfer compressibility ($\Delta_{tr}\varphi_k^0$) of water + L-alanine + 0.03 $mol.kg^{-1}$ ciprofloxacin system at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively

0.03 $mol.kg^{-1}$ Ciprofloxacin + Water + L-Alanine			
Temp (K)	$\varphi_k^0 \times 10^{14}$ ($m^3.mol^{-1}.Pa^{-1}$)	$S_k \times 10^{14}$ ($m^3.mol^{-1}.kg$)	$\Delta K^0_{\varphi,s(Tr)} \times 10^{14}$
293.15K	-2.881	0.9808	-0.1497
298.15K	-2.6693	0.9848	-0.1617
303.15K	-2.3964	0.836	-0.0821
308.15K	-2.1628	0.6456	0.0002
313.15K	-1.9387	0.5399	0.0514
318.15K	-1.8085	0.643	-0.0289

Table 4.60: Limiting apparent molar adiabatic compressibility (φ_k^0), experimental slope (S_k) and transfer compressibility ($\Delta_{tr}\varphi_k^0$) of water + L-alanine + 0.045 $mol.kg^{-1}$ ciprofloxacin system at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively

0.045 $mol.kg^{-1}$ Ciprofloxacin + Water + L-Alanine			
Temp (K)	$\varphi_k^0 \times 10^{14}$ ($m^3.mol^{-1}.Pa^{-1}$)	$S_k \times 10^{14}$ ($m^3.mol^{-1}.kg$)	$\Delta K^0_{\varphi,s(Tr)} \times 10^{14}$
293.15K	-2.8026	1.0984	-0.0713
298.15K	-2.5599	0.9958	-0.0522
303.15K	-2.3899	1.0688	-0.0756
308.15K	-2.1965	1.1192	-0.0335
313.15K	-1.938	1.0103	0.0521
318.15K	-1.63	0.9588	0.1496

Table 4.61: Limiting apparent molar adiabatic compressibility (φ_k^0), experimental slope (S_k) and transfer compressibility ($\Delta_{tr}\varphi_k^0$) of water + L-alanine + 0.06 mol.kg^{-1} ciprofloxacin system at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively

0.045 mol.kg^{-1} Ciprofloxacin + Water + L-Alanine			
Temp (K)	$\varphi_k^0 \times 10^{14}$ ($m^3.mol^{-1}.Pa^{-1}$)	$S_k \times 10^{14}$ ($m^3.mol^{-1}.kg$)	$\Delta K^0_{\varphi,s(Tr)} \times 10^{14}$
293.15K	-2.881	0.9808	-0.1497
298.15K	-2.6693	0.9848	-0.1617
303.15K	-2.3964	0.8360	-0.0821
308.15K	-2.1628	0.6456	0.0002
313.15K	-1.9387	0.5399	0.0514
318.15K	-1.8085	0.6430	-0.0289

Table 4.62: Limiting apparent molar adiabatic compressibility (φ_k^0), experimental slope (S_k) and transfer compressibility ($\Delta_{tr}\varphi_k^0$) of water + Glycine + 0.03 mol.kg^{-1} ciprofloxacin system at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively

0.03 mol.kg^{-1} Ciprofloxacin + Water + Glycine			
Temp (K)	$\varphi_k^0 \times 10^{14}$ ($m^3.mol^{-1}.Pa^{-1}$)	$S_k \times 10^{14}$ ($m^3.mol^{-1}.kg$)	$\Delta K^0_{\varphi,s(Tr)} \times 10^{14}$
293.15K	-3.0924	0.6953	-0.2094
298.15K	-2.9772	0.7130	-0.2619
303.15K	-2.8381	0.7050	-0.2955
308.15K	-2.7113	0.6977	-0.3042
313.15K	-2.4997	0.5177	-0.2527
318.15K	-2.3932	0.5448	-0.2775

Table 4.63: Limiting apparent molar adiabatic compressibility (φ_k^0), experimental slope (S_k) and transfer compressibility ($\Delta_{tr}\varphi_k^0$) of water + Glycine + 0.045 mol.kg^{-1} ciprofloxacin system at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively

0.045 mol.kg^{-1} Ciprofloxacin + Water + Glycine			
Temp (K)	$\varphi_k^0 \times 10^{14}$ ($m^3.mol^{-1}.Pa^{-1}$)	$S_k \times 10^{14}$ ($m^3.mol^{-1}.kg$)	$\Delta K^0_{\varphi,s(Tr)} \times 10^{14}$
293.15K	-2.6424	0.3499	0.2406
298.15K	-2.4734	0.3554	0.2099
303.15K	-2.3007	0.3581	0.2259
308.15K	-2.1522	0.2592	0.2229
313.15K	-2.0894	0.3380	0.1536
318.15K	-1.9397	0.2990	0.1634

Table 4.64: Limiting apparent molar adiabatic compressibility (φ_k^0), experimental slope (S_k) and transfer compressibility ($\Delta_{tr}\varphi_k^0$) of water + Glycine + 0.06 mol.kg^{-1} ciprofloxacin system at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively

0.06 mol.kg^{-1} Ciprofloxacin + Water + Glycine			
Temp (K)	$\varphi_k^0 \times 10^{14}$ ($m^3.mol^{-1}.Pa^{-1}$)	$S_k \times 10^{14}$ ($m^3.mol^{-1}.kg$)	$\Delta K^0_{\varphi,s(Tr)} \times 10^{14}$
293.15K	-2.7487	0.6702	0.1343
298.15K	-2.5784	0.6815	0.137
303.15K	-2.4486	0.7082	0.094
308.15K	-2.2963	0.7049	0.1108
313.15K	-2.2188	0.7831	0.0282
318.15K	-2.0558	0.7026	0.0599

Table 4.65: Acoustic impedance ($Z \times 10^{-6}$/kg.m^{-2}.s^{-1}) of aqueous L-alanine as a function of molality (m/mol.kg^{-1}) at different temperature

L-alanine+Water						
m/mol.kg^{-1}	293.15K	298.15K	303.15K	308.15K	313.15K	318.15K
0.0	1.4804	1.4925	1.5026	1.5108	1.5170	1.5215
0.1	1.4913	1.5032	1.5131	1.5211	1.5271	1.5305
0.2	1.5023	1.5138	1.5235	1.5313	1.5371	1.5406
0.3	1.5126	1.5240	1.5335	1.5411	1.5467	1.5503
0.4	1.5235	1.5347	1.5440	1.5513	1.5568	1.5599
0.5	1.5340	1.5449	1.5539	1.5611	1.5664	1.5700

Table 4.66: Acoustic impedance ($Z \times 10^{-6}$/kg.m^{-2}.s^{-1}) of aqueous Glycine as a function of molality (m/mol.kg^{-1}) at different temperature

Glycine+Water						
m/mol.kg^{-1}	293.15K	298.15K	303.15K	308.15K	313.15K	318.15K
0.0	1.4804	1.4925	1.5026	1.5108	1.5170	1.5215
0.1	1.4905	1.5025	1.5125	1.5204	1.5265	1.5325
0.2	1.5007	1.5125	1.5223	1.5302	1.5361	1.5418
0.3	1.5105	1.5221	1.5318	1.5396	1.5454	1.5511
0.4	1.5204	1.5319	1.5406	1.5491	1.5545	1.5603
0.5	1.5301	1.5413	1.5507	1.5581	1.5637	1.5692

Table 4.67: Acoustic impedance ($Z\times10^{-6}$/kg.m^{-2}.s^{-1}) of L-alanine in aqueous solution of ciprofloxacin (0.03 mol.kg^{-1}) as a function of molality (m/mol.kg^{-1}) at different temperature

0.03 mol.kg^{-1} Ciprofloxacin + L-Alanine + Water						
m/mol.kg^{-1}	293.15K	298.15K	303.15K	308.15K	313.15K	318.15K
0.0	1.4889	1.5008	1.5108	1.5187	1.5248	1.5290
0.1	1.4998	1.5115	1.5212	1.5289	1.5345	1.5387
0.2	1.5113	1.5223	1.5316	1.5393	1.5446	1.5482
0.3	1.5215	1.5326	1.5418	1.5494	1.5546	1.5579
0.4	1.5319	1.5428	1.5518	1.5592	1.5644	1.5675
0.5	1.5423	1.5530	1.5619	1.5691	1.5739	1.5764

Table 4.68: Acoustic impedance ($Z\times10^{-6}$/kg.m^{-2}.s^{-1}) of L-alanine in aqueous solution of ciprofloxacin (0.045mol.kg^{-1}) as a function of molality (m/mol.kg^{-1}) at different temperature

0.045 mol.kg^{-1} Ciprofloxacin+L-Alanine+Water						
m/mol.kg^{-1}	293.15K	298.15K	303.15K	308.15K	313.15K	318.15K
0.0	1.4931	1.5049	1.5148	1.5226	1.5288	1.5330
0.1	1.5043	1.5159	1.5255	1.5332	1.5390	1.5425
0.2	1.5147	1.5260	1.5354	1.5431	1.5486	1.5520
0.3	1.5255	1.5366	1.5457	1.5532	1.5585	1.5618
0.4	1.5360	1.5471	1.5561	1.5631	1.5683	1.5718
0.5	1.5476	1.5584	1.5673	1.5749	1.5799	1.5835

Table 4.69: Acoustic impedance ($Z\times10^{-6}$/kg.m^{-2}.s^{-1}) of L-alanine in aqueous solution of ciprofloxacin (0.06 mol.kg^{-1}) as a function of molality (m/mol.kg^{-1}) at different temperature

0.06 mol.kg^{-1} Ciprofloxacin+L-Alanine+Water						
m/mol.kg^{-1}	293.15K	298.15K	303.15K	308.15K	313.15K	318.15K
0.0	1.4973	1.5090	1.5188	1.5268	1.5327	1.5367
0.1	1.5081	1.5196	1.5294	1.5368	1.5423	1.5464
0.2	1.5190	1.5305	1.5398	1.5472	1.5526	1.5564
0.3	1.5297	1.5409	1.5500	1.5572	1.5625	1.5661
0.4	1.5399	1.5507	1.5598	1.5668	1.5717	1.5753
0.5	1.5500	1.5605	1.5692	1.5760	1.5809	1.5844

Table 4.70: Acoustic impedance ($Z\times10^{-6}$/kg.m^{-2}.s^{-1}) of Glycine in aqueous solution of ciprofloxacin (0.03 mol.kg^{-1}) as a function of molality (m/mol.kg^{-1}) at different temperature

0.03 mol.kg^{-1} Ciprofloxacin+Glycine+Water						
m/mol.kg^{-1}	293.15K	298.15K	303.15K	308.15K	313.15K	318.15K
0.0	1.4889	1.5008	1.5108	1.5187	1.5248	1.5290
0.1	1.4991	1.5109	1.5207	1.5285	1.5344	1.5388
0.2	1.5115	1.5230	1.5326	1.5404	1.5460	1.5500
0.3	1.5243	1.5357	1.5451	1.5525	1.5581	1.5619
0.4	1.5356	1.5469	1.5561	1.5634	1.5685	1.5723
0.5	1.5466	1.5577	1.5668	1.5739	1.5792	1.5828

Table 4.71: Acoustic impedance ($Z\times10^{-6}$/kg.m^{-2}.s^{-1}) of Glycine in aqueous solution of ciprofloxacin (0.045mol.kg^{-1}) as a function of molality (m/mol.kg^{-1}) at different temperature

0.045 mol.kg^{-1} Ciprofloxacin+Glycine+Water						
m/mol.kg^{-1}	293.15K	298.15K	303.15K	308.15K	313.15K	318.15K
0.0	1.4931	1.5049	1.5148	1.5226	1.5288	1.5330
0.1	1.5029	1.5146	1.5244	1.5321	1.5376	1.5415
0.2	1.5126	1.5241	1.5337	1.5413	1.5470	1.5509
0.3	1.5225	1.5338	1.5432	1.5507	1.5562	1.5599
0.4	1.5325	1.5438	1.5530	1.5601	1.5657	1.5694
0.5	1.5422	1.5532	1.5623	1.5694	1.5748	1.5785

Table 4.72: Acoustic impedance ($Z\times10^{-6}$/kg.m^{-2}.s^{-1}) of Glycine in aqueous solution of ciprofloxacin (0.06 mol.kg^{-1}) as a function of molality (m/mol.kg^{-1}) at different temperature

0.06 mol.kg^{-1} Ciprofloxacin+Glycine+Water						
m/mol.kg^{-1}	293.15K	298.15K	303.15K	308.15K	313.15K	318.15K
0.0	1.4973	1.5090	1.5188	1.5268	1.5327	1.5367
0.1	1.5073	1.5188	1.5284	1.5361	1.5418	1.5457
0.2	1.5172	1.5286	1.5380	1.5455	1.5511	1.5553
0.3	1.5269	1.5380	1.5473	1.5547	1.5601	1.5638
0.4	1.5368	1.5479	1.5571	1.5643	1.5693	1.5731
0.5	1.5461	1.5570	1.5660	1.5731	1.5782	1.5818

Table 4.73: Relative association (R_A) of aqueous L-alanine as a function of molality (m/mol.kg^{-1}) at different temperature

L-Alanine+Water						
m/mol.kg^{-1}	293.15K	298.15K	303.15K	308.15K	313.15K	318.15K
0.0	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
0.1	0.9984	0.9986	0.9987	0.9988	0.9989	0.9991
0.2	0.9967	0.9971	0.9974	0.9977	0.9979	0.9982
0.3	0.9952	0.9957	0.9961	0.9966	0.9969	0.9973
0.4	0.9936	0.9943	0.9949	0.9954	0.9959	0.9964
0.5	0.9920	0.9928	0.9936	0.9943	0.9949	0.9957

Table 4.74: Relative association (R_A) of aqueous Glycine as a function of molality (m/mol.kg^{-1}) at different temperature

Glycine+Water						
m/mol.kg^{-1}	293.15K	298.15K	303.15K	308.15K	313.15K	318.15K
0.0	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
0.1	0.9984	0.9986	0.9987	0.9988	0.9989	0.9991
0.2	0.9967	0.9971	0.9974	0.9977	0.9979	0.9982
0.3	0.9952	0.9957	0.9961	0.9966	0.9969	0.9973
0.4	0.9936	0.9943	0.9949	0.9954	0.9959	0.9964
0.5	0.9920	0.9928	0.9936	0.9943	0.9949	0.9957

Table 4.75: Relative association (R_A) of L-alanine in aqueous solution of ciprofloxacin (0.03 mol.kg^{-1}) as a function of molality (m/mol.kg^{-1}) at different temperature

0.03 mol.kg^{-1} Ciprofloxacin+L-Alanine+Water						
m/mol.kg^{-1}	293.15K	298.15K	303.15K	308.15K	313.15K	318.15K
0.0	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
0.1	0.998273	0.998484	0.998643	0.998785	0.998812	0.998914
0.2	0.996472	0.996778	0.997201	0.997501	0.997606	0.997734
0.3	0.994929	0.995546	0.996033	0.996301	0.996502	0.996747
0.4	0.993403	0.994124	0.994761	0.995173	0.995454	0.995782
0.5	0.991922	0.992773	0.993516	0.994012	0.994502	0.99487

Table 4.76: Relative association (R_A) of L-alanine in aqueous solution of ciprofloxacin (0.045mol.kg^{-1}) as a function of molality (m/mol.kg^{-1}) at different temperature

0.045 mol.kg^{-1} Ciprofloxacin+L-Alanine+Water						
m/mol.kg^{-1}	293.15K	298.15K	303.15K	308.15K	313.15K	318.15K
0.0	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
0.1	0.9982	0.9983	0.9985	0.9986	0.9989	0.9991
0.2	0.9967	0.9970	0.9973	0.9975	0.9979	0.9981
0.3	0.9951	0.9956	0.9961	0.9963	0.9968	0.9970
0.4	0.9935	0.9942	0.9948	0.9952	0.9958	0.9960
0.5	0.9919	0.9929	0.9937	0.9941	0.9949	0.9951

Table 4.77: Relative association (R_A) of L-alanine in aqueous solution of ciprofloxacin (0.06 mol.kg^{-1}) as a function of molality (m/mol.kg^{-1}) at different temperature

0.06 mol.kg^{-1} Ciprofloxacin+L-Alanine+Water						
m/mol.kg^{-1}	293.15K	298.15K	303.15K	308.15K	313.15K	318.15K
0.0	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
0.1	0.9984	0.9986	0.9986	0.9988	0.9989	0.9991
0.2	0.9968	0.9969	0.9972	0.9977	0.9980	0.9983
0.3	0.9950	0.9954	0.9958	0.9964	0.9968	0.9972
0.4	0.9935	0.9942	0.9946	0.9954	0.9958	0.9964
0.5	0.9920	0.9928	0.9936	0.9944	0.9950	0.9957

Table 4.78: Relative association (R_A) of Glycine in aqueous solution of ciprofloxacin (0.03 mol.kg^{-1}) as a function of molality (m/mol.kg^{-1}) at different temperature

0.03 mol.kg^{-1} Ciprofloxacin+Glycine+Water						
m/mol.kg^{-1}	293.15K	298.15K	303.15K	308.15K	313.15K	318.15K
0.0	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
0.1	0.9983	0.9985	0.9986	0.9988	0.9988	0.9989
0.2	0.9965	0.9968	0.9972	0.9975	0.9976	0.9977
0.3	0.9949	0.9955	0.9960	0.9963	0.9965	0.9967
0.4	0.9934	0.9941	0.9948	0.9952	0.9955	0.9958
0.5	0.9919	0.9928	0.9935	0.9940	0.9945	0.9949

Table 4.79: Relative association (R_A) of Glycine in aqueous solution of ciprofloxacin (0.045mol.kg^{-1}) as a function of molality (m/mol.kg^{-1}) at different temperature

0.045 mol.kg^{-1} Ciprofloxacin+Glycine+Water						
m/mol.kg^{-1}	293.15K	298.15K	303.15K	308.15K	313.15K	318.15K
0.0	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
0.1	0.9984	0.9986	0.9986	0.9987	0.9988	0.9989
0.2	0.9966	0.9968	0.9972	0.9975	0.9976	0.9977
0.3	0.9959	0.9955	0.9960	0.9963	0.9965	0.9967
0.4	0.9934	0.9941	0.9948	0.9952	0.9955	0.9958
0.5	0.9919	0.9929	0.9936	0.9941	0.9946	0.9950

Table 4.80: Relative association (R_A) of Glycine in aqueous solution of ciprofloxacin (0.06mol.kg^{-1}) as a function of molality (m/mol.kg^{-1}) at different temperature

0.06 mol.kg^{-1} Ciprofloxacin+Glycine+Water						
m/mol.kg^{-1}	293.15K	298.15K	303.15K	308.15K	313.15K	318.15K
0.0	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
0.1	0.9985	0.9985	0.9986	0.9986	0.9987	0.9989
0.2	0.9967	0.9968	0.9972	0.9975	0.9976	0.9977
0.3	0.9960	0.9955	0.9960	0.9963	0.9965	0.9967
0.4	0.9935	0.9941	0.9948	0.9952	0.9955	0.9958
0.5	0.9920	0.9928	0.9938	0.9942	0.9946	0.9951

Table 4.81: Hydration number (n_H) of aqueous L-alanine as a function of molality (m/mol.kg^{-1}) at different temperature

Only water + L-Alanine						
m/mol.kg^{-1}	293.15K	298.15K	303.15K	308.15K	313.15K	318.15K
0.1	6.52	6.30	6.11	5.86	5.56	5.24
0.2	6.41	6.21	6.01	5.75	5.42	5.11
0.3	6.32	6.10	5.92	5.66	5.33	4.94
0.4	6.22	6.01	5.82	5.55	5.23	4.79
0.5	6.11	5.91	5.72	5.41	5.11	4.70

Table 4.82: Hydration number (n_H) of aqueous Glycine as a function of molality (m/mol.kg^{-1}) at different temperature

Only water + Glycine						
m/mol.kg^{-1}	293.15K	298.15K	303.15K	308.15K	313.15K	318.15K
0.1	5.78	5.60	5.47	5.34	5.23	6.01
0.2	5.73	5.57	5.41	5.31	5.19	5.95
0.3	5.63	5.47	5.33	5.21	5.11	5.87
0.4	5.57	5.41	5.24	5.16	5.02	5.80
0.5	5.48	5.32	5.18	5.06	4.98	5.73

Table 4.83: Hydration number (n_H) of L-alanine in aqueous solution of ciprofloxacin (0.03 mol.kg^{-1}) as a function of molality (m/mol.kg^{-1}) at different temperature

0.03 mol.kg^{-1} Ciprofloxacin + Water + L-Alanine						
m/mol.kg^{-1}	293.15K	298.15K	303.15K	308.15K	313.15K	318.15K
0.1	6.44	6.28	6.10	5.84	5.52	5.22
0.2	6.36	6.20	6.01	5.78	5.48	5.15
0.3	6.25	6.11	5.90	5.66	5.41	5.06
0.4	6.15	6.01	5.81	5.59	5.34	4.96
0.5	6.03	5.92	5.73	5.54	5.27	4.87

Table 4.84: Hydration number (n_H) of L-alanine in aqueous solution of ciprofloxacin (0.045 mol.kg^{-1}) as a function of molality (m/mol.kg^{-1}) at different temperature

0.045 mol.kg^{-1} Ciprofloxacin + Water + L-Alanine						
m/mol.kg^{-1}	293.15K	298.15K	303.15K	308.15K	313.15K	318.15K
0.1	6.30	6.21	6.11	6.04	5.94	5.87
0.2	6.20	6.15	6.01	5.93	5.84	5.78
0.3	6.10	6.07	5.92	5.83	5.74	5.68
0.4	5.78	6.00	5.85	5.74	5.63	5.58
0.5	5.65	5.91	5.78	5.63	5.53	5.47

Table 4.85: Hydration number (n_H) of L-alanine in aqueous solution of ciprofloxacin (0.06 $mol.kg^{-1}$) as a function of molality ($m/mol.kg^{-1}$) at different temperature

0.06 $mol.kg^{-1}$ Ciprofloxacin + Water + L-Alanine						
$m/mol.kg^{-1}$	293.15K	298.15K	303.15K	308.15K	313.15K	318.15K
0.1	6.24	6.20	6.05	5.86	5.59	5.45
0.2	6.16	6.16	5.96	5.78	5.53	5.41
0.3	6.06	6.06	5.85	5.71	5.50	5.37
0.4	5.97	5.96	5.75	5.59	5.43	5.30
0.5	5.86	5.85	5.66	5.49	5.33	5.21

Table 4.86: Hydration number (n_H) of Glycine in aqueous solution of ciprofloxacin (0.03 $mol.kg^{-1}$) as a function of molality ($m/mol.kg^{-1}$) at different temperature

0.03 $mol.kg^{-1}$ Ciprofloxacin + Water + Glycine						
$m/mol.kg^{-1}$	293.15K	298.15K	303.15K	308.15K	313.15K	318.15K
0.1	5.73	5.64	5.57	5.48	5.35	5.22
0.2	5.68	5.55	5.47	5.36	5.22	5.14
0.3	5.58	5.44	5.34	5.29	5.17	5.09
0.4	5.47	5.37	5.27	5.15	5.03	4.96
0.5	5.38	5.25	5.18	5.06	4.98	4.85

Table 4.87: Hydration number (n_H) of Glycine in aqueous solution of ciprofloxacin (0.045 $mol.kg^{-1}$) as a function of molality ($m/mol.kg^{-1}$) at different temperature

0.045 $mol.kg^{-1}$ Ciprofloxacin + Water + Glycine						
$m/mol.kg^{-1}$	293.15K	298.15K	303.15K	308.15K	313.15K	318.15K
0.1	5.65	5.47	5.33	5.10	4.96	4.83
0.2	5.57	5.41	5.28	5.05	4.94	4.78
0.3	5.51	5.34	5.20	5.01	4.90	4.72
0.4	5.44	5.29	5.15	4.95	4.84	4.68
0.5	5.35	5.20	5.06	4.91	4.80	4.66

Table 4.88: Hydration number (n_H) of Glycine in aqueous solution of ciprofloxacin (0.06 $mol.kg^{-1}$) as a function of molality ($m/mol.kg^{-1}$) at different temperature

0.06 $mol.kg^{-1}$ Ciprofloxacin + Water + Glycine						
$m/mol.kg^{-1}$	293.15K	298.15K	303.15K	308.15K	313.15K	318.15K
0.1	5.52	5.43	5.30	5.20	4.99	4.87
0.2	5.49	5.36	5.25	5.14	4.97	4.85
0.3	5.45	5.31	5.21	5.10	4.93	4.83
0.4	5.41	5.29	5.17	5.04	4.90	4.81
0.5	5.38	5.23	5.10	4.98	4.85	4.77

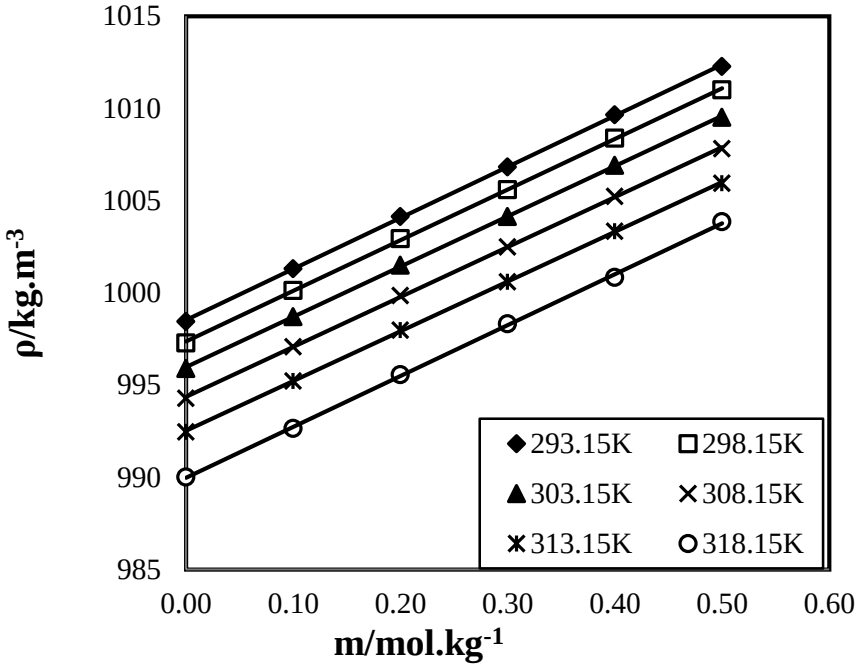


Figure 4.1: Plots of Density (ρ) vs. Molality (m) of L-alanine + water system at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively.

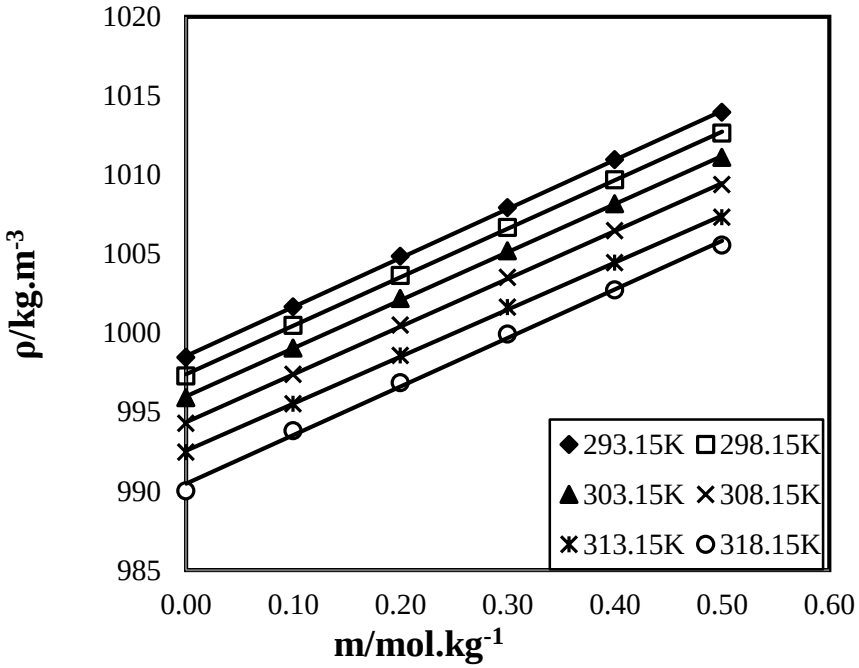


Figure 4.2: Plots of Density (ρ) vs. Molality (m) of Glycine + water system at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively.

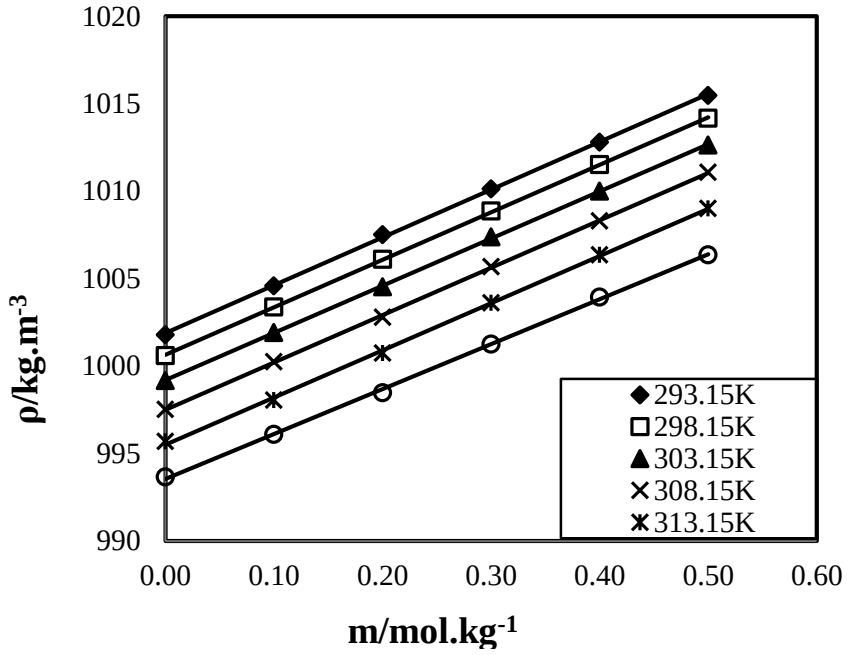


Figure 4.3: Plots of Density (ρ) vs. Molality (m) of water + L-alanine + 0.03 mol.kg^{-1} ciprofloxacin system at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively.

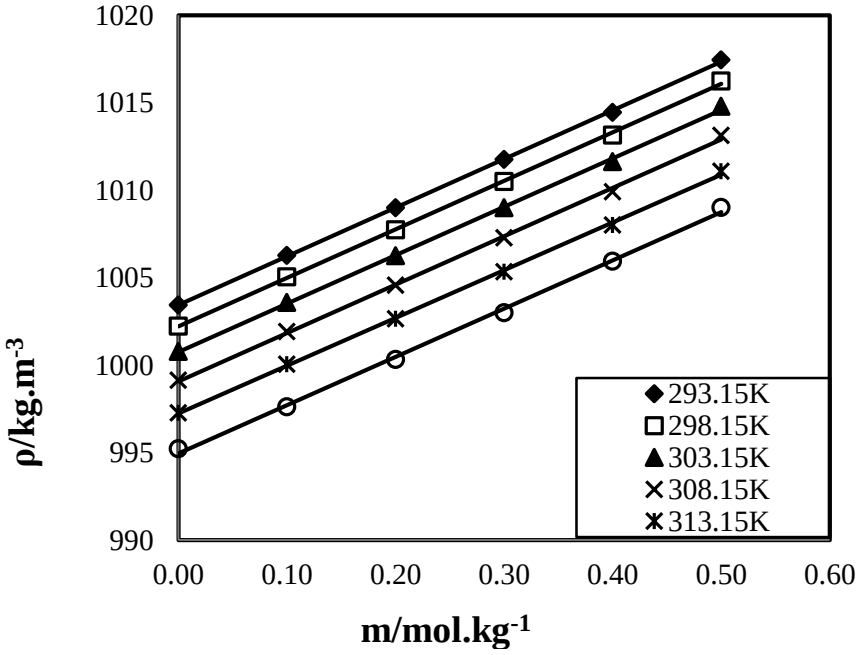


Figure 4.4: Plots of Density (ρ) vs. Molality (m) of water + L-alanine + 0.045 mol.kg^{-1} ciprofloxacin system at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively.

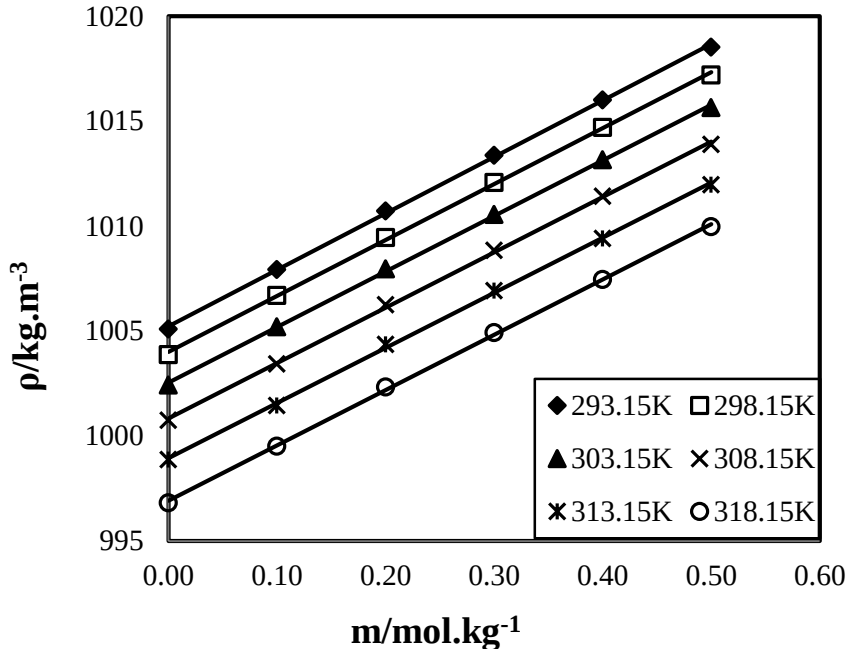


Figure 4.5: Plots of Density (ρ) vs. Molality (m) of water + L-alanine + 0.06 mol.kg^{-1} ciprofloxacin system at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively

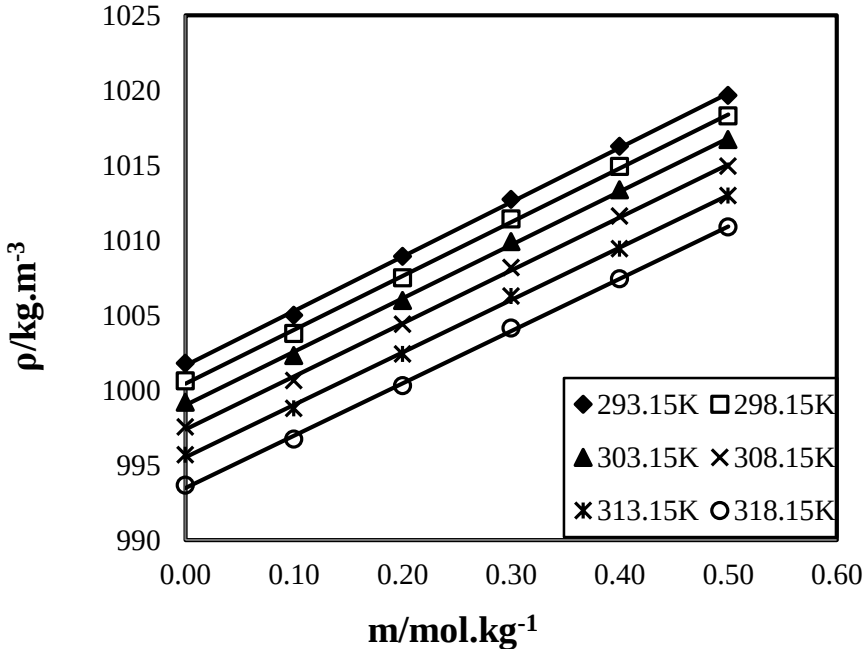


Figure 4.6: Plots of Density (ρ) vs. Molality (m) of water + Glycine + 0.03 mol.kg^{-1} ciprofloxacin system at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively.

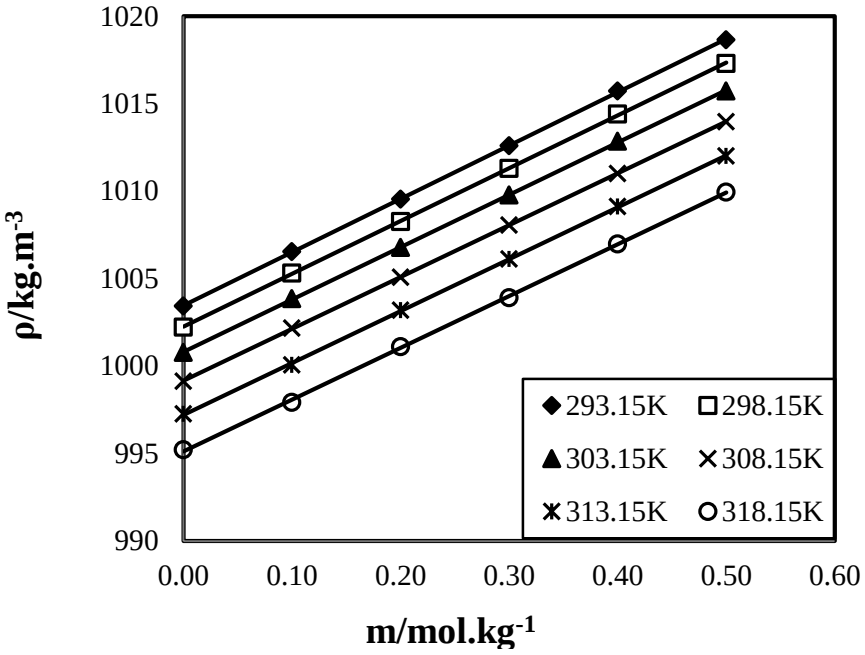


Figure 4.7: Plots of Density (ρ) vs. Molality (m) of water + Glycine + 0.045 mol.kg^{-1} ciprofloxacin system at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively.

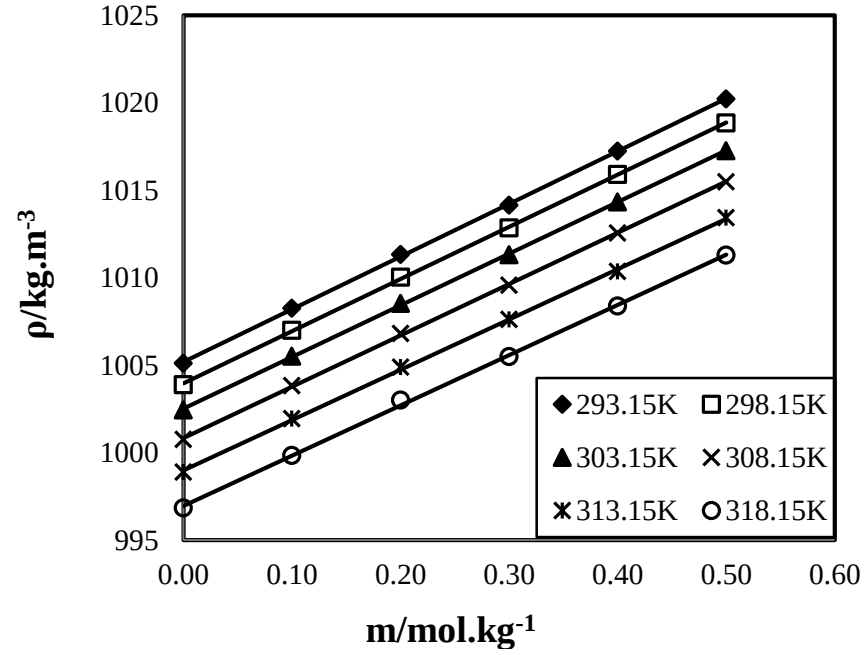


Figure 4.8: Plots of Density (ρ) vs. Molality (m) of water + Glycine + 0.06 mol.kg^{-1} ciprofloxacin system at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively.

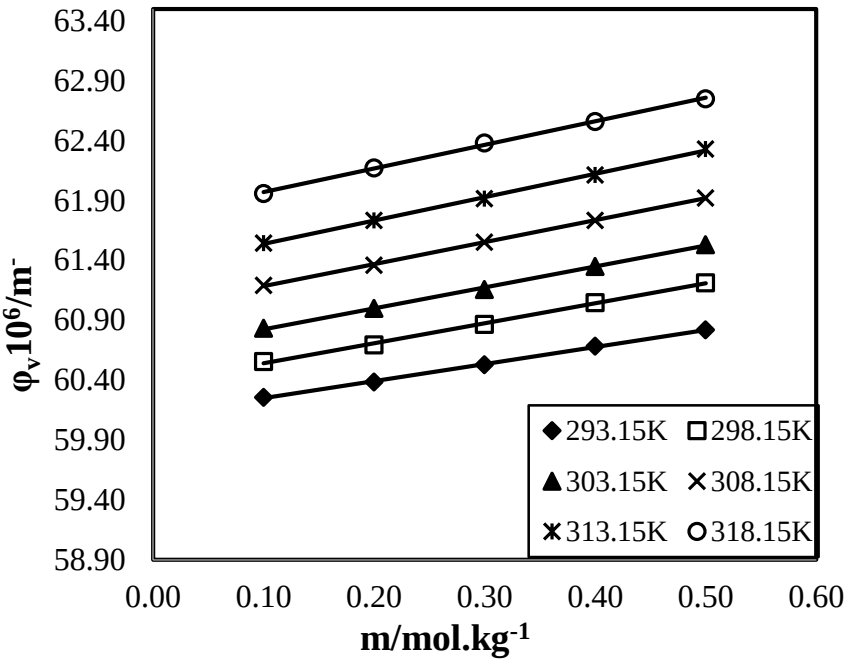


Figure 4.9: Plots of Apparent molar volume (ϕ_v) vs. Molality of water + L-alanine system at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively.

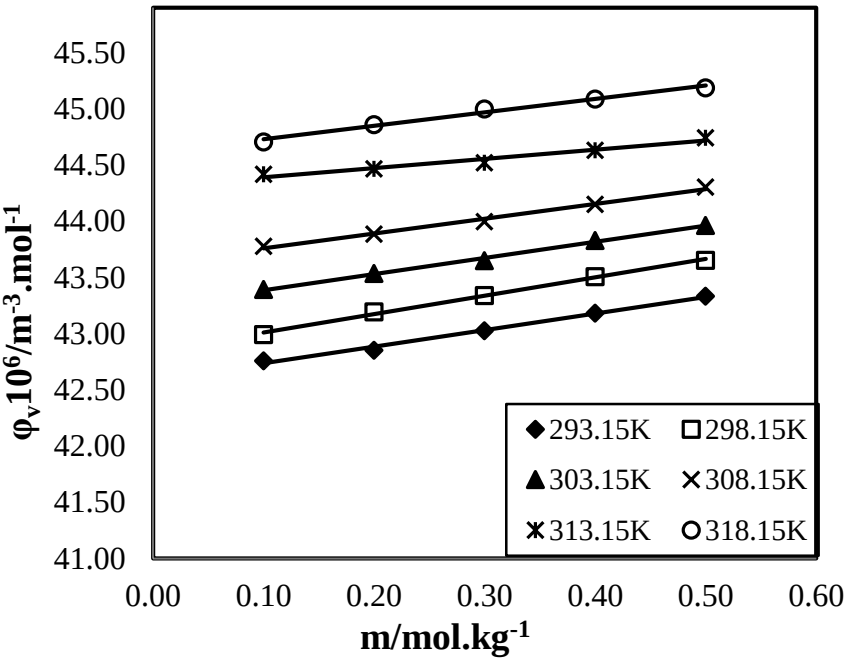


Figure 4.10: Plots of Apparent molar volume (ϕ_v) vs. Molality of water + Glycine systems at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively.

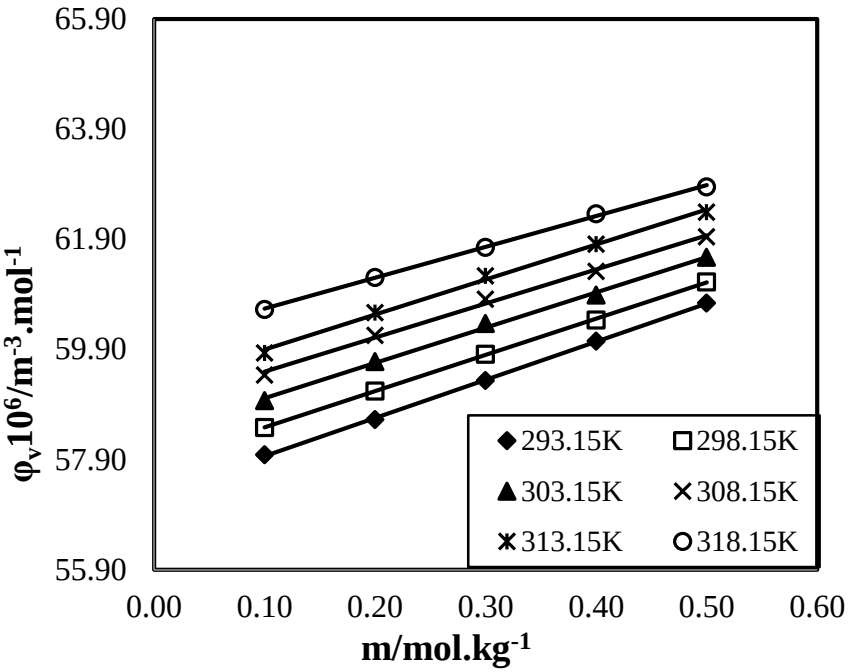


Figure 4.11: Plots of Apparent molar volume (ϕ_v) vs. Molality of water+L-alanine+0.03 mol.kg^{-1} ciprofloxacin system at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively.

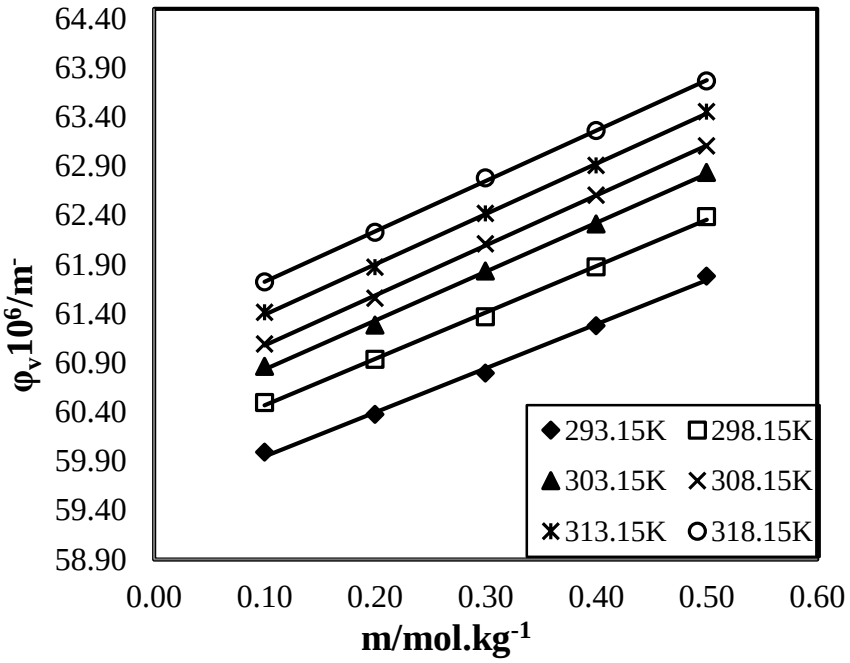


Figure 4.12: Plots of Apparent molar volume (ϕ_v) vs. Molality of water + L-alanine + 0.045 mol.kg^{-1} ciprofloxacin system at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively.

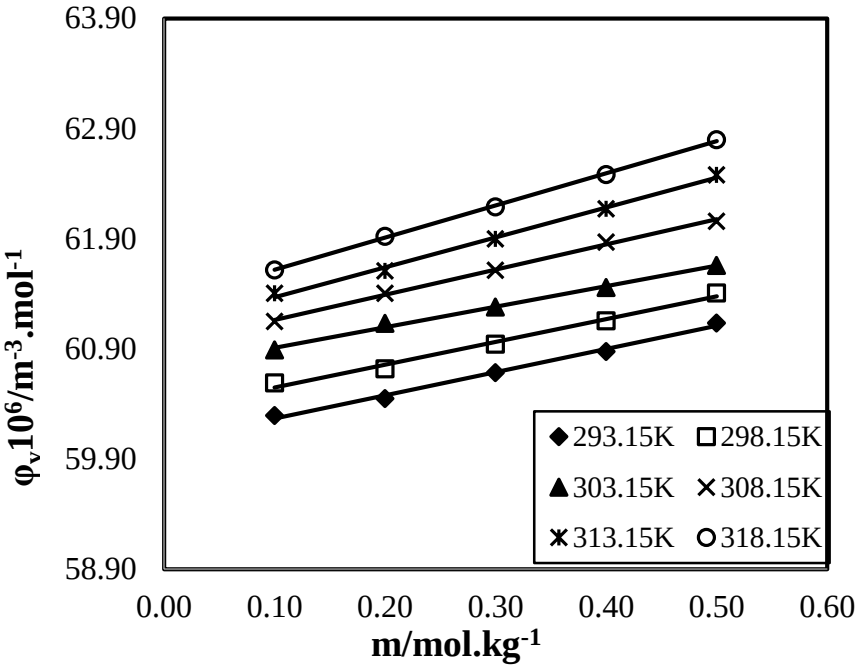


Figure 4.13: Plots of Apparent molar volume (ϕ_v) vs. Molality of water + L-alanine + 0.06 mol.kg^{-1} ciprofloxacin system at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively.

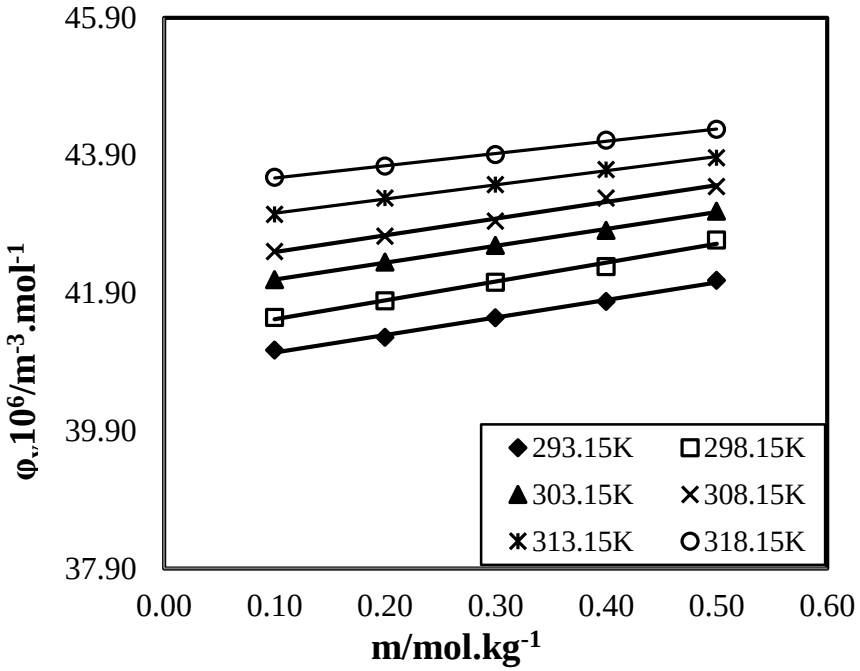


Figure 4.14: Plots of Apparent molar volume (ϕ_v) vs. Molality of water + Glycine + 0.03 mol.kg^{-1} ciprofloxacin systems at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively.

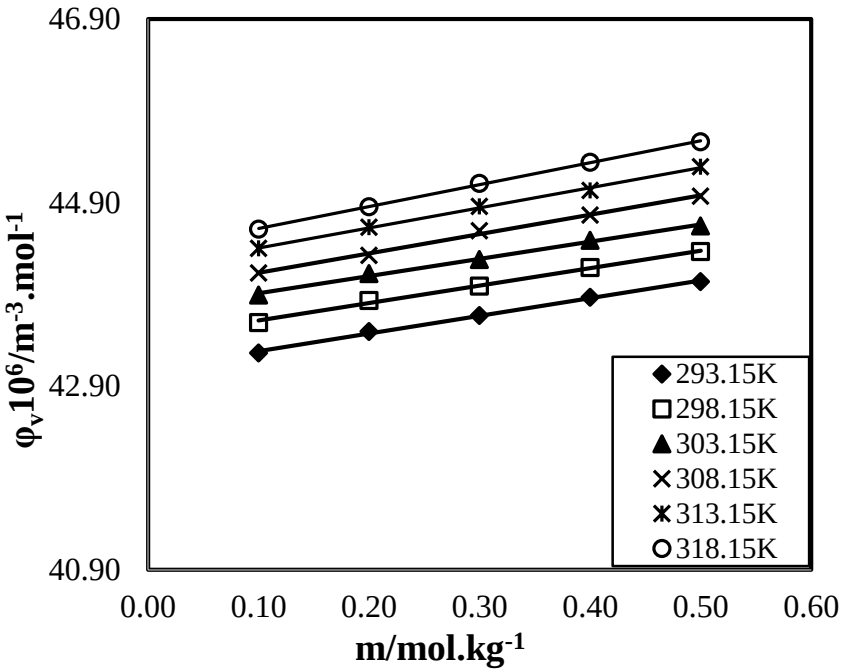


Figure 4.15: Plots of Apparent molar volume (ϕ_v) vs. Molality of water + Glycine + 0.045 mol.kg^{-1} ciprofloxacin systems at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively.

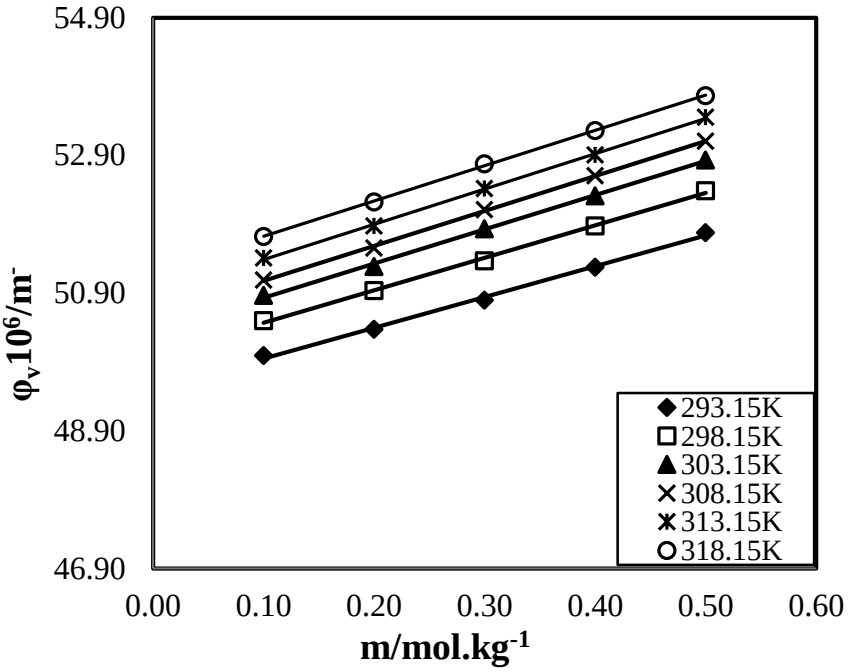


Figure 4.16: Plots of Apparent molar volume (ϕ_v) vs. Molality of water + Glycine + 0.06 mol.kg^{-1} ciprofloxacin systems at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively.

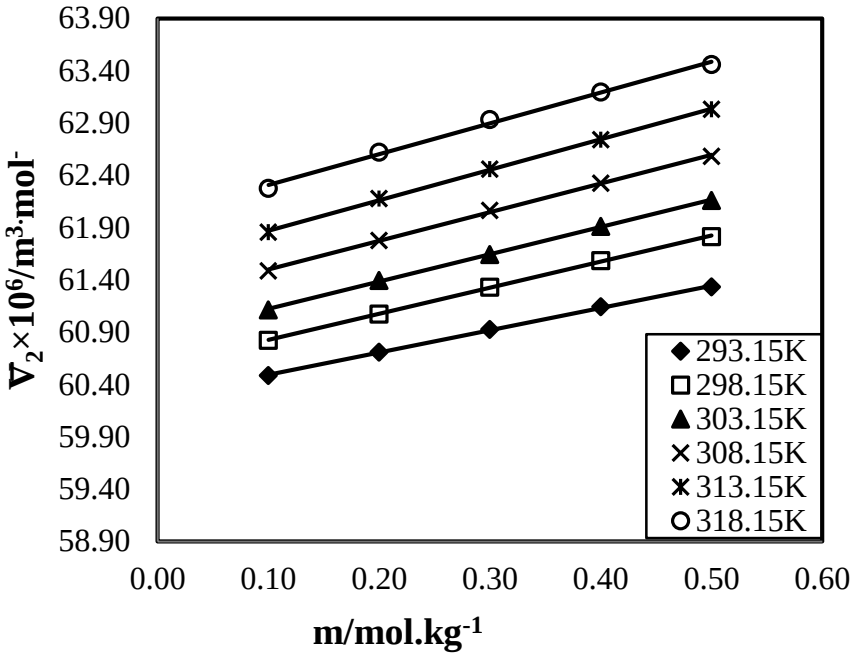


Figure 4.17: Plots of Partial molar volume ($\bar{V}_2$) vs. Molality of water + L-alanine system at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively.

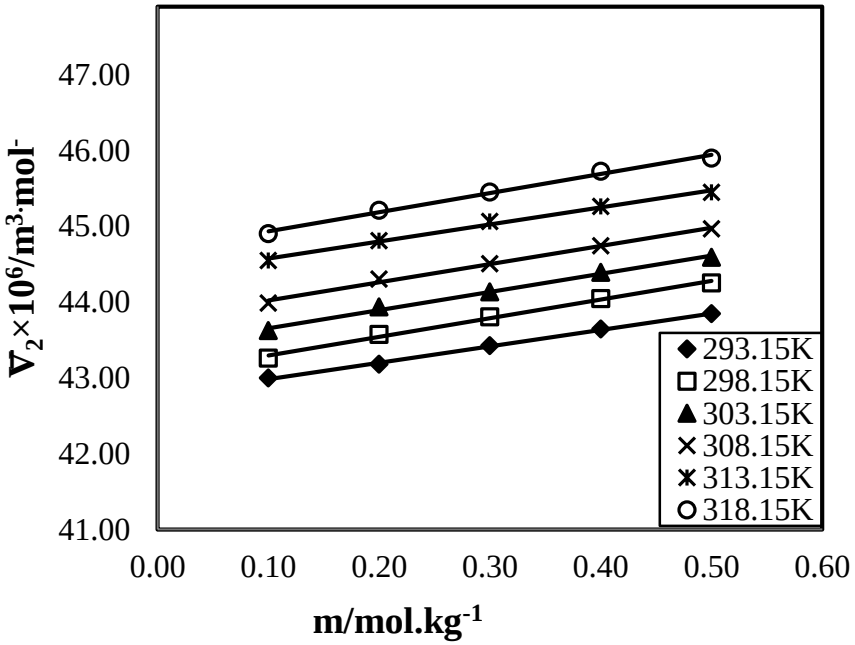


Figure 4.18: Plots of Partial molar volume ($\bar{V}_2$) vs. Molality of water + Glycine systems at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively.

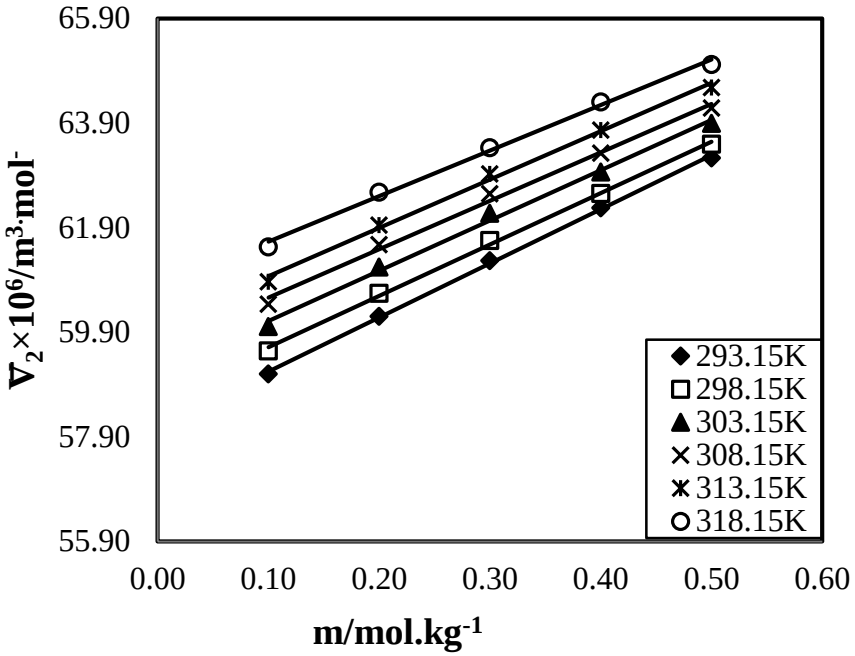


Figure 4.19: Plots of Partial molar volume ($\bar{V}_2$) vs. Molality of water + L-alanine + 0.03 mol.kg^{-1} ciprofloxacin system at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively.

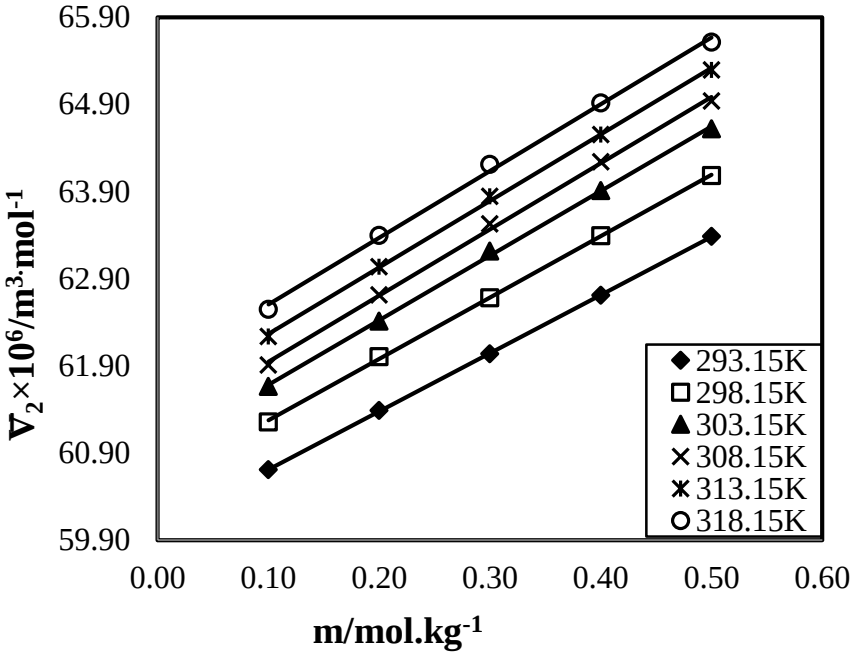


Figure 4.20: Plots of Partial molar volume ($\bar{V}_2$) vs. Molality of water + L-alanine + 0.045 mol.kg^{-1} ciprofloxacin system at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively.

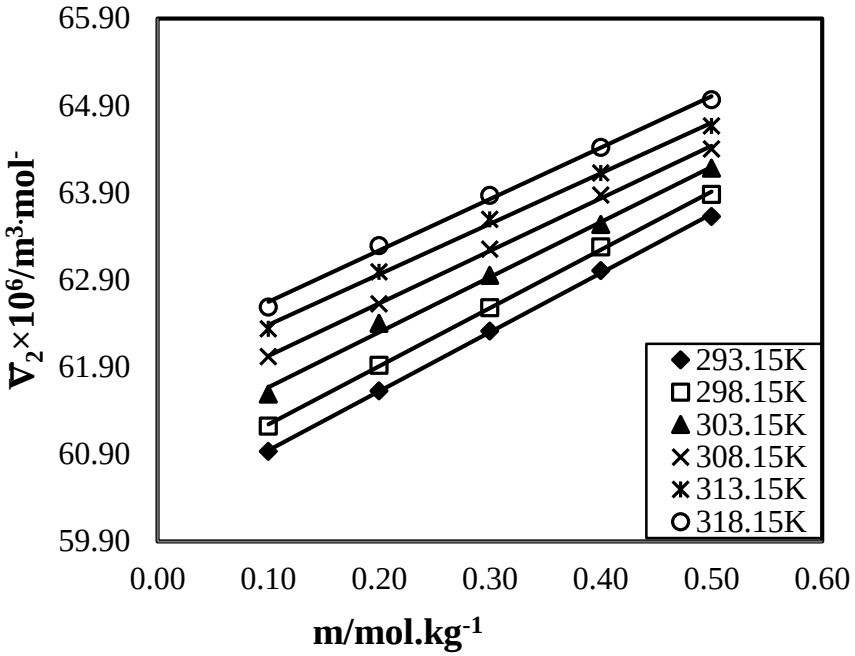


Figure 4.21: Plots of Partial molar volume ($\bar{V}_2$) vs. Molality of water + L-alanine + 0.06 mol.kg^{-1} ciprofloxacin system at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively.

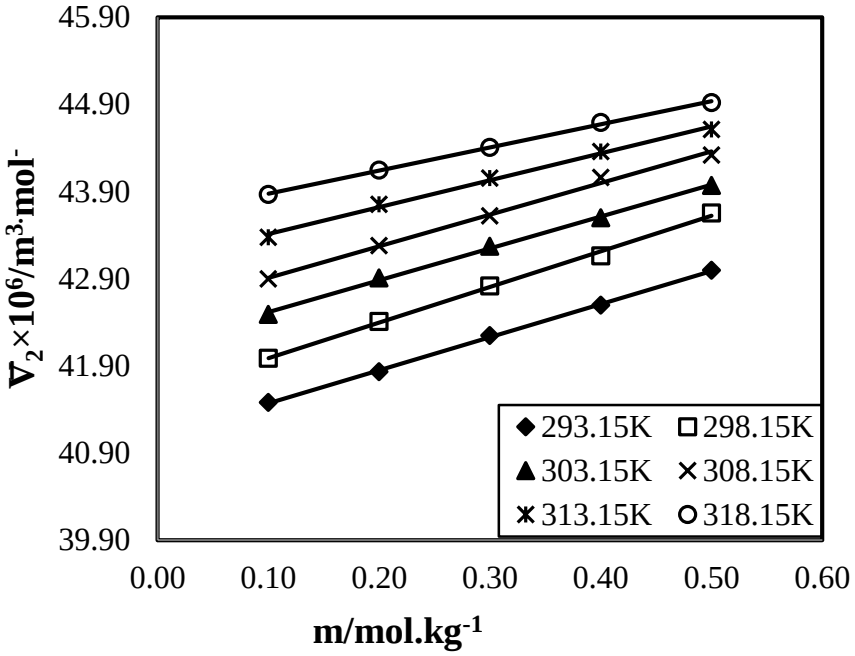


Figure 4.23: Plots of Partial molar volume ($\bar{V}_2$) vs. Molality of water + Glycine + 0.03 mol.kg^{-1} ciprofloxacin systems at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively.

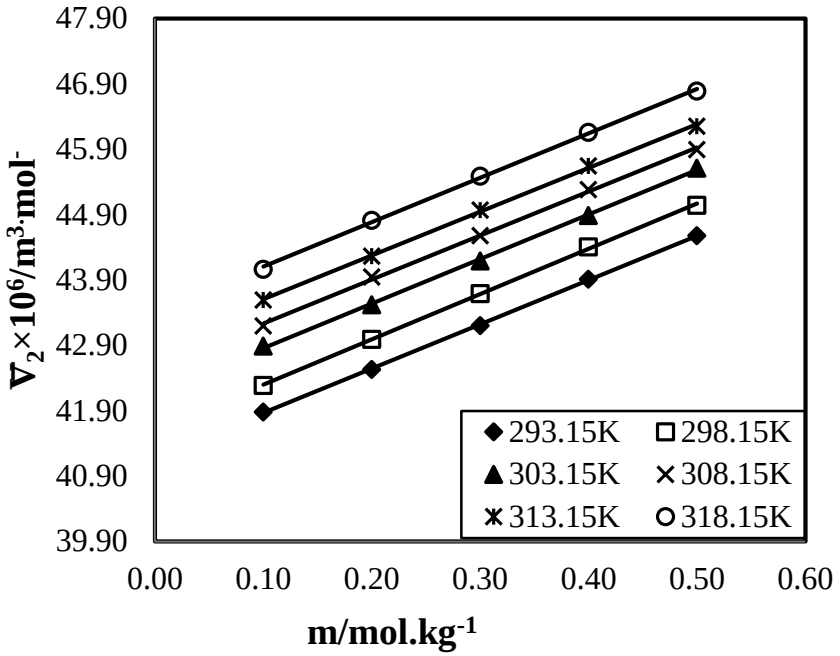


Figure 4.24: Plots of Partial molar volume ($\bar{V}_2$) vs. Molality of water + Glycine + 0.045 mol.kg^{-1} ciprofloxacin systems at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively.

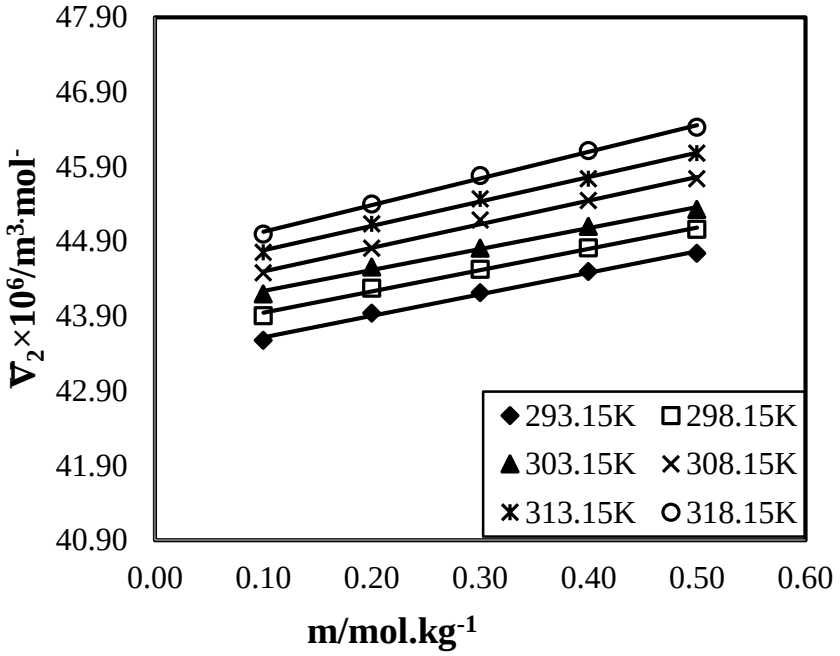


Figure 4.25: Plots of Partial molar volume ($\bar{V}_2$) vs. Molality of water + Glycine + 0.06 mol.kg^{-1} ciprofloxacin systems at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively.

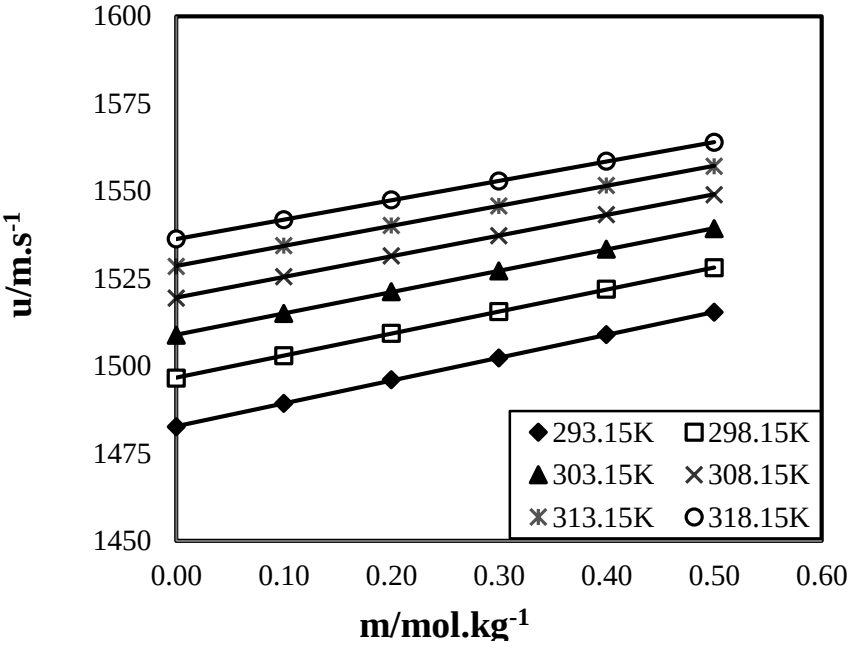


Figure 4.26: Plots of Sound velocity (u) vs. Molality (m) of L-alanine + water system at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively.

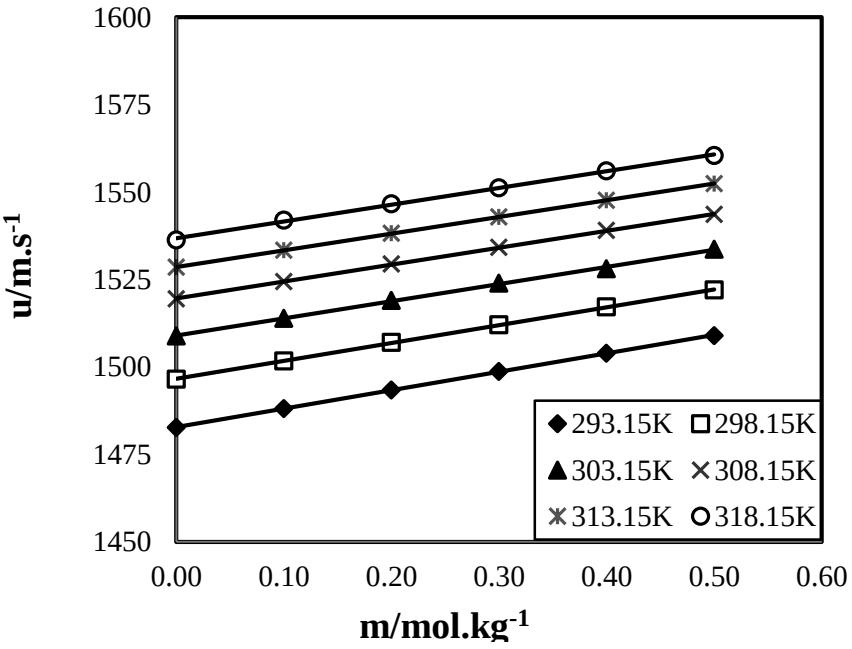


Figure 4.27: Plots of Sound velocity (u) vs. Molality (m) of Glycine + water system at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively.

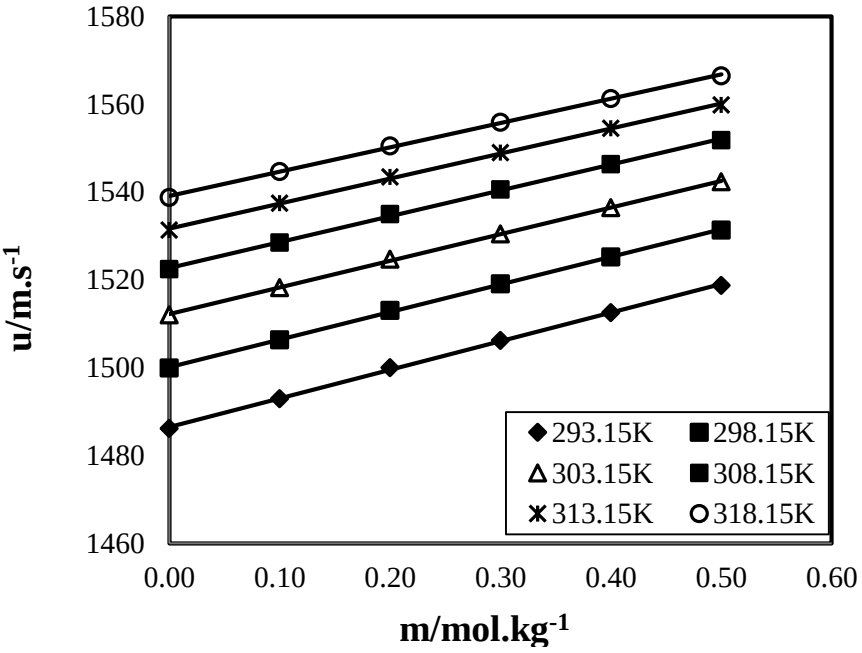


Figure 4.28: Plots of Sound velocity (u) vs. Molality (m) of water + L-alanine + 0.03 mol.kg^{-1} ciprofloxacin system at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively.

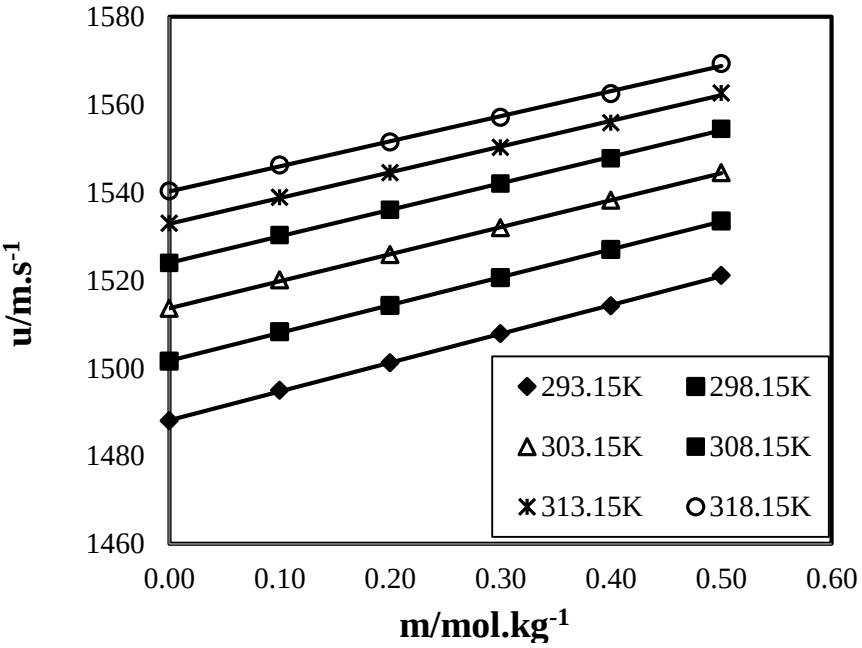


Figure 4.29: Plots of Sound velocity (u) vs. Molality (m) of water + L-alanine + 0.045 mol.kg^{-1} ciprofloxacin system at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively.

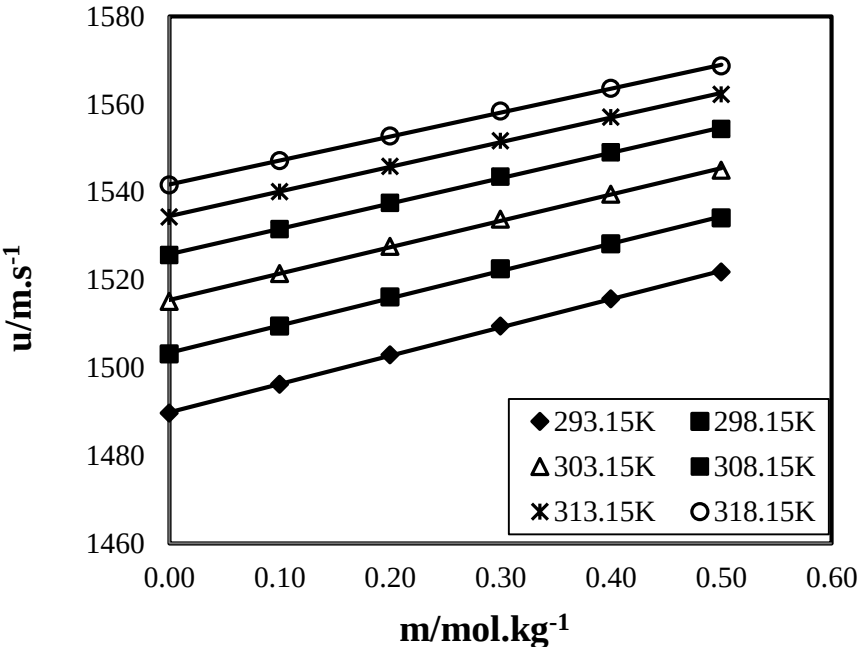


Figure 4.30: Plots of Sound velocity (u) vs. Molality (m) of water + L-alanine + 0.06 $mol.kg^{-1}$ ciprofloxacin system at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively.

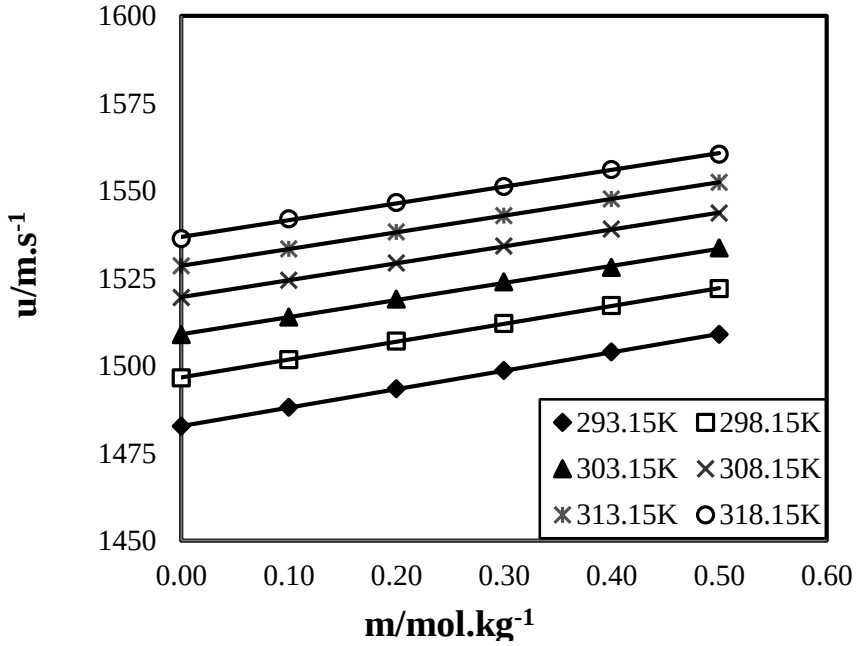


Figure 4.31: Plots of Sound velocity (u) vs. Molality (m) of water + Glycine + 0.03 $mol.kg^{-1}$ ciprofloxacin system at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively.

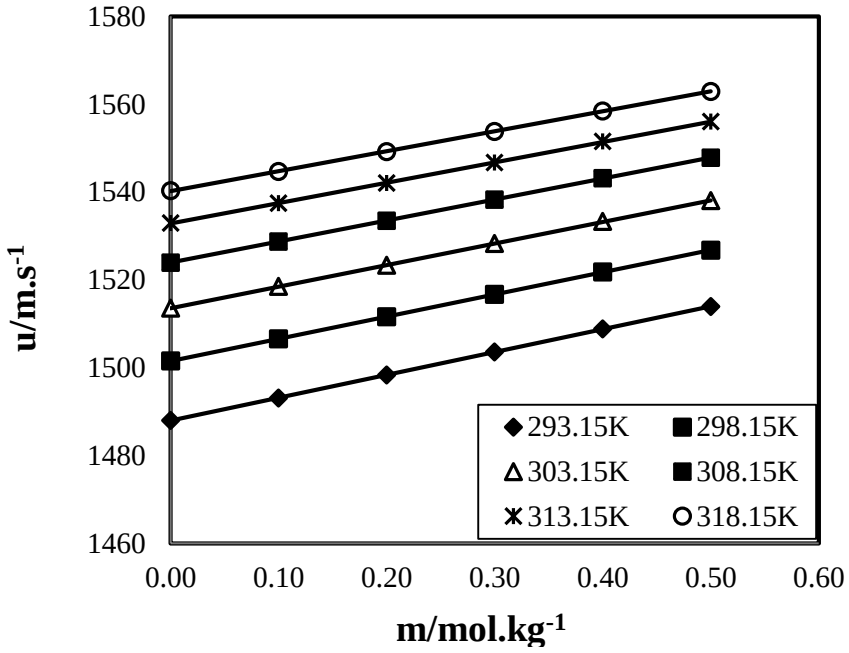


Figure 4.32: Plots of Sound velocity (u) vs. Molality (m) of water + Glycine + 0.045 mol.kg^{-1} ciprofloxacin system at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively.

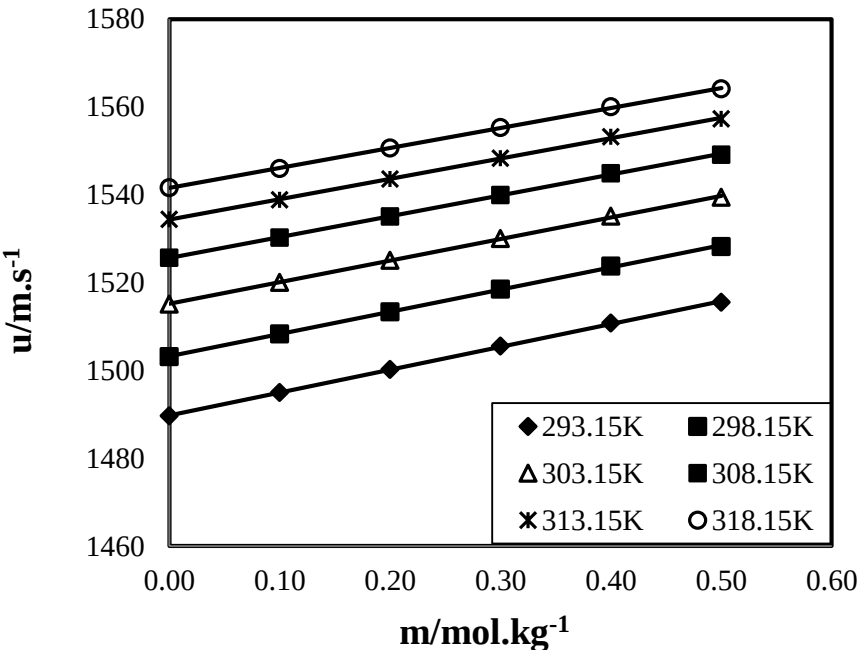


Figure 4.33: Plots of Sound velocity (u) vs. Molality (m) of water + Glycine + 0.06 mol.kg^{-1} ciprofloxacin system at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively.

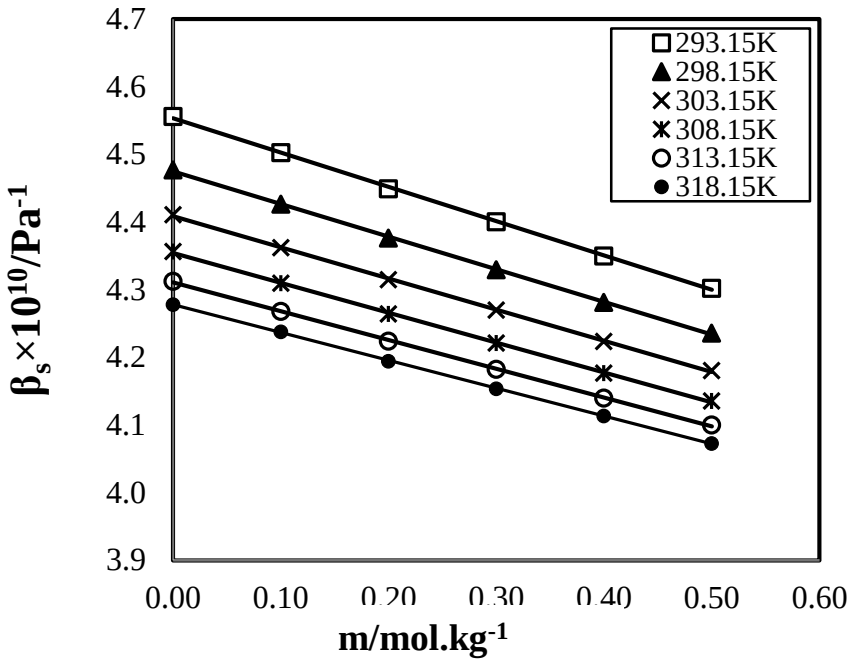


Figure 4.34: Plots of Adiabatic compressibility (β_s) vs. Molality (m) of L-alanine + water system at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively.

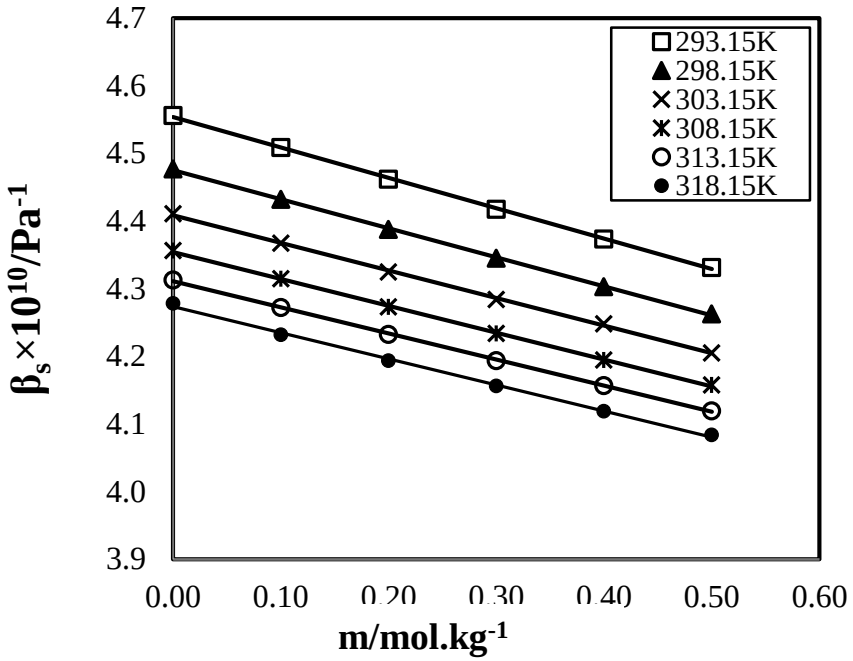


Figure 4.35: Plots of Adiabatic compressibility (β_s) vs. Molality (m) of Glycine + water system at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively.

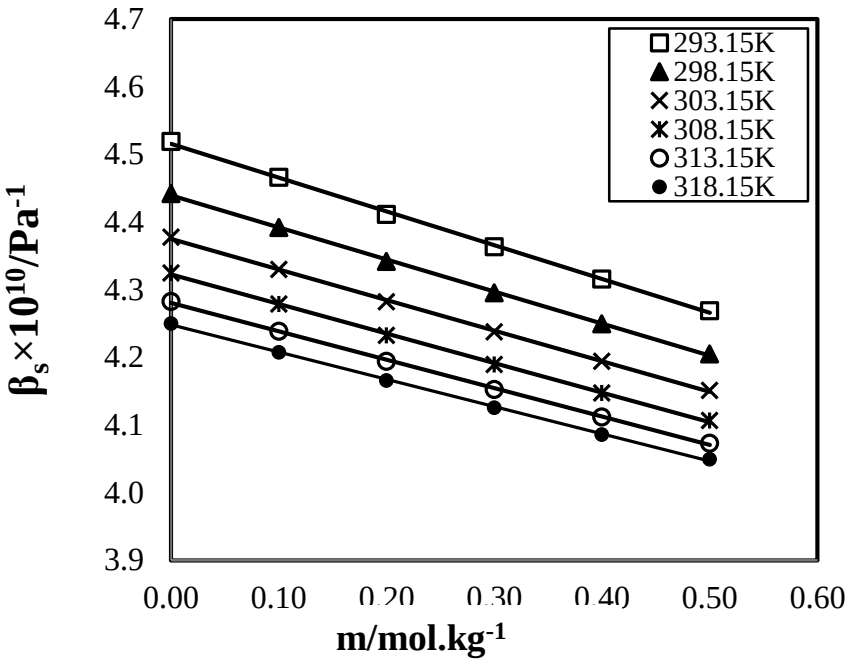


Figure 4.36: Plots of Adiabatic compressibility (β_s) vs. Molality (m) of water + L-alanine + 0.03 mol.kg^{-1} ciprofloxacin system at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively.

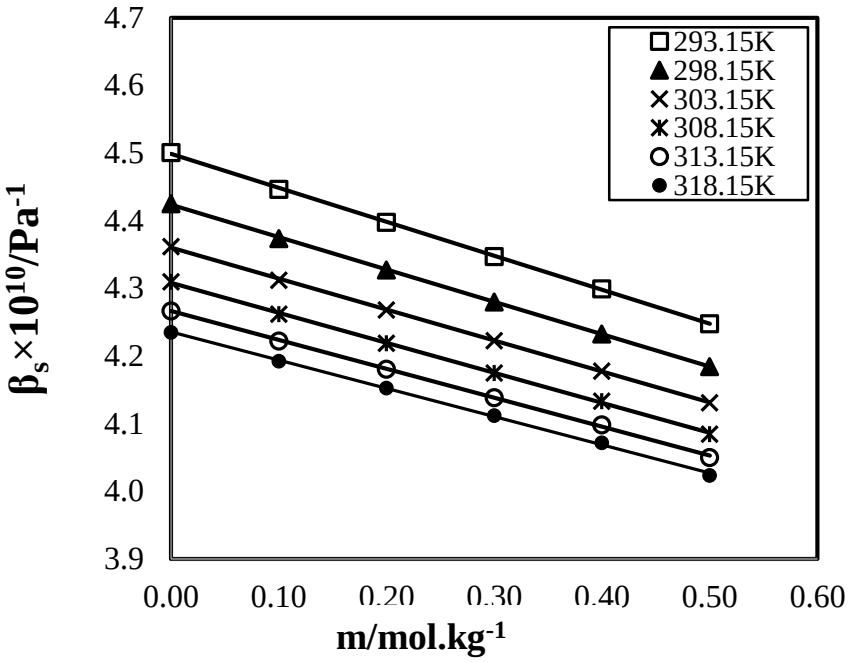


Figure 4.37: Plots of Adiabatic compressibility (β_s) vs. Molality (m) of water + L-alanine + 0.045 mol.kg^{-1} ciprofloxacin system at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively

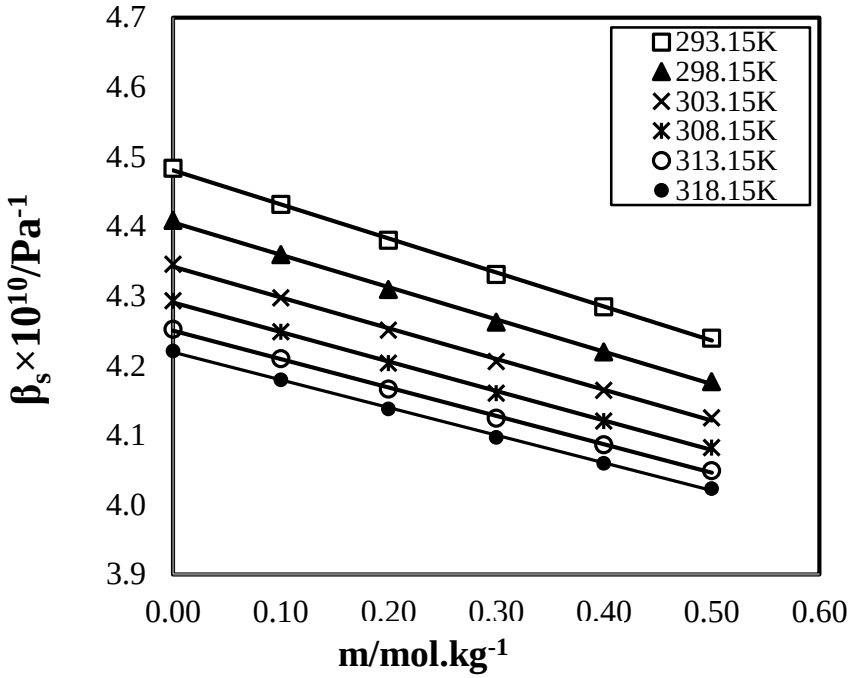


Figure 4.38: Plots of Adiabatic compressibility (β_s) vs. Molality (m) of water + L-alanine + 0.06 mol.kg^{-1} ciprofloxacin system at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively.

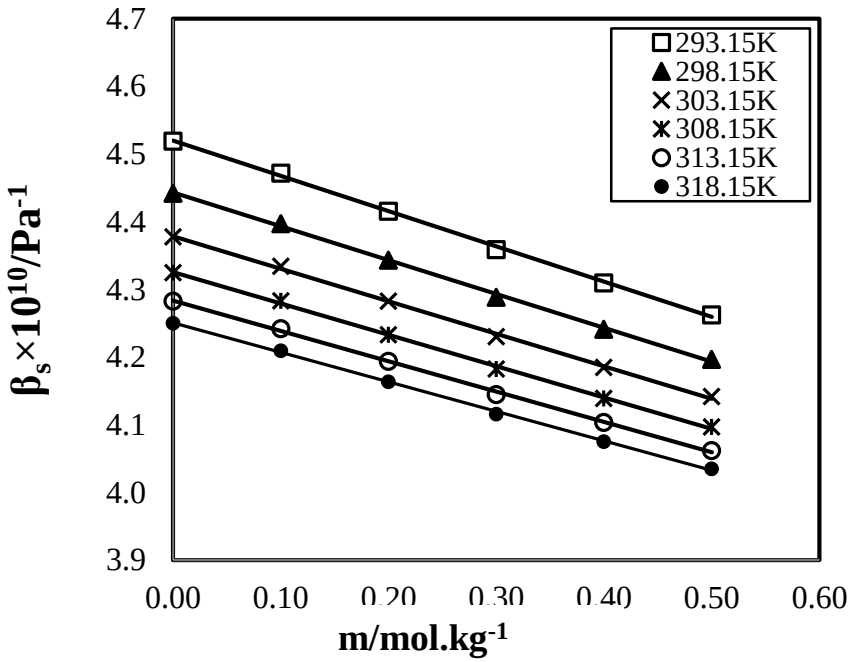


Figure 4.39: Plots of Adiabatic compressibility (β_s) vs. Molality (m) of water + Glycine + 0.03 mol.kg^{-1} ciprofloxacin system at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively.

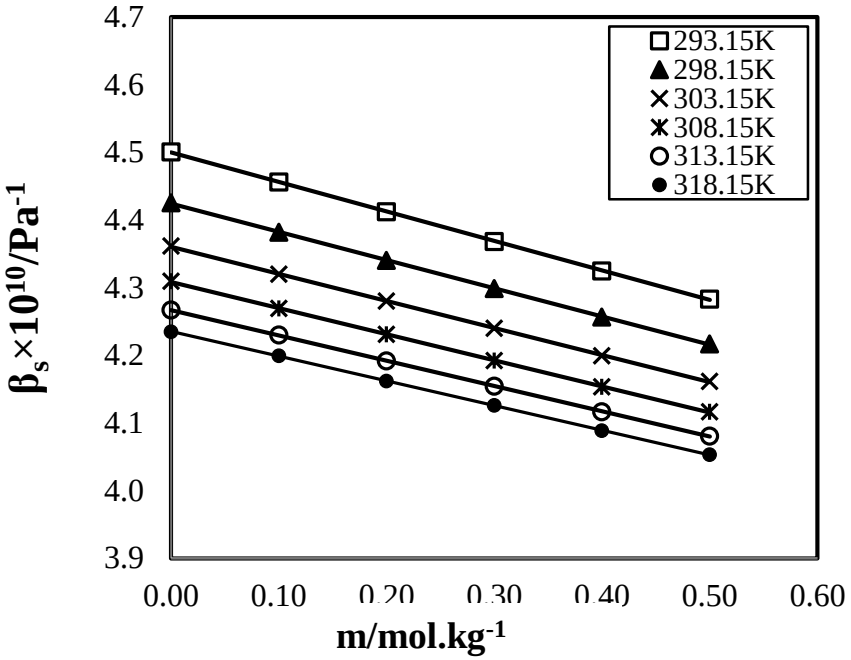


Figure 4.40: Plots of Adiabatic compressibility (β_s) vs. Molality (m) of water + Glycine + 0.045 mol.kg^{-1} ciprofloxacin system at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively.

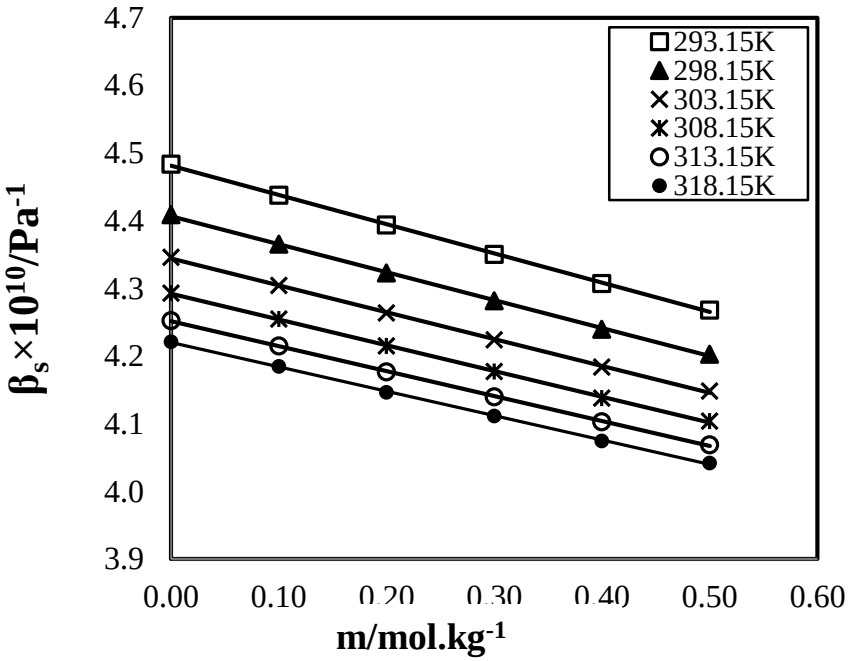


Figure 4.41: Plots of Adiabatic compressibility (β_s) vs. Molality (m) of water + Glycine + 0.06 mol.kg^{-1} ciprofloxacin system at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively.

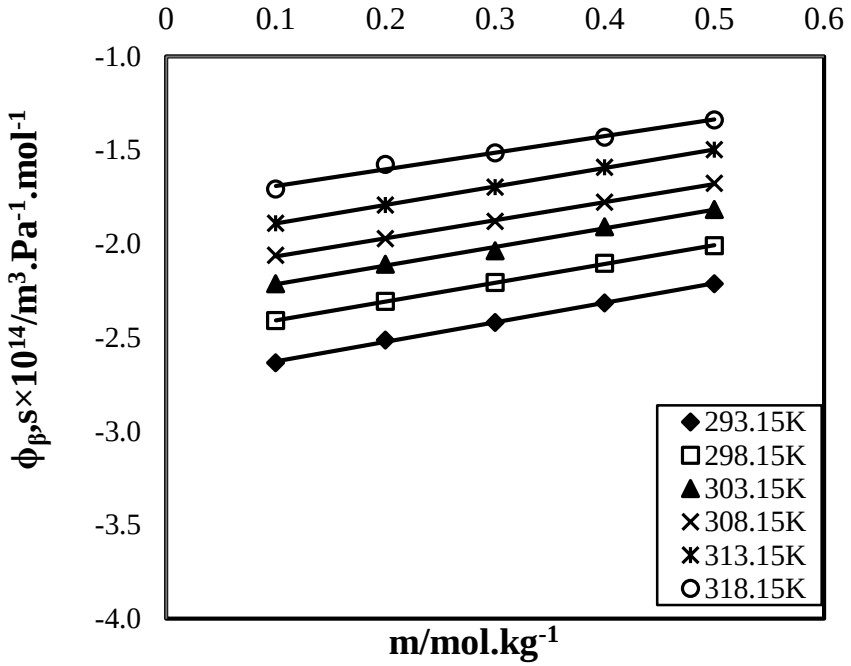


Figure 4.42: Plots of Apparent molar adiabatic compressibility (ϕ_k) vs. Molality (m) of L-alanine + water system at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively.

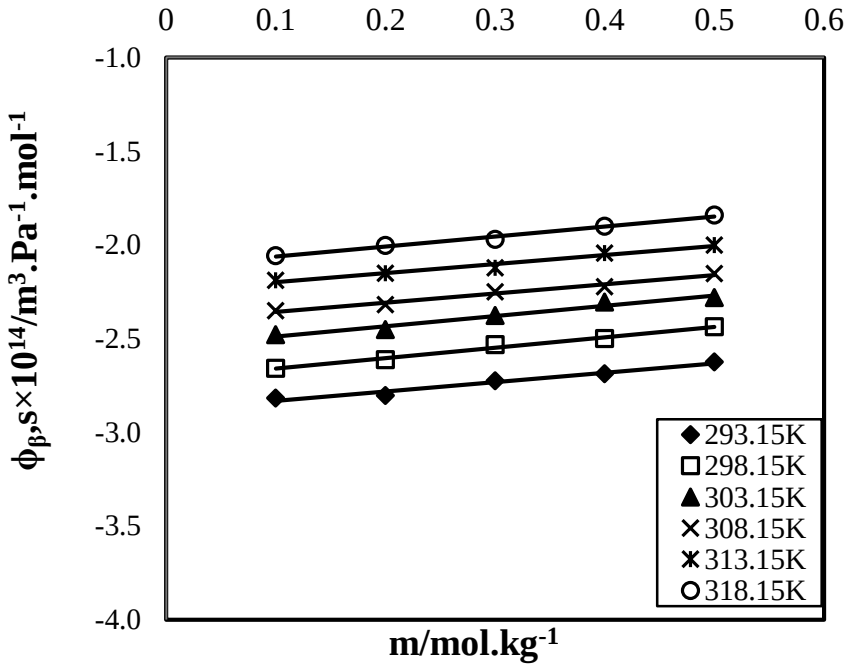


Figure 4.43: Plots of Apparent molar adiabatic compressibility (ϕ_k) vs. Molality (m) of Glycine + water system at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively.

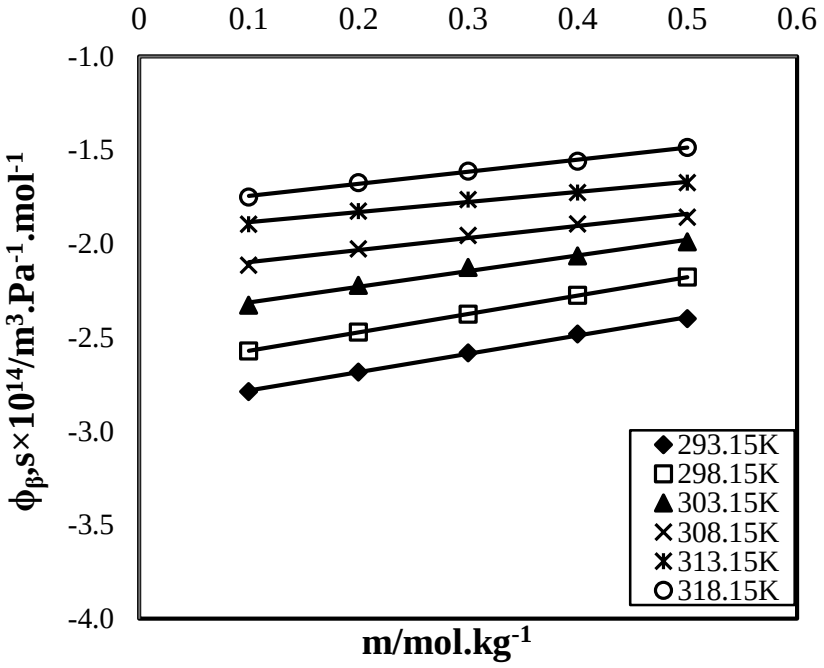


Figure 4.44: Plots of Apparent molar adiabatic compressibility (ϕ_k) vs. Molality (m) of water + L-alanine + 0.03 mol.kg^{-1} ciprofloxacin system at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively.

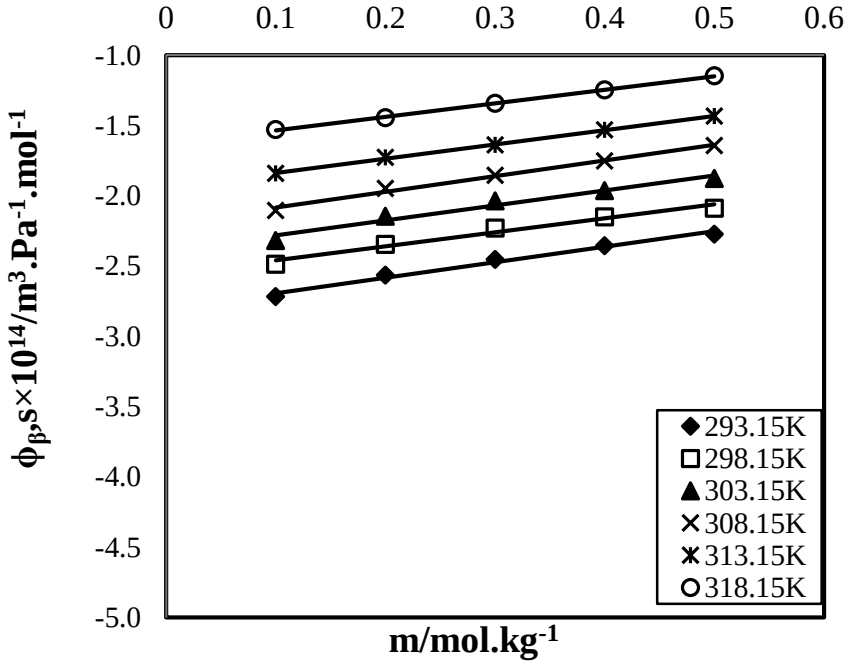


Figure 4.45: Plots of Apparent molar adiabatic compressibility (ϕ_k) vs. Molality (m) of water + L-alanine + 0.045 mol.kg^{-1} ciprofloxacin system at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively.

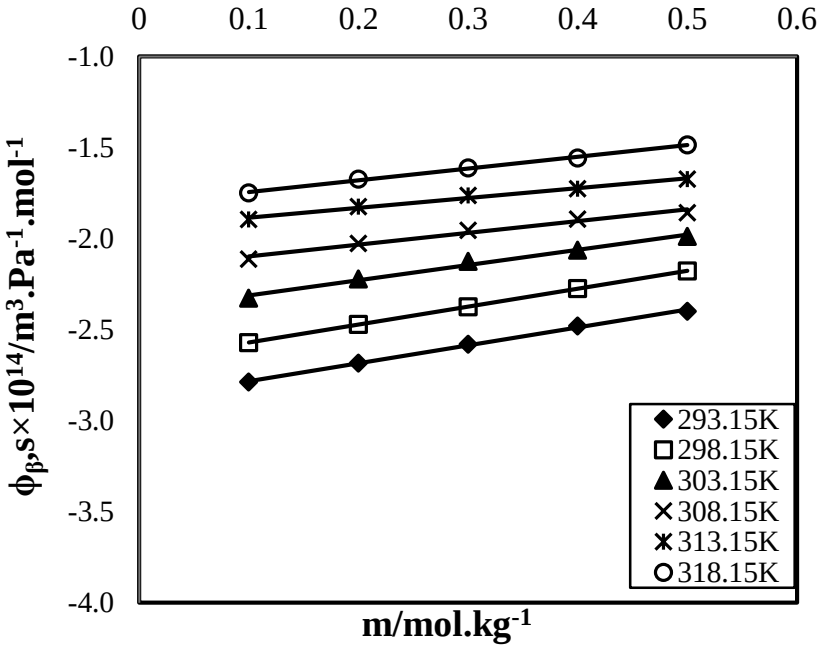


Figure 4.46: Plots of Apparent molar adiabatic compressibility (ϕ_k) vs. Molality (m) of water + L-alanine + 0.06 mol.kg^{-1} ciprofloxacin system at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively.

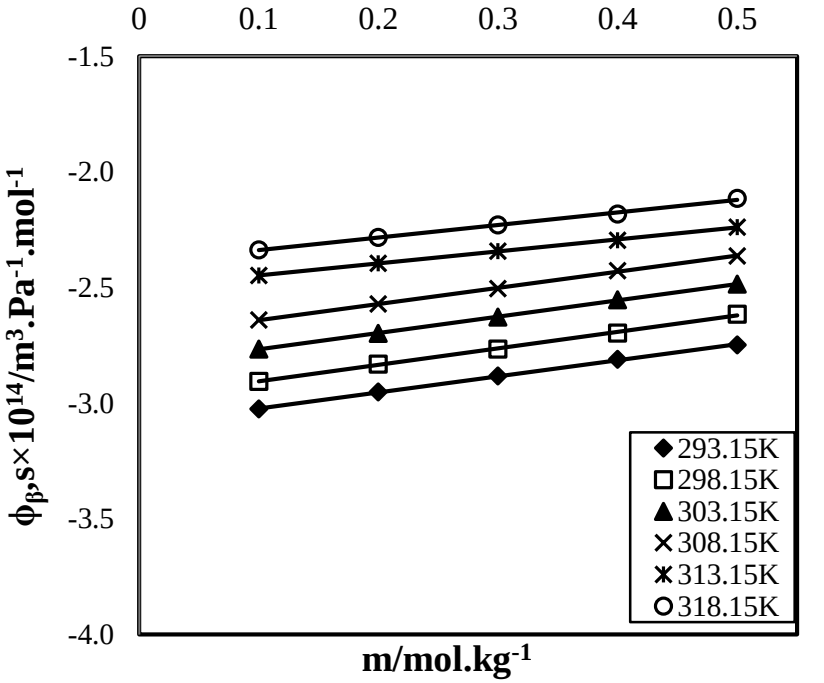


Figure 4.48: Plots of Apparent molar adiabatic compressibility (ϕ_k) vs. Molality (m) of water + Glycine + 0.03 mol.kg^{-1} ciprofloxacin system at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively.

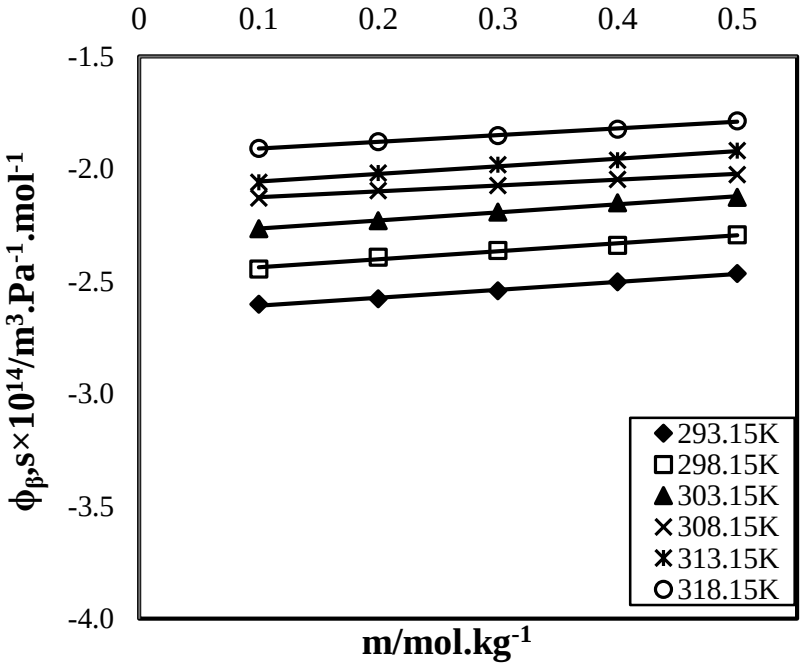


Figure 4.49: Plots of Apparent molar adiabatic compressibility (ϕ_k) vs. Molality (m) of water + Glycine + 0.045 mol.kg^{-1} ciprofloxacin system at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively.

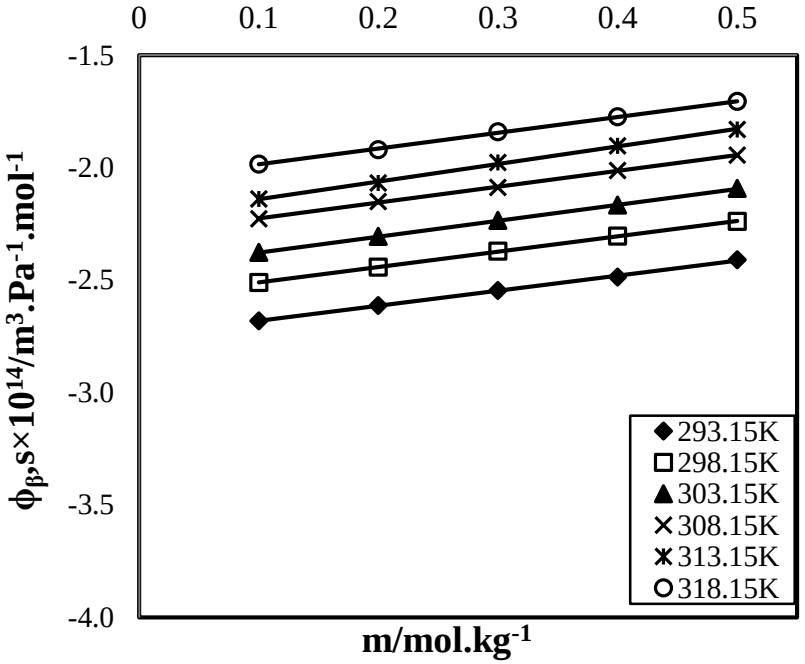


Figure 4.50: Plots of Apparent molar adiabatic compressibility (ϕ_k) vs. Molality (m) of water + Glycine + 0.06 mol.kg^{-1} ciprofloxacin system at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively.

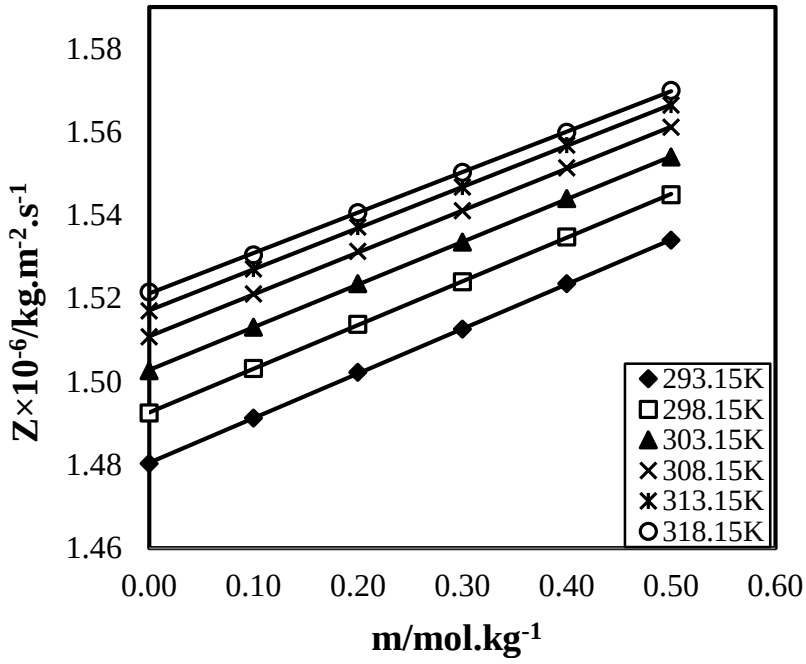


Figure 4.51: Plots of Acoustic impedance (Z) vs. Molality (m) of L-alanine + water system at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively.

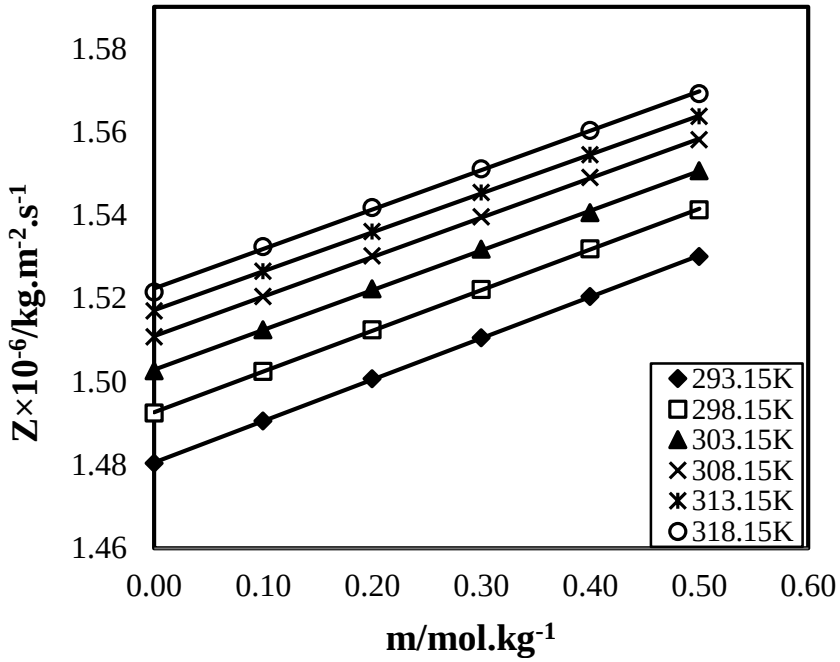


Figure 4.52: Plots of Acoustic impedance (Z) vs. Molality (m) of Glycine + water system at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively.

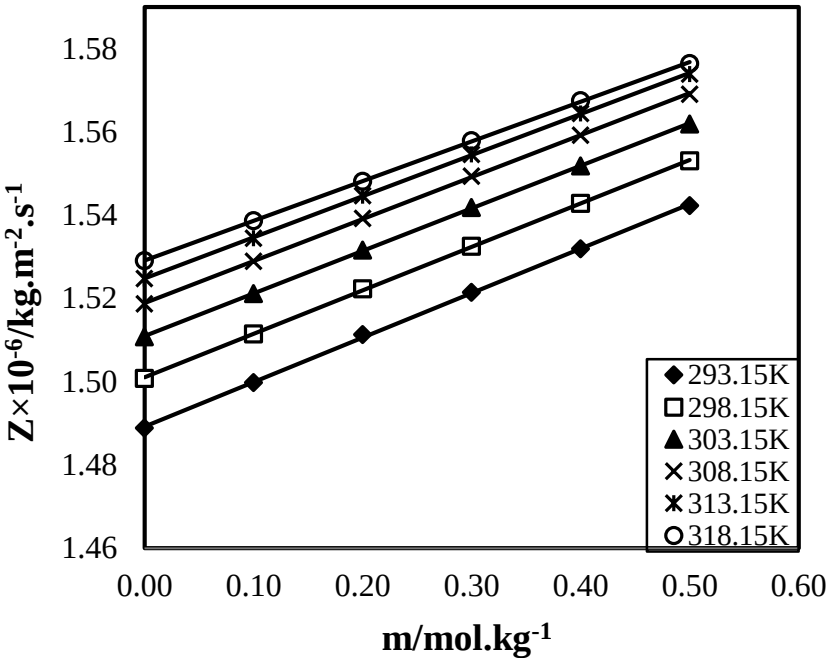


Figure 4.53: Plots of Acoustic impedance (Z) vs. Molality (m) of water + L-alanine + 0.03 mol.kg^{-1} ciprofloxacin system at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively.

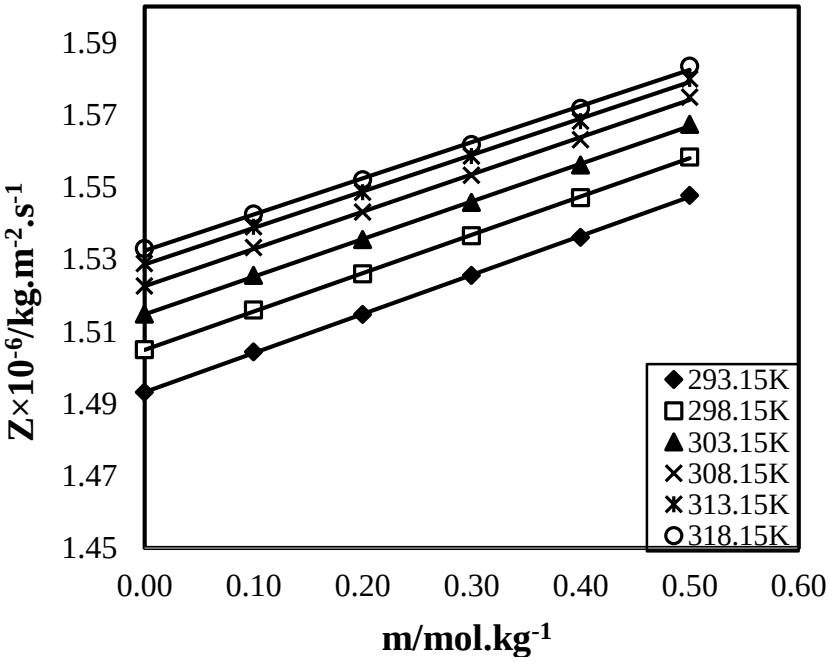


Figure 4.54: Plots of Acoustic impedance (Z) vs. Molality (m) of water + L-alanine + 0.045 mol.kg^{-1} ciprofloxacin system at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively.

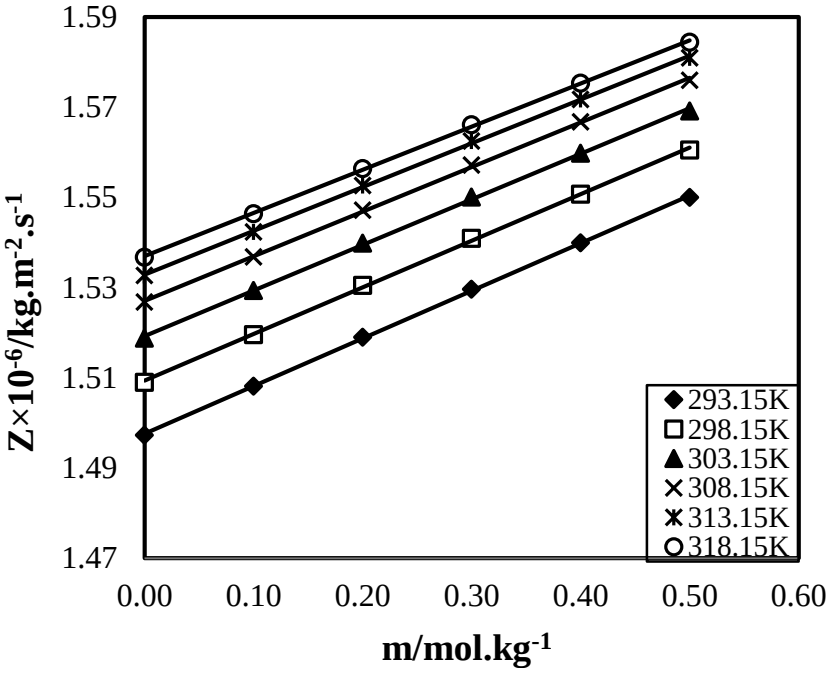


Figure 4.55: Plots of Acoustic impedance (Z) vs. Molality (m) of water + L-alanine + 0.06 mol.kg^{-1} ciprofloxacin system at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively.

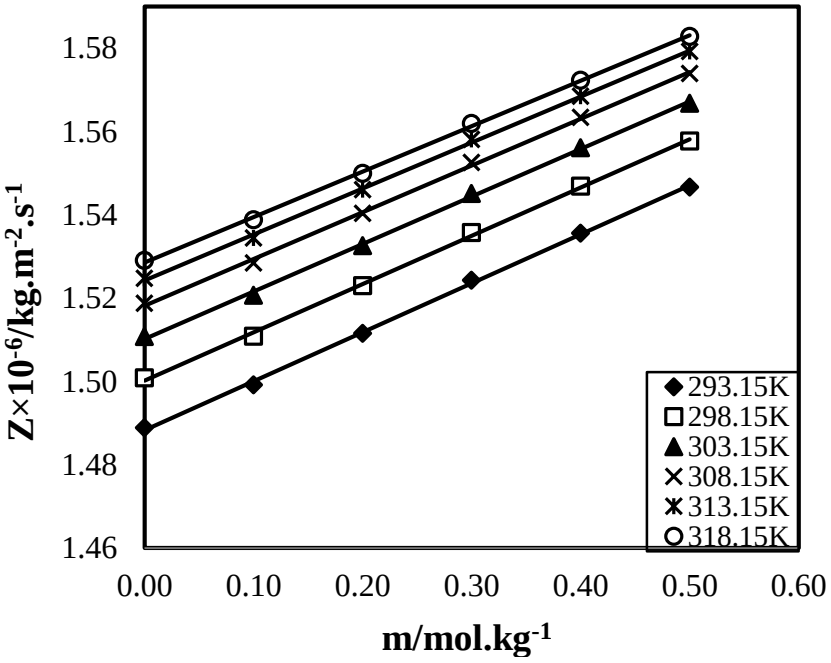


Figure 4.56: Plots of Acoustic impedance (Z) vs. Molality (m) of water + Glycine + 0.03 mol.kg^{-1} ciprofloxacin system at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively.

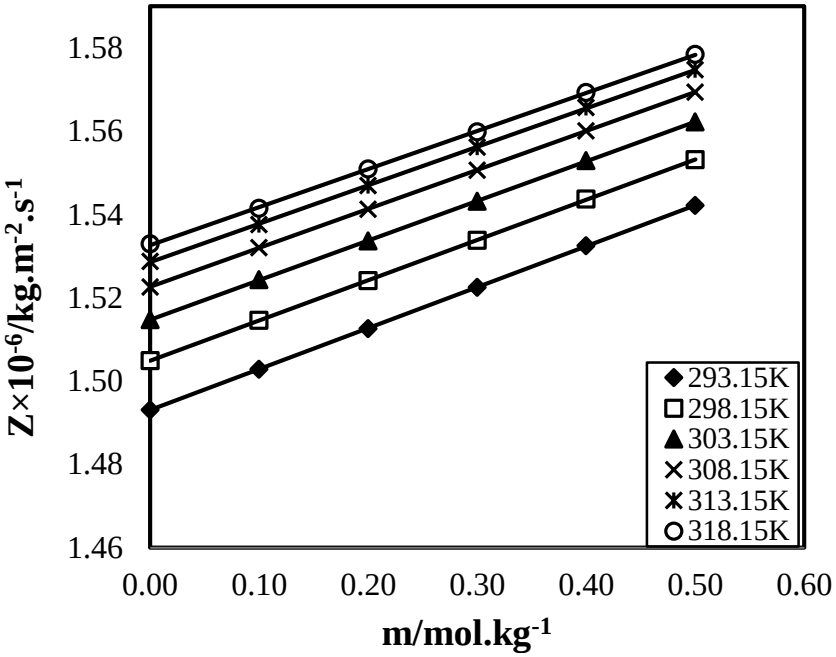


Figure 4.57: Plots of Acoustic impedance (Z) vs. Molality (m) of water + Glycine + 0.045 mol.kg^{-1} ciprofloxacin system at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively.

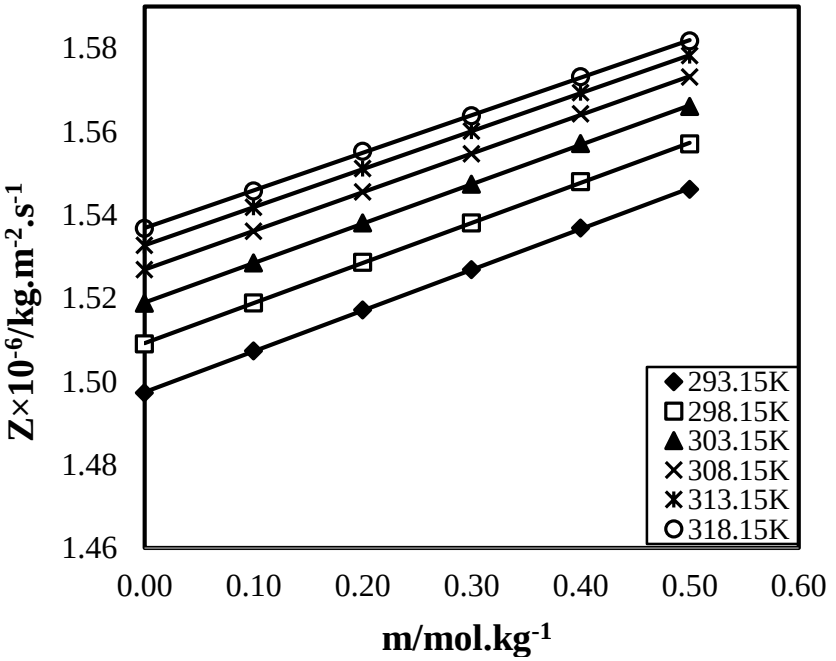


Figure 4.58: Plots of Acoustic impedance (Z) vs. Molality (m) of water + Glycine + 0.06 mol.kg^{-1} ciprofloxacin system at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively.

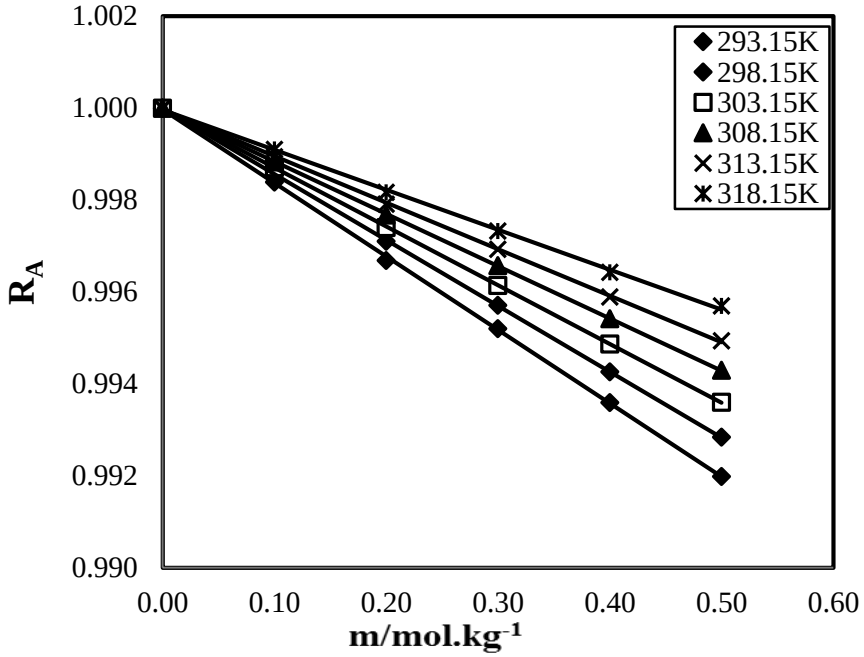


Figure 4.59: Plots of Relative association (R_A) vs. Molality (m) of L-alanine + water system at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively.

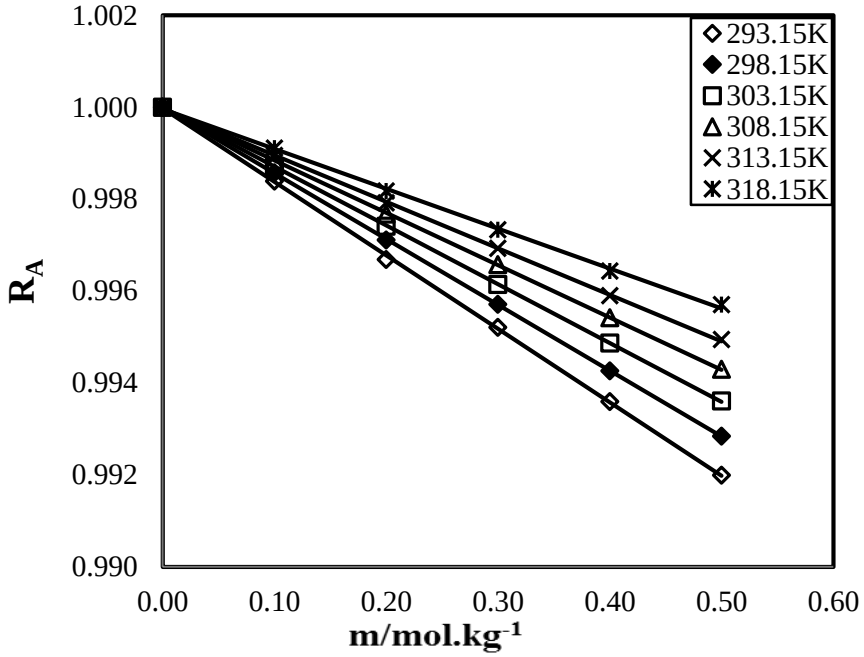


Figure 4.60: Plots of Relative association (R_A) vs. Molality (m) of Glycine + water system at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively.

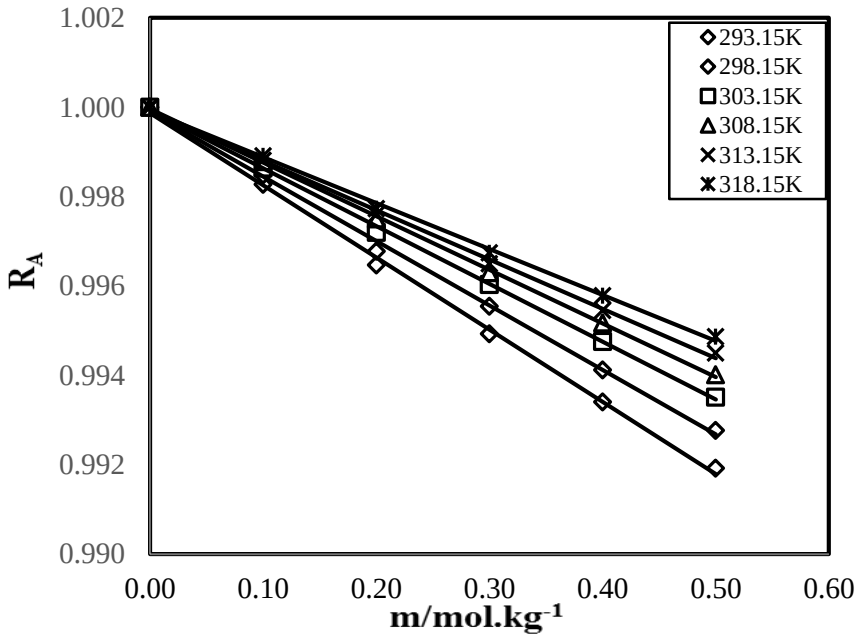


Figure 4.61: Plots of Relative association (R_A) vs. Molality (m) of water + L-alanine + 0.03 mol.kg^{-1} ciprofloxacin system at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively.

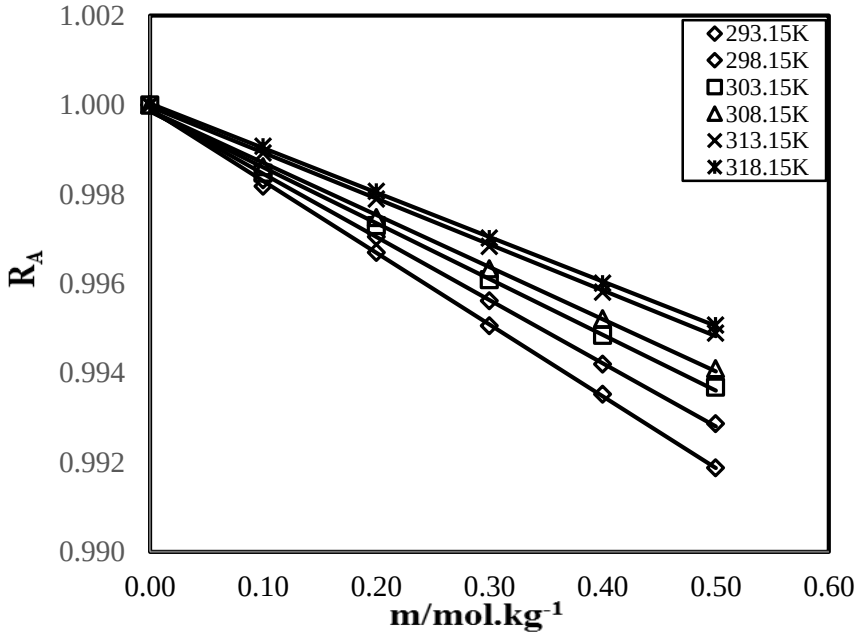


Figure 4.62: Plots of Relative association (R_A) vs. Molality (m) of water + L-alanine + 0.045 mol.kg^{-1} ciprofloxacin system at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively.

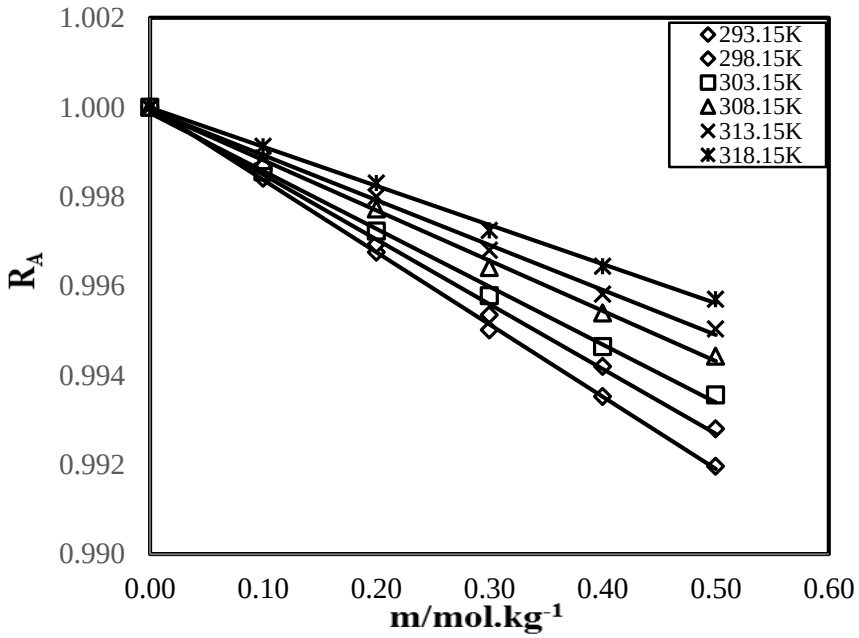


Figure 4.63: Plots of Relative association (R_A) vs. Molality (m) of water + L-alanine + 0.06 mol.kg^{-1} ciprofloxacin system at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively.

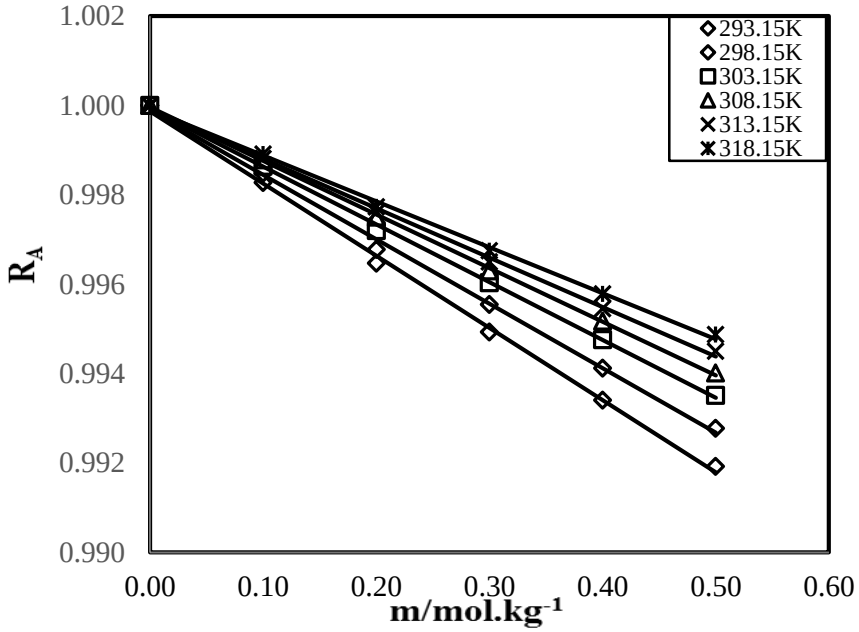


Figure 4.64: Plots of Relative association (R_A) vs. Molality (m) of water + Glycine + 0.03 mol.kg^{-1} ciprofloxacin system at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively.

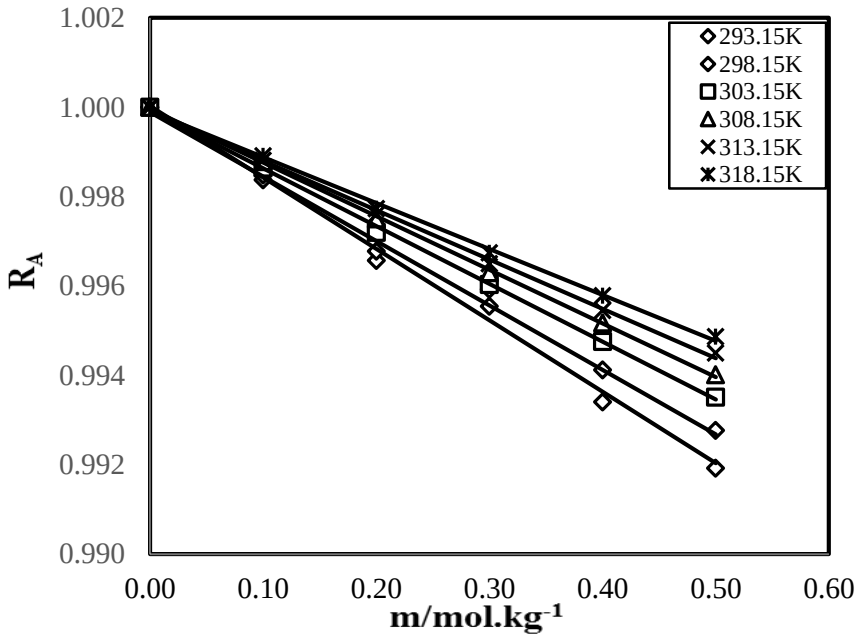


Figure 4.65: Plots of Relative association (R_A) vs. Molality (m) of water + Glycine + 0.045 mol.kg^{-1} ciprofloxacin system at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively.

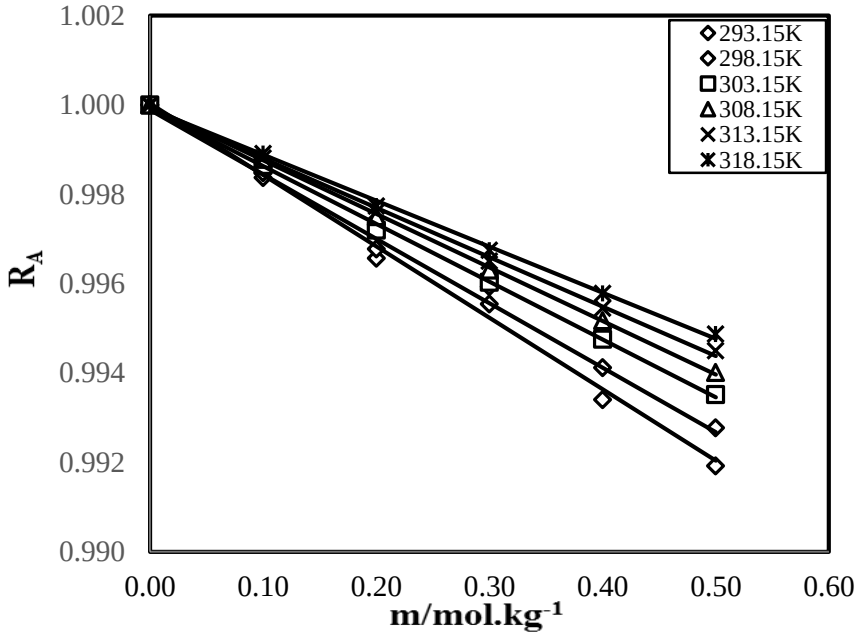


Figure 4.66: Plots of Relative association (R_A) vs. Molality (m) of water + Glycine + 0.06 mol.kg^{-1} ciprofloxacin system at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively.

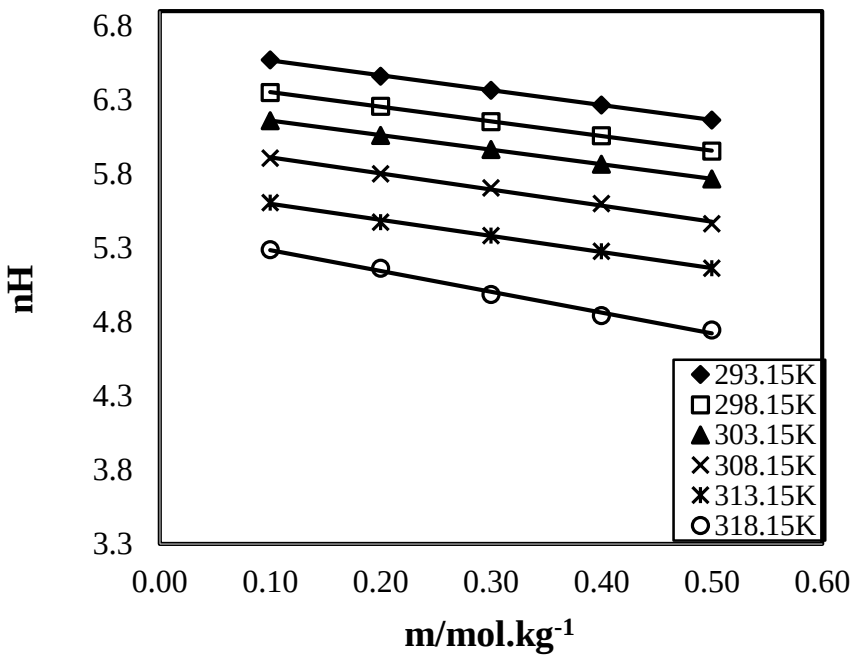


Figure 4.67: Plots of Hydration number (n_H) vs. Molality (m) of L-alanine + water system at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively

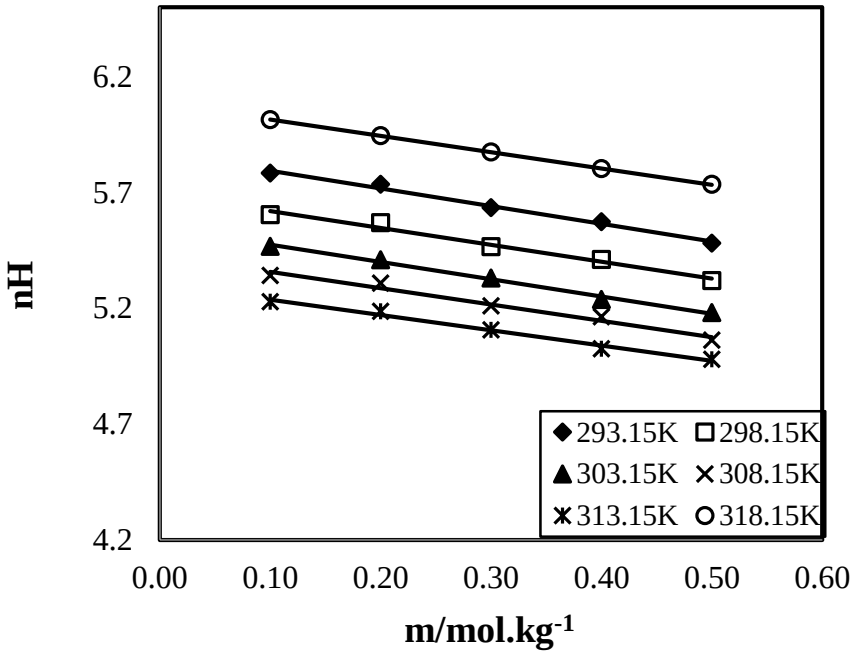


Figure 4.68: Plots of Hydration number (n_H) vs. Molality (m) of Glycine + water system at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively.

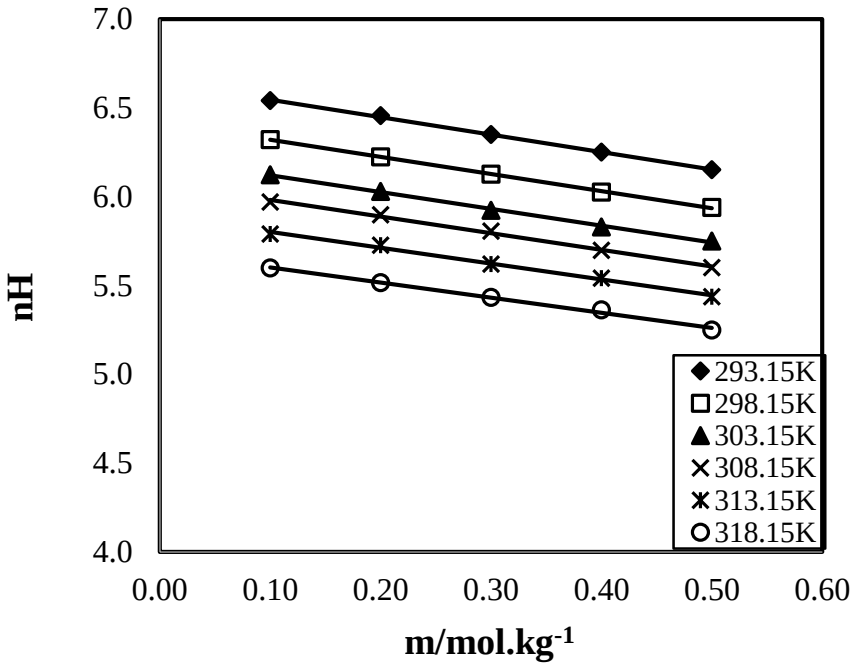


Figure 4.69: Plots of Hydration number (n_H) vs. Molality (m) of water + L-alanine + 0.03 mol.kg^{-1} ciprofloxacin system at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively.

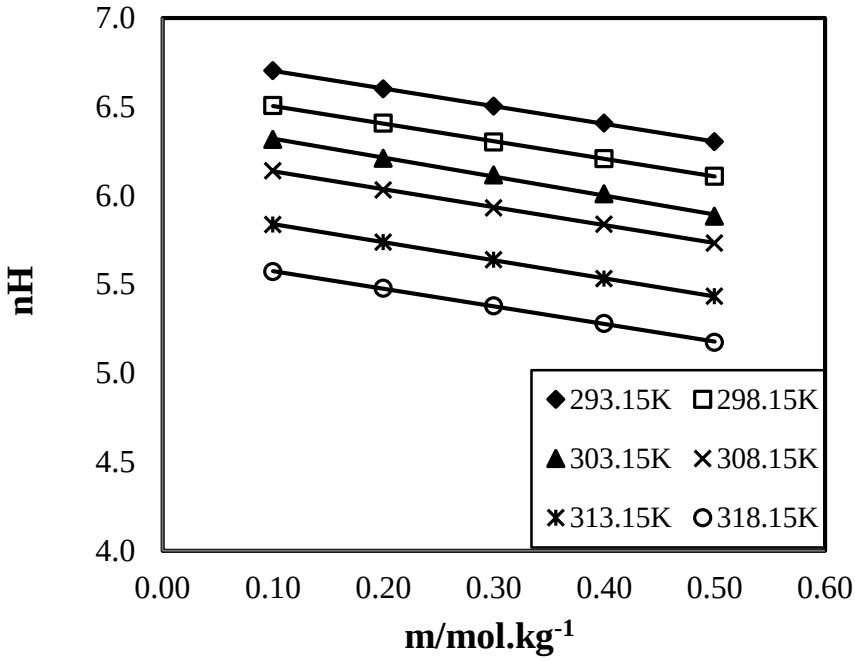


Figure 4.70: Plots of Hydration number (nH) vs. Molality (m) of water + L-alanine + 0.045 mol.kg^{-1} ciprofloxacin system at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively.

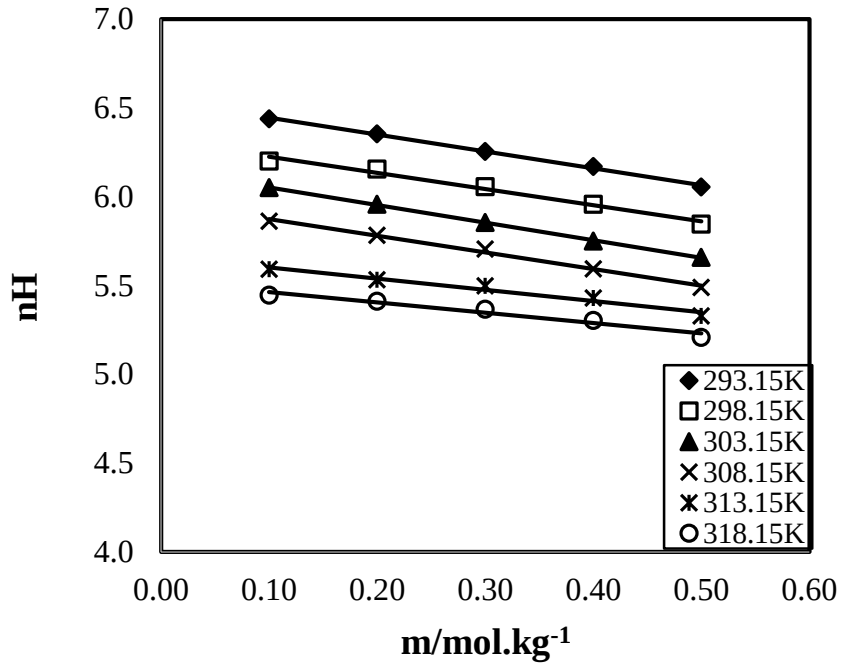


Figure 4.71: Plots of Hydration number (n_H) vs. Molality (m) of water + L-alanine + 0.06 mol.kg^{-1} ciprofloxacin system at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively.

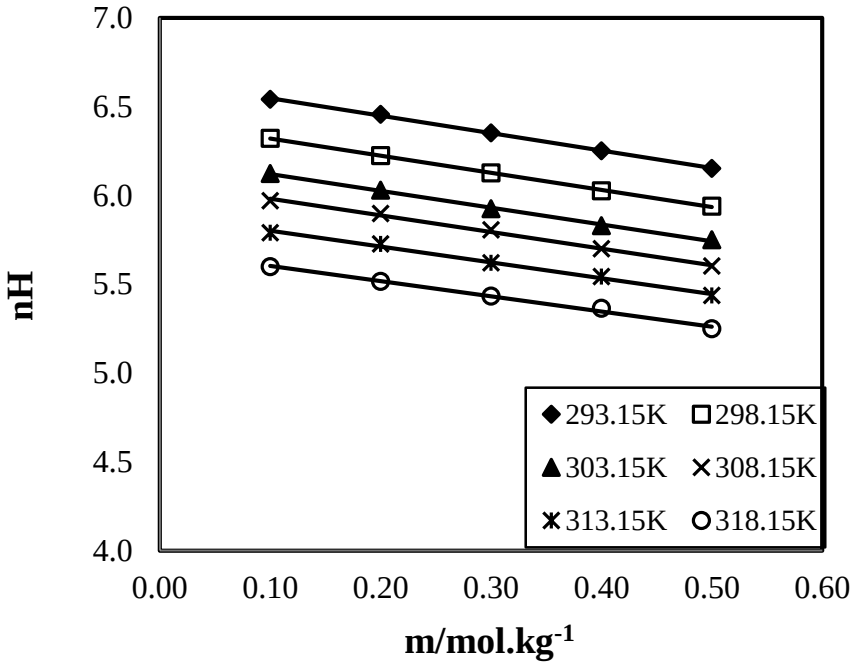


Figure 4.72: Plots of Hydration number (n_H) vs. Molality (m) of water + Glycine + 0.03 mol.kg^{-1} ciprofloxacin system at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively.

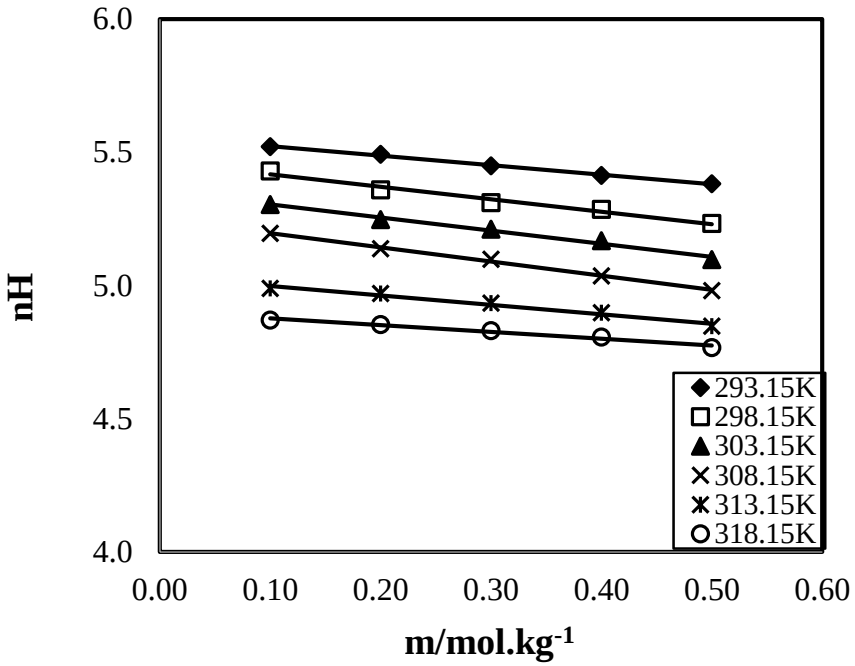


Figure 4.73: Plots of Hydration number (n_H) vs. Molality (m) of water + Glycine + 0.045 mol.kg^{-1} ciprofloxacin system at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively.

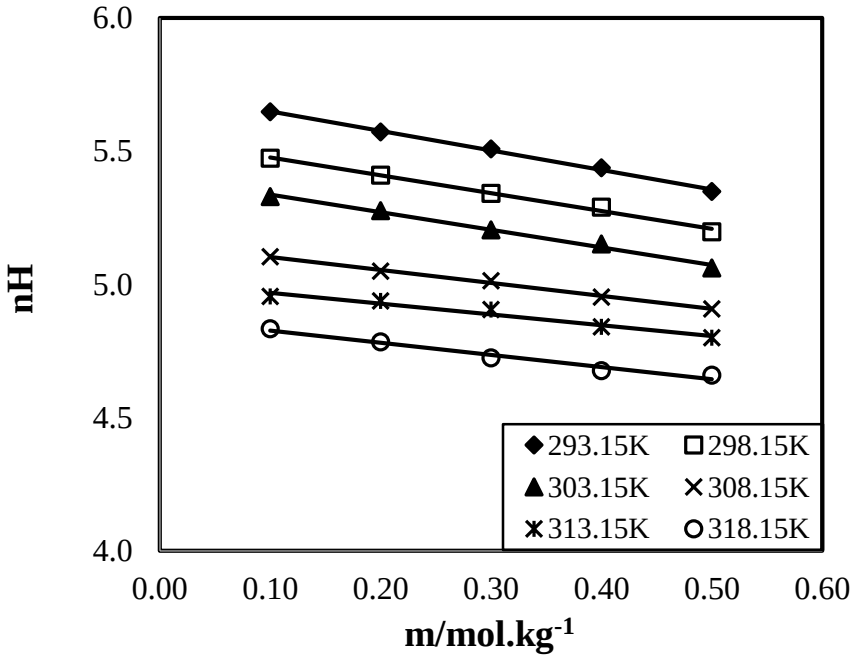


Figure 4.74: Plots of Hydration number (n_H) vs. Molality (m) of water + Glycine + 0.06 mol.kg^{-1} ciprofloxacin system at 293.15K, 298.15K, 303.15K, 308.15K, 313.15K and 318.15K respectively.

CHAPTER V

Conclusion

Densities and sound velocities of L-alanine and glycine in water and in aqueous (0.03, 0.045 and 0.06) mol.kg^{-1} ciprofloxacin solutions have been measured in the temperature range between 293.15 K to 318.15 K with an interval of 5 K temperature. Volumetric and acoustic properties such as apparent molar volume (φ_v), limiting apparent molar volume (φ_v^0), limiting apparent molar volume transfer ($\Delta tr\varphi_v^0$), apparent molar expansibilities (E_φ^0) and Hepler's constant $(\delta^2\varphi_v^0/\delta T^2)_p$, adiabatic compressibility (βs), apparent molar adiabatic compressibility (φ_k), limiting apparent molar adiabatic compressibility (φ_k^0), apparent molar adiabatic compressibility of transfer ($\Delta_{tr}\varphi_k^0$), acoustic impedance (Z), relative association (R_A) and hydration number (n_H) have been calculated.

Apparent molar properties, limiting apparent molar properties and compressibility studies indicate the presence of strong solute–solvent interactions in the binary and ternary systems. The solute– solvent interactions increase in glycine and L-alanine. The Hepler's constant $(\delta^2\varphi_v^0/\delta T^2)_p$ shows the structure making property of amino acids in aqueous ciprofloxacin solution. Hydrophilic-hydrophilic or ion-hydrophilic are dominating for glycine in binary and ternary systems, whereas for L-alanine hydrophobic-hydrophobic interactions are dominating. From the above experimental results we can conclude:

- Strong solute-solvent interactions are present in all systems.
- The mode of interaction of L-alanine is different from glycine in all systems.
- The water molecules around amino acids are less compressible than water molecules in the bulk solution.
- The compressibility of ternary solution is less than binary solution.

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